

Alfred J. Tria
Giles R. Scuderi
Fred D. Cushner
Editors

Complex Cases in Total Knee Arthroplasty

A Compendium
of Current Techniques

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Springer

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Foreword

Total knee arthroplasty is arguably the most successful musculoskeletal surgical intervention of the last century—having now surpassed even Charnley’s seminal total hips in numbers, social impact, and longevity. Emboldened by the power of this procedure, we have now extended its indications to younger, older, and more complex patients. Mechanically and materially, there have been many triumphs, especially over the last two decades. Biologically, there remain more challenges, from allergy to particular osteolysis to infection, where we remain embarrassingly ineffective.

The price for this great gift is, however, a far more diverse set of options and decisions for us to address in the beginning of the procedure and more catastrophic consequences when our devices—or their host—fail at the end. As surgeons, we must be prepared to harvest the seeds we have sown.

This superlative text addresses a great number of those issues, not with dogmatic directives, but rather with options and decision points. They are presented by an international group of supremely gifted surgeons who have devoted their careers to vetting and refining the ensuing solutions and techniques to our recurrent challenges in total knee arthroplasty.

The editors are to be commended for their exceptional choice of authors, for their very appealing case model compendium of special problems with bulleted solutions, and for their courage to address many controversial and complex challenges whose successful resolution this volume will hopefully effect. This effort is very much in the spirit of the editors’ common mentor, John N. Insall, the true father of modern knee arthroplasty, who would be very proud to witness this text today. It should reside on the desk of every thoughtful knee surgeon who will inevitably be confronted with unique or problematic arthroplasty issues.

Robert E. Booth Jr, MD
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Preface

Total knee arthroplasty has become a routine procedure for the management of the arthritic knee, and the surgical technique has become more reproducible, yet there are complex cases that pose a challenge for surgeons. This book was produced with a clinical case-based approach to provide surgeons with strategies and surgical options for dealing with these challenging cases. Divided into two main sections covering both primary and revision total knee arthroplasty, each chapter opens with a brief introduction, followed by a handful of case studies demonstrating different surgical techniques, providing more than one method to approach the specific knee condition. To assist us in preparing this book, we brought together leading experts in total knee arthroplasty and asked them to share with us their experience for dealing with complex issues in primary and revision surgery. We are honored that each of them has helped us complete this practical real-world case-based approach to total knee arthroplasty, which is intended to be a resource for residents, fellows, and orthopedic surgeons. We are also honored to have Dr. Robert Booth write the foreword for our book and acknowledge the impact that our past mentor, John N. Insall, MD, has had on our careers and teachings.

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Contents

Part I Primary Total Knee Arthroplasty

1 The Varus Knee.....	3
Giles R. Scuderi, Trevor P. Scott, Amar S. Ranawat, Chitranjan S. Ranawat, Chad D. Watts, Walter B. Beaver, Trevor J. Shelton, and Stephen M. Howell	
Introduction.....	3
Option 1: Medial Collateral Ligament Pie Crusting of the Fixed Varus Knee	4
Option 2: Medial Release for the Varus Knee.....	10
Option 3: Kinematically Aligned Total Knee Arthroplasty Corrects a Severe Varus Deformity and Flexion Contracture to Native Alignment Without Soft Tissue Release	16
References.....	26
2 The Fixed Valgus Knee.....	29
Alfred J. Tria, Oren Goltzer, Mark J. Spangehl, Henry D. Clarke, Jacob M. Conjeski, Giles R. Scuderi, Leo A. Whiteside, David Rodriguez-Quintana, and Brian S. Parsley	
Introduction.....	29
Option 1: Pie-Crust Technique for the Fixed Valgus Knee in Primary Total Knee Arthroplasty	29
Option 2: Lateral Femoral Epicondylar Osteotomy for Correction of Fixed Valgus Deformity in Total Knee Arthroplasty	39
Option 3: Alignment and Ligament Balancing in the Valgus Knee Done Through the Medial Parapatellar Approach.....	45
Option 4: Total Knee Arthroplasty for Fixed Valgus Deformities Through a Lateral Parapatellar Approach.....	58
References.....	65
3 Fixed Flexion Contracture.....	69
Fred D. Cushner, Andrew A. Freiberg, Tiffany N. Castillo, Jared S. Preston, Dexter K. Bateman, Bertrand W. Parcells, and Alfred J. Tria	
Introduction.....	69
Option 1: Implant Choice: Cruciate-Retaining Femoral Component	70

Option 2: Fixed Flexion Contracture Treated with a Posterior-Stabilized Total Knee Design	75
References	81
4 Patellofemoral Arthritis	83
Giles R. Scuderi, James F. Fraser, Jess H. Lonner, Dexter K. Bateman, Jared S. Preston, Bertrand W. Parcells, and Alfred J. Tria	
Introduction	83
Option 1: Patellofemoral Arthroplasty	85
Option 2: Total Knee Arthroplasty	93
References	99
5 Retained Hardware	103
Fred D. Cushner, Nirav H. Amin, Antonio G. Manocchio, and Adolph V. Lombardi Jr.	
Introduction	103
Option 1: Retained Hardware or Partial Removal in Complexed Total Knee Arthroplasty	104
Option 2: Removal of All Hardware	108
References	114
6 The Super Obese Knee	117
Alfred J. Tria, Paraskevi (Vivian) Papas, Fred D. Cushner, Jason Wong, and Jeffrey A. Geller	
Introduction	117
Option 1: Surgical Technique with Specific Instrumentation	117
Option 2: Surgical Technique with Conventional Instrumentation	126
References	133
7 Total Knee Arthroplasty Following a Sepsis History	135
Fred D. Cushner, Nicholas B. Frisch, Brian Darrith, Craig J. Della Valle, Casey R. Antholz, and Keith R. Reinhardt	
Introduction	135
Option 1: Previous Knee Sepsis—One Stage	136
Option 2: Previous Knee Sepsis Treated with Two-Stage Revision Arthroplasty	143
References	149
8 Management of Extra-articular Deformity	151
Giles R. Scuderi, Steven B. Haas, Jonathan L. Berliner, Michael J. Assayag, S. Robert Rozbruch, Anton Khlopas, Grayson P. Connors, Chukwuweike U. Gwam, Jaydev B. Mistry, Ronald E. Delanois, Michael A. Mont, Bertrand W. Parcells, Dexter K. Bateman, Jared S. Preston, and Alfred J. Tria	
Introduction	151
Option 1: Tibia—Correction with the Implant	152
Option 2: Tibial Osteotomy and TKA	160

Option 3: Correction of Femoral Extra-articular Deformity with Implant	168
Option 4: Femoral Osteotomy and TKA.	171
References.....	175

Part II Revision Total Knee Arthroplasty

9 Management of the Infected Total Knee Arthroplasty	179
Alfred J. Tria, Joshua Bingham, Mark J. Spangehl, Henry D. Clarke, Thorsten Gehrke, Akos Zahar, Mustafa Citak, Majd Tarabichi, Javad Parvizi, David N. Shau, and George N. Guild III	
Introduction.....	179
Option 1: Irrigation and Debridement.....	179
Option 2: One-Stage Revision Arthroplasty in the Management of Infected Total Knee Arthroplasty	187
Option 3: Use of Static Spacer for Treatment of Infected Total Knee Arthroplasty as a Two-Stage Procedure	193
Option 4: Two-Stage Procedure with Mobile Spacer	197
References.....	205
10 Flexion Instability.....	207
Giles R. Scuderi, Zachary P. Berliner, José A. Rodriguez, Gregg R. Klein, and Michael A. Kelly	
Introduction.....	207
Option 1: Tibial Component Revision for Flexion Instability	208
Option 2: Flexion Instability—Complete Revision	212
References.....	217
11 Global Instability	219
Alfred J. Tria, Marcel A. Bas, Stephen Stephan, Matthew S. Hepinstall, Kevin I. Perry, and Arlen D. Hanssen	
Introduction.....	219
Option 1: Tibial Component Revision	219
Option 2: The Complete Revision	226
References.....	230
12 The Stiff Knee	231
Fred D. Cushner, David A. Crawford, Keith R. Berend, Stephen Petis, and Robert Trousdale	
Introduction.....	231
Option 1: Tibial Component Revision	232
Option 2: The Stiff Total Knee Arthroplasty—Complete Revision	237
References.....	243
13 Management of Tibial Bone Loss	245
Giles R. Scuderi, Thomas J. Parisi, Douglas A. Dennis, David G. Lewallen, Russell E. Windsor, and Danielle Y. Poncio	
Introduction.....	245

Option 1: Management of Severe Tibial Bone Loss:	
Tibial Bone Graft	246
Option 2: Tibial Augments and Cones	254
Option 3: Proximal Tibial Prosthesis	259
References	265
14 Management of Severe Femoral Bone Loss	269
Alfred J. Tria, Richard W. Rutherford, Douglas A. Dennis, David G. Lewallen, R. Michael Meneghini, and Kirsten Jansen	
Introduction	269
Option 1: Femoral Bone Grafting for Severe Femoral Bone Loss	269
Option 2: Femoral Augments and Cones	277
Option 3: Distal Femoral Prosthesis	283
References	286
15 Managing Patella Defects	289
Fred D. Cushner, Stephen Petis, Michael Taunton, Arlen Hanssen, Michael D. Ries, Kelly G. Vince, and Michel Malo	
Introduction	289
Option 1: Patellar Bone Grafting	290
Option 2: Patellar Augments	295
Option 3: Gullwing Patellar Osteotomy for Osteolytic Deformity	302
References	309
16 Management of Patella Tendon Rupture	311
Giles R. Scuderi, Nicholas B. Frisch, Richard A. Berger, James A. Browne, Mark E. Mildren, Andrea Baldini, Vincenzo Franceschini, and Michele D'Amato	
Introduction	311
Option 1: Management of Patellar Tendon Rupture—Extensor Mechanism Allograft	312
Option 2: Management of Extensor Mechanism Deficiency Using Knitted Polypropylene Graft	320
Option 3: Structural Proximal Tibia and Patellar Tendon for Chronic Rupture	325
References	330
17 Management of Periprosthetic Femur Fracture	333
Alfred J. Tria, Jason M. Jennings, Raymond H. Kim, Aldo M. Riesgo, and William L. Griffin	
Introduction	333
Option 1: Management of Periprosthetic Femur Fracture—Open Reduction Internal Fixation (ORIF)	333
Option 2: Distal Femoral Replacement	338
References	343

18	Management of Failed Unicondylar Arthroplasty	347
	Fred D. Cushner, Christopher Dodd, Hemant Pandit, and David J. Mayman	
	Introduction	347
	Option 1: Converting Medial Unicondylar Arthroplasty to Total Knee Arthroplasty	348
	Option 2: Converting Lateral Unicondylar Arthroplasty to Total Knee Arthroplasty	353
	References	360
19	Failed Patellofemoral Arthroplasty	363
	Fred D. Cushner, Adam Norwood, and Giles R. Scuderi	
	Introduction	363
	Option 1: Management of Failed Patellofemoral Arthroplasty	364
	References	369
20	Management of Prior Knee Fusion	371
	Alfred J. Tria and Dror Paley	
	Introduction	371
	Option 1: Knee Replacement After Knee Fusion or Ankylosis Combined with Paley modified Judet Quadricepsplasty	371
	References	386
21	Management of Soft Tissue Defects	387
	Giles R. Scuderi, Michael P. Nett, Germán A. Norambuena, H. John Cooper, Oren Lerman, and Irena Karanetz	
	Introduction	387
	Option 1: Local Wound Care	388
	Option 2: Negative-Pressure Dressing Approach	396
	Option 3: Flap Reconstruction	404
	References	411
	Index	415

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Part I

Primary Total Knee Arthroplasty

The Varus Knee

Giles R. Scuderi, Trevor P. Scott, Amar S. Ranawat,
Chitranjan S. Ranawat, Chad D. Watts,
Walter B. Beaver, Trevor J. Shelton,
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Introduction

Giles R. Scuderi

Fixed angular deformity in the coronal plane necessitates special consideration to restore normal alignment during total knee arthroplasty (TKA). Osteoarthritis with a varus deformity is one of the most common deformities presenting for TKA. A recent longitudinal study revealed that 58% of knees with osteoarthritis presented with a varus deformity compared to 18% with valgus deformity [1]. Pathologic and surgical reviews have shown that fixed varus deformity is associ-

ated with medial tibial and femoral bone loss and contracture of the medial supporting structures including the deep and superficial medial collateral ligaments and posteromedial capsule.

At the present time, there are various options for correcting a fixed varus deformity, but it is well accepted that accurate soft tissue balance with restoration of the mechanical alignment of the knee joint is critical to a successful outcome. Insall and Ranawat first described the traditional method of soft tissue release [2]; however, it has become evident that over-release of the medial collateral ligaments can potentially lead to instability and elevation of the joint line. Soft tissue release has evolved over the years, to more sequential and controlled releases of the medial supporting structures. While Verdonk described the use of a pie-crusting technique to release the medial collateral ligament when correcting a varus deformity [3], Ranawat adopted a controlled lengthening of the superficial medial collateral ligament by incising it in an inside-out pie-crust manner combined with a capsulotomy of the posteromedial capsule at the level of the tibial resection [4].

The degree of deformity is variable, and severe fixed varus deformity of the knee can pose a challenging problem requiring complete distal release of the superficial medial collateral ligament and insertion of the pes anserinus or osteotomy of the femoral insertion of the medial collateral ligament [5]. In cases with excessive release of the

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medial collateral ligament with the possibility of medial instability, a more constrained implant may be needed to provide adequate stability. Understanding the implications with soft tissue release is paramount to a successful TKA, and the following case reports will describe the various techniques for correcting an osteoarthritic knee with varus deformity.

Option 1: Medial Collateral Ligament Pie Crusting of the Fixed Varus Knee

Trevor P. Scott, Amar S. Ranawat, and Chitranjan S. Ranawat

Case Presentation

History

The patient is a 72-year-old male with 3 years of worsening left knee pain. His pain is primarily medial and is worse with activity and with stairs. It limits his walking to three to five blocks at a

time, and he no longer gets adequate pain relief from NSAIDs. His most recent corticosteroid injection was 6 months ago and provided temporary pain relief. He denies any pain in his hip or lumbar spine. There is no history of trauma or prior surgery to the left knee.

Physical Exam

The patient is a fit and athletic male in his 70s. He is in no acute distress and alert and oriented four times. The patient ambulates with an antalgic gait. Left knee skin is intact and there is minimal quadriceps atrophy. The knee is in varus alignment of 10°, which is not correctable. Range of motion is 15°–105°. There is laxity of lateral structures on varus stress. There is tenderness to palpation along the medial and to a lesser extent the lateral joint line. There is positive patellofemoral grind test. The left lower extremity is neurovascularly intact.

Radiographs and Advanced Imaging

Radiographs demonstrate tricompartmental osteoarthritis with varus alignment (Fig. 1.1).



Fig. 1.1

Anteroposterior (AP)
(a) and lateral (b) views
of the patient's knee
demonstrate a significant
varus deformity

Surgical Approach

Spinal anesthesia is given along with a saphenous nerve block. The patient is then positioned supine on the operating table with a high-thigh tourniquet. A post is placed at the level of the tourniquet for support, and a sandbag is placed at the mid-tibia to assist with positioning in flexion. A straight midline incision is drawn in extension from two fingerbreadths above the patella to the bottom of the tibial tubercle. The initial exposure is performed without the use of the tourniquet. The knee is then flexed up and the skin incision is made utilizing a scalpel. Electrocautery is used for hemostasis and further dissection. A standard medial parapatellar arthrotomy is performed with electrocautery to aid in further hemostasis. We raise the medial soft tissue sleeve in flexion and take care to protect the superficial medial collateral ligament (sMCL) and the pes anserinus insertion. The cruciates and remaining menisci are resected. The patella is everted, and the tibia is then subluxed anterior to the femur utilizing the “Ran-sall” maneuver, which involves hyperflexion and external rotation of the knee (Fig. 1.2). These maneuvers allow visualization of the entire articular surface of the tibia.

We utilize a PFC SIGMA posterior-stabilized (PS) implant (DePuy Synthes, Warsaw, IN, USA). Following exposure the extramedullary tibial cutting jig is placed to make a 90° cut to the long axis of the tibia. We take an 8–10 mm cut from the high point of the less affected lateral



Fig. 1.2 Exposure of the entire articular surface of the tibia utilizing the “Ran-sall” maneuver of hyperflexion and external rotation. The lateral cortex is colored in, and the medial osteophytes identified by the digital blue line are resected

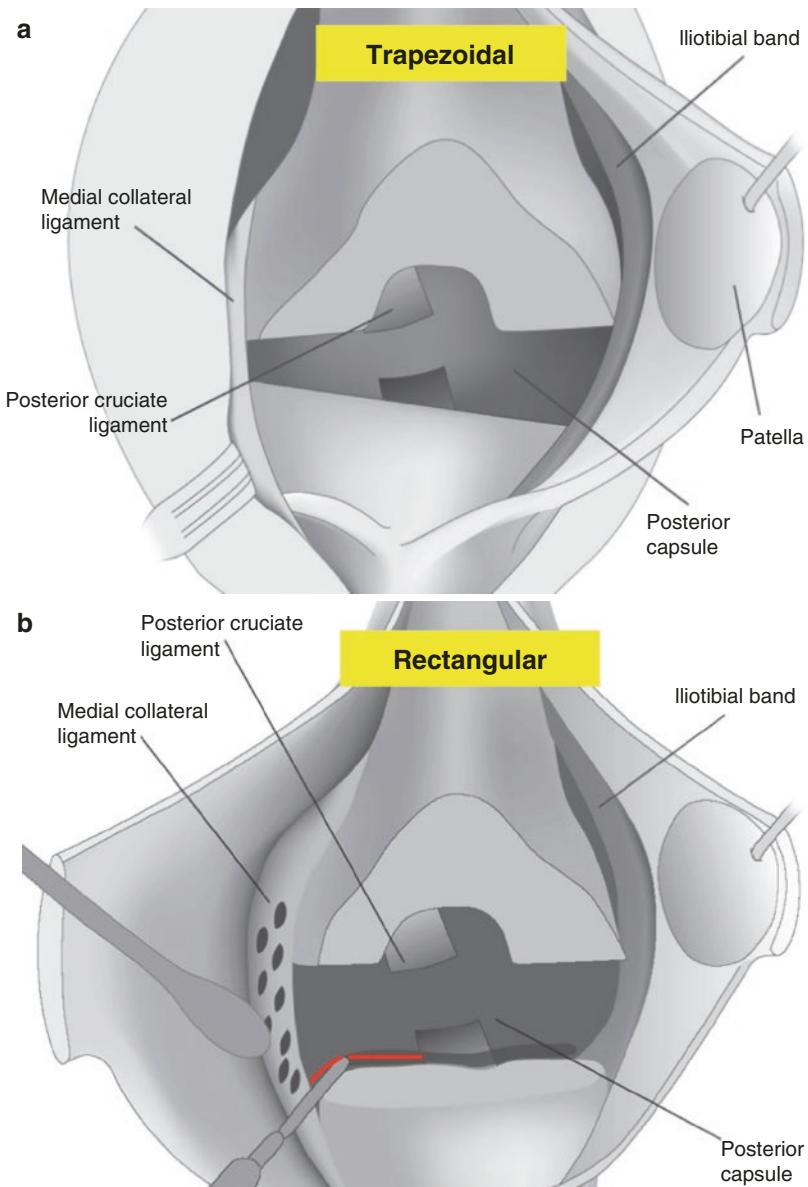
tibial plateau. If there is evidence of >1 cm lateral soft tissue elongation, i.e., a varus thrust on ambulation or medial femoral subluxation on anteroposterior (AP) radiographs, then a lesser depth cut (6–8 mm) is utilized. Making a thick tibial cut in the setting of a large deformity may result in a very large extension gap that may become difficult to balance in flexion. The tibial cut is then assessed with a drop rod to check the alignment is indeed 90°. If correct we then perform a reduction osteotomy of medial osteophytes. The patella is then prepared in the usual fashion.

The intramedullary femoral alignment guide is then placed, and a 5° valgus cut is made in the majority of cases. The depth of the cut is set to 8–10 mm, and only in rare circumstances of severe flexion contracture is more bone resected because this may raise the joint line and cause midflexion instability.

At this point the knee is brought into extension and a spacer block is placed into the extension gap. If bleeding is excessive at this point, the tourniquet may be utilized. The key point is to recognize that if the spacer block can fit in the lateral side of the knee, then the depth of bone resection is deemed appropriate. The challenge then lies in releasing the medial soft tissue sleeve. This is accomplished by placing a laminar spreader into the extension gap which is trapezoidal in shape due to the tight medial structure (Fig. 1.3) and performing the release. The posterior cruciate ligament (PCL) remnant and posteromedial capsule are released at the level of the tibia using electrocautery. This resection is carried forward as anterior as the posterior border of the sMCL (Fig. 1.4). A periosteal elevator is utilized to check completeness of the release.

The spacer block is then placed in the knee and now should fit in easily. At this point varus and valgus stability is checked, and in the varus knee continued medial structure tightness is often noted. In this case the knee is placed under valgus stress, and digital palpation is utilized to identify tight bands of tissue of the sMCL. These are incised in a pie-crust fashion with an 11 blade scalpel in an oblique fashion (Fig. 1.5). Three to five oblique stabs are made. The knee is then

Fig. 1.3 (a) The contracted medial soft tissue will result in a trapezoid-shaped extension gap. (b) Demonstrates the posteromedial capsular release to create a rectangular extension gap



manipulated under valgus stress and extension with the spacer block is in place. Our goal is 2–3 mm of springy give equally both medially and laterally (Fig. 1.6). Slightly increased lateral laxity is accepted if equivalent balance cannot be obtained.

Finally, the knee is brought to 90° of flexion, and utilizing a posterior referencing cutting guide, the “parallel to the tibial” cut technique is utilized for the AP femoral cut (Fig. 1.7). Care is taken not to notch the anterior femur. Posterior

femoral osteophytes are resected at this point. The remaining aspect of the knee replacement is completed in standard fashion.

Postoperatively a sterile dressing is placed, and ASA is used for DVT prophylaxis unless the patient has risk factor for a thromboembolic event in which case Coumadin is utilized. Twenty-four hours of perioperative antibiotics are given. The patient is weight bearing as tolerated and ambulates with physical therapy on postoperative day 0 or 1.

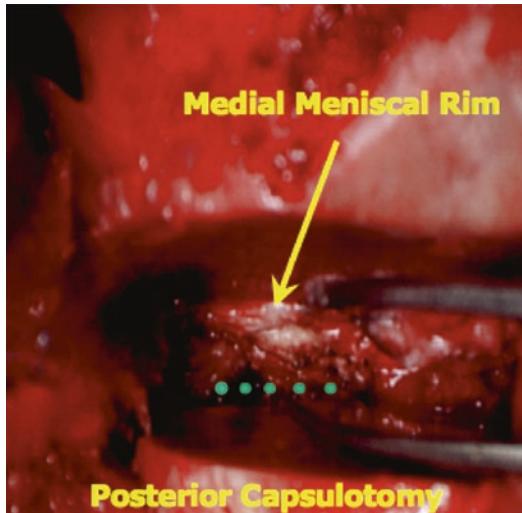


Fig. 1.4 Medial release is performed at the level of the tibia along the posterior medial capsule. Release may be brought as far anterior as the posterior border of the sMCL



Fig. 1.5 A laminar spreader may be used to place the knee under tension in extension, alternately a spacer block may be used, and an 11 blade is utilized for oblique stab incisions into contracted bands of the sMCL

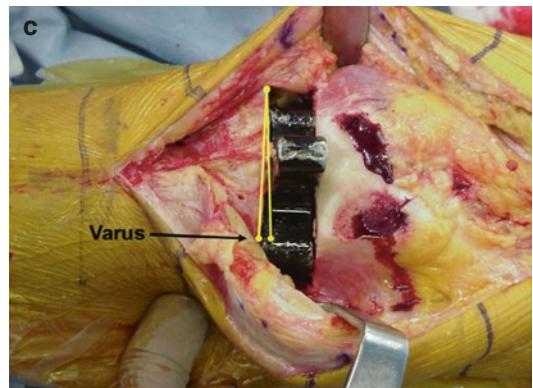
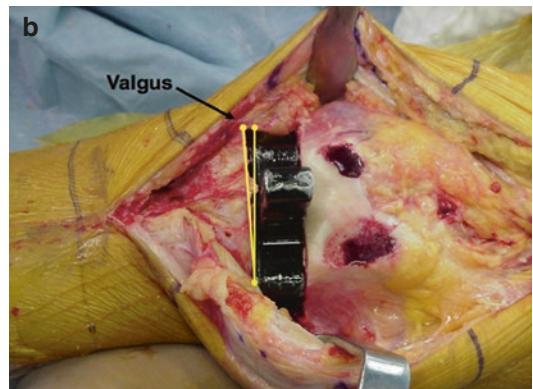
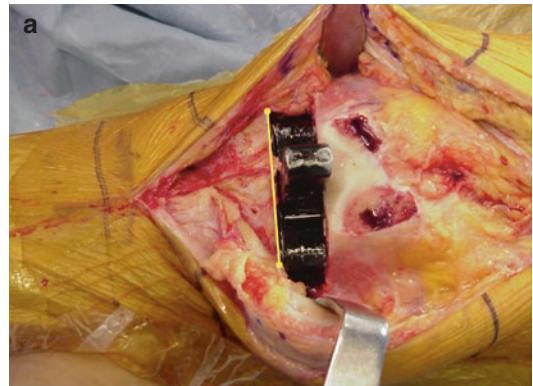


Fig. 1.6 (a) The knee following releases with spacer block in place. (b) Demonstrates 2–3 mm of medial “springy give” under valgus stress. (c) Demonstrates 2–3 mm of “springy give” laterally under varus stress

Postoperative Result

The patient underwent an uneventful postoperative course and was discharged from our facility on postoperative day 3. He transitioned to ambulation without aid at 6 weeks. Radiographs at his first postoperative visit demonstrate well-aligned TKA, and physical exam demonstrated no medial or lateral instability (Fig. 1.8).

Clinical Results

Varus deformity is the most commonly encountered alignment abnormality in total knee arthroplasty, and it often presents with concomitant flexion deformity. The three most basic principles of total knee arthroplasty include establishment of equivalent and rectangular flexion and

extension gaps, neutral alignment of the knee, and equivalent medial and lateral soft tissue tension. In knees with minimal deformity, this is often relatively straightforward and may be achieved simply by correct placement of bone cuts. However, in more severe disease, a combination of bone loss from the medial tibial plateau and medial femoral condyle and contracture of

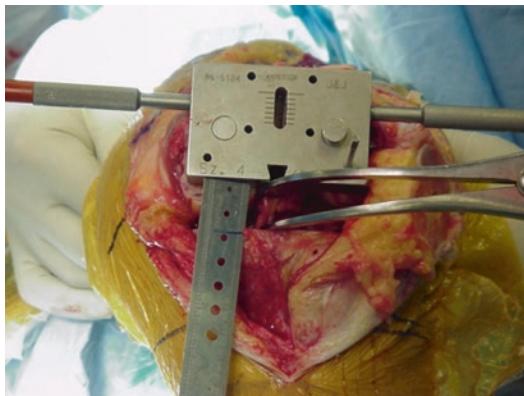


Fig. 1.7 “Parallel to the tibia” technique for rotation of the femoral component

the medial soft tissue sleeve and sometimes elongation of the lateral soft tissue can make it impossible to achieve these goals by bone cuts alone [4]. Traditionally this was addressed using the method described by Insall et al. in 1979 which involved subperiosteal release of the posteromedial capsule, the semimembranosus tendon, the distal attachment of the superficial MCL, and occasionally the pes anserinus insertion [6]. However this technique has been noted to potentially result in over-release of medial structures as it can be challenging to correctly titrate the release. Further it has been suggested that the subperiosteal release may result in hematoma, postoperative pain, and elevation of the joint line. Moreover it provides limited ability to control flexion versus extension contractures and may result in a need for a constrained prosthesis if over-release occurs [4, 7]. This may be because in severe varus deformity the medial sleeve release often involves both distal attachments of the sMCL, which have been shown to contribute to stability of the medial aspect of the knee [7, 8].

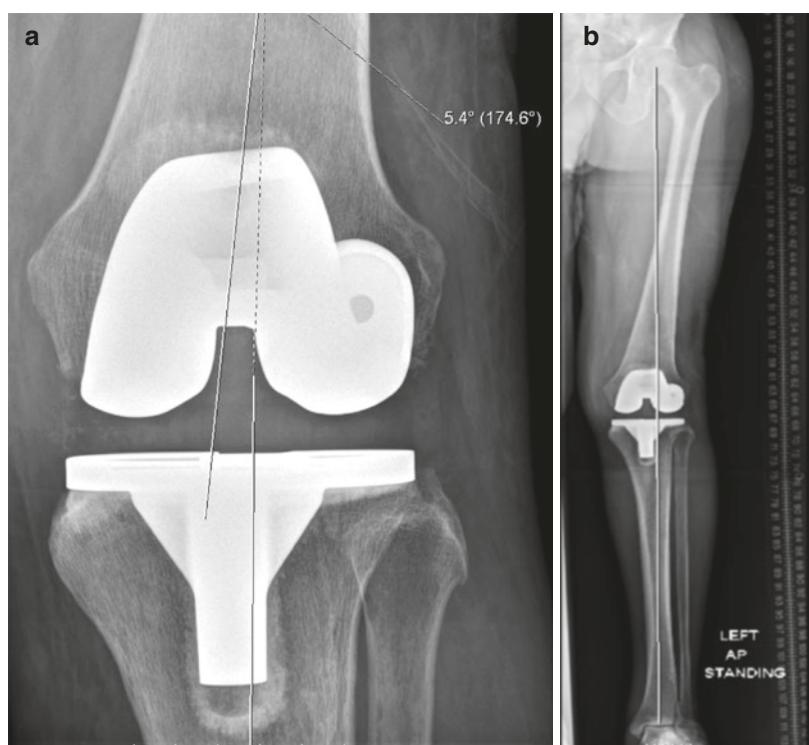


Fig. 1.8 Postoperative radiographs demonstrating well-aligned components

The senior author has extensive experience with pie crusting of tight lateral soft tissue structures in valgus flexed knees [9]. In order to address the concerns with the traditional medial release, we have applied these principles to medial release in fixed varus knees. In a study of 31 knees treated with this technique, we found that we were able to improve preoperative alignment from a mean of $21.1^\circ \pm 4^\circ$ of varus and $10^\circ \pm 3.5^\circ$ flexion contracture to $4.5^\circ \pm 1.6^\circ$ of valgus and complete resolution of the flexion contracture in all but three patients (each of whom had less than 5° residual contracture). In that study only two TC3-constrained polyethylene inserts were required, both of which were for residual lateral-sided laxity [4].

Other authors have advocated similar pie-crusting techniques. Engh suggested a similar technique of releasing the sMCL at the joint line in 2003, though he emphasized doing this in isolation as opposed to combining it with release of the posterior medial capsule [10]. Verdonk et al. recommended pie crusting of the sMCL with an 11 blade scalpel in mildly varus knees that needed less than 6–8 mm of release; if greater release was needed, they proceeded to subperiosteal release of the sMCL. Though in their paper they did not directly address flexion contractures, they did note that 63% of the knees in the study required release of the semimembranosus for residual flexion deformity. Their study of 359 knees with relatively mild preoperative varus of less than 11° found their algorithm to reliably reproduce neutral coronal alignment and Knee Society Score (KSS) improvement [3]. Bellemans et al. advocated a similar technique utilizing a 19 gauge needle for outside-in pie crusting of the sMCL and dMCL though in keeping with their surgical technique, they performed pie crusting in either flexion, extension, or both depending upon which position the knees was tight [11]. With this technique they found they were able to correct the alignment of 34/35 knees with an average preoperative deformity of 12.5° though they did identify one case of over-release [11].

We continue to believe that soft tissue balancing should be performed in extension. A recent

cadaver study of the pie-crusting technique of just the MCL demonstrated that pie crusting in extension resulted in relatively equivalent increase in flexion and extension gap laxity medially, whereas pie crusting in a flexion position resulted in preferential release of the flexion gap and may be more likely to result in over-release [12].

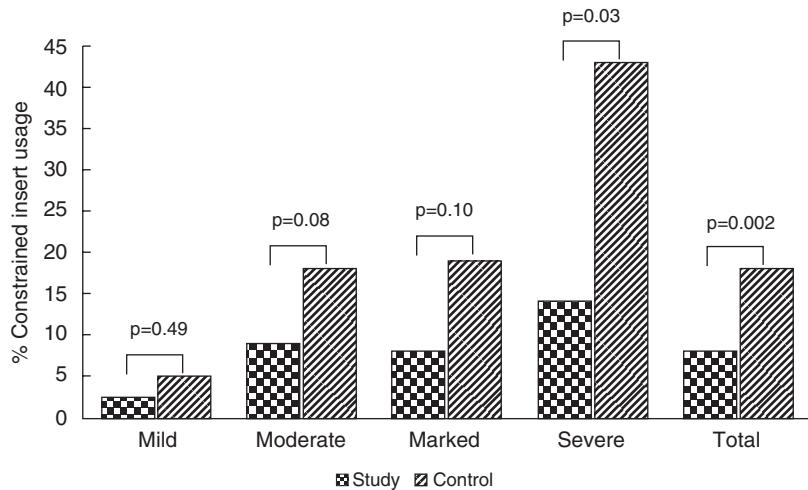
One concern with medial pie crusting is over-release and potential rupture of the sMCL. Meneghini et al. performed a cadaver study examining pie crusting of the MCL with a 15 blade and did find that unlike traditional release the MCL after pie crusting tended to fail at the joint line in a stepwise mechanism. However, there was no difference in mechanical strength of the MCL between the traditional release group and the pie-crusting group. Of note they also performed this study in cadavers in which the only residual medial soft tissue was the MCL, and they used a 15 blade as opposed to an 11 blade [13]. Further in a different biomechanical cadaver study by Mihalko et al., there was no difference in failure between traditional subperiosteal release and pie-crusting technique, and knees that had undergone pie crusting demonstrated significantly less internal rotation instability [14]. Clinical studies have demonstrated few cases of intraoperative over-release with this technique, and to the best of our knowledge, there have been no reports of late failure of the medial soft tissue [3, 4, 7, 11, 15]. In fact one recent paper demonstrated a significant difference in the need for less constrained polyethylene tibial inserts with the pie-crusting technique than a traditional release, a finding which was more marked with greater degrees of deformity (Fig. 1.9) [7].

In summary pie crusting of the sMCL and release of the posterior medial capsule at the tibial cut surface are safe and effective procedures for dealing with all but the most significant cases of varus and allow reliable correction of varus and flexion malalignment.

Key Points

- Varus knees with flexion contracture are a commonly encountered knee deformity.

Fig. 1.9 Bar chart demonstrates the use of constrained inserts in the study group and the control group by preoperative varus deformity (From Goudarz Mehdikhani et al. [3], with permission)



- Release of the posterior medial capsule from the tibial border and pie crusting of the sMCL in extension with an 11 blade can reliably and safely correct both flexion and varus deformity without late instability.

mity of 7° which does not correct with valgus stress. Stable end points are present with varus/valgus stress. His patella tracks in midline with crepitus through range of motion. He has severe pain with squatting and getting out of a chair. Quadriceps strength is 4/5.

Option 2: Medial Release for the Varus Knee

Chad D. Watts and Walter B. Beaver

Case Presentation

History

The patient is a 66-year-old male who has a 30-year status post-open medial meniscectomy of his left knee. He has increasing pain and varus deformity over the last 5 years. He now has difficulty ambulating over two city blocks and a recent reduction in ability to perform activities of daily living. He has had appropriate conservative measures which include NSAIDs, multiple injections, and physical therapy. Recent steroid shots lasted less than 2 weeks. He now presents for surgical consideration.

Physical Exam

Height 5'7", weight 188 lbs, and BMI 29.5 kg/m². He walks with an antalgic gait with a varus thrust and has a moderate effusion. Range of motion is 10°–95°. He has a fixed varus defor-

Radiographs and Imaging

Preoperative templating is performed using long-leg standing radiographs to measure the angle of divergence between the anatomic and mechanical femoral axes, which is used to determine the distal femoral resection angle (Fig. 1.10).

Surgical Approach

In the present case, a standard medial parapatellar approach was used leaving a 1 mm cuff of medial quadriceps tendon proximally. The arthrotomy was extended distally to the level of the tibial tubercle. The anterior horn of the medial meniscus was incised, and a triangular tissue flap was developed subperiosteally from the medial tibia, allowing for access to the deep medial collateral ligament (MCL), which is typically the tightest structure contributing to fixed varus deformity (Fig. 1.11).

A curved osteotome was driven along the medial joint line using a small mallet to release the meniscotibial fibers of the deep MCL (Fig. 1.12). With the osteotome still in place and

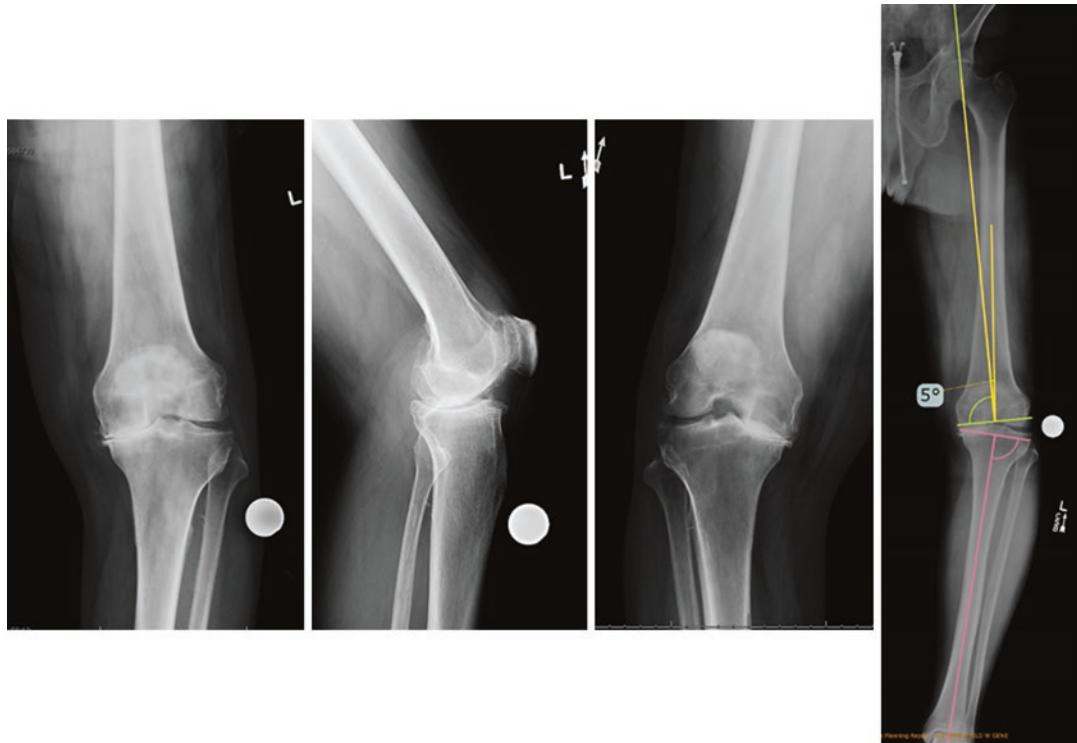


Fig. 1.10 Anteroposterior, lateral, posterior cerebral arteries, and long-leg views of the left knee prior to surgery (left to right). A varus deformity with medial tibial

bone loss is present. On a long-leg standing view, we measured a 5° divergence between patient's mechanical and anatomical femoral axes



Fig. 1.11 Medial parapatellar arthrotomy



Fig. 1.12 Deep medial collateral ligament release

acting as a retractor, electrocautery was used to complete the release of the deep MCL.

The distal femur was then cut at 5° of valgus, as determined preoperatively using a long-leg standing radiograph. The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) were then released from the notch. The tibia was then translated forward and externally rotated, while further medial capsule was released just below the joint line. It is imperative to keep the medial capsular release at or near the joint line. Extending the medial release distally toward the pes insertion may result in over-release, resulting in a loose medial flexion gap. A posterior Meckel retractor was used to assist with anterior translation of the tibia, and a sharp Hohmann retractor was used to apply tension to the medial capsular structures during their release. Once the proximal tibia has been translated forward and exposed, it was then cut perpendicular with the axis of the tibia using an extramedullary guide (Fig. 1.13).

A spacer block was then placed with the knee in extension. During this step, a drop rod was

placed to confirm appropriate coronal and sagittal tibial resection (Fig. 1.14). Varus and valgus stress was applied, and we found that the medial extension gap was slightly tighter than the lateral gap. The tibia was again subluxated and externally rotated, and medial tibial osteophytes were removed with a rongeur. The medial subperiosteal release was extended around the posterior aspect of the knee, incrementally releasing the posteromedial corner, posterior oblique ligament, and posterior capsule. A spacer block was again placed in extension and our medial and lateral gaps were symmetric. If there is symmetric laxity, incrementally larger spacer blocks are placed until there is no liftoff with varus/valgus stress. In severe fixed deformities, such a release may not adequately correct coronal alignment in extension. If we remain unbalanced following these maneuvers, our next step is to perform a medial tibial reduction osteotomy, wherein medial tibial bone is progressively removed with a saw or rongeur. If this maneuver still proves insufficient, only then will we consider releasing the pes

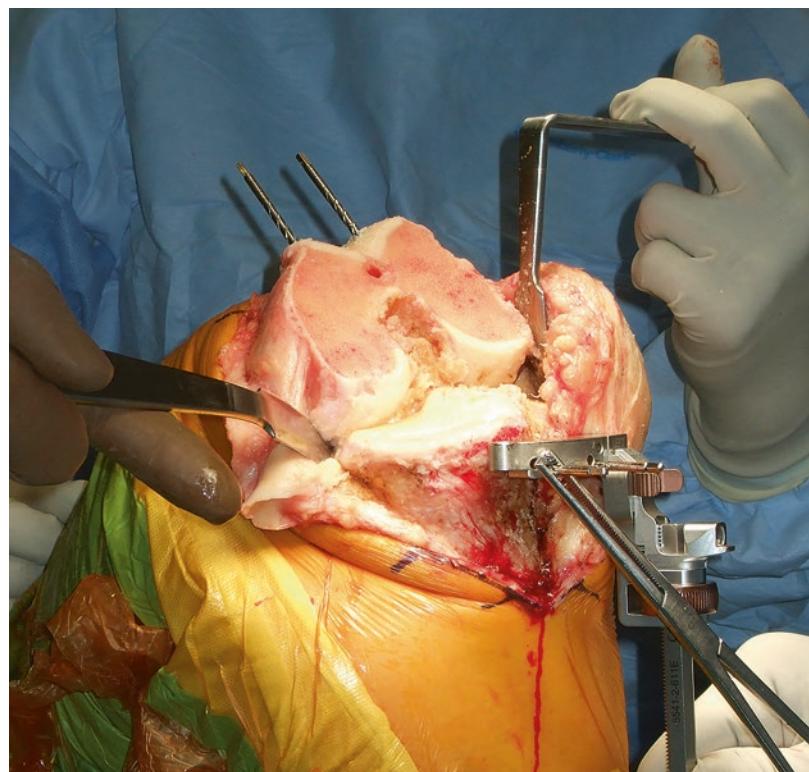
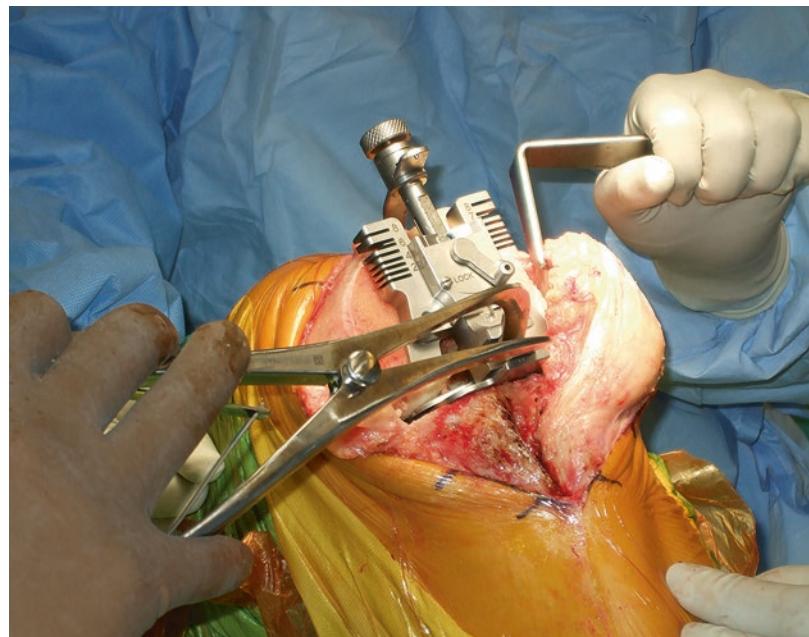


Fig. 1.13 Exposure for cutting of the proximal tibia

Fig. 1.14 Knee in extension with spacer block and alignment rod



Fig. 1.15 A gap-balance device is used to tension the collateral ligaments and set femoral rotation



anserine tendons or pie crusting the superficial MCL. At this point a constrained prosthesis may be necessary.

The knee was then flexed to 90°, and a gap-balancing tension device was used to set the rotation of the femoral cutting block, with a gap equal to that which we determined in extension (Fig. 1.15).

Prior to making any femoral cuts, a spacer block was inserted posterior to the 4-in-1 cutting block with the knee in flexion, and the hip was

internally and externally rotated to ensure that medial and lateral gaps were balanced in flexion, without any liftoff (Fig. 1.16).

The anterior, posterior, chamfer, and box cuts were then made in the femur. The tibial preparation was made with appropriate external rotation. In this case, there was a medial defect in the tibial plateau that was not fully removed with the proximal tibial cut. Rather than preparing for a medial augment, two cancellous screws were

Fig. 1.16 A spacer block is used to check flexion gap balance prior to cutting through the 4-in-1 block

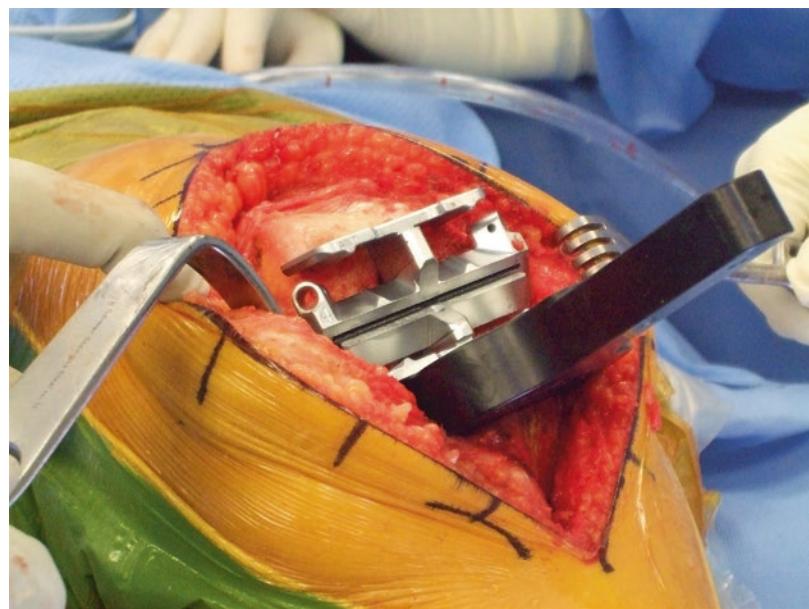


Fig. 1.17 Trial implants are placed to evaluate motion, stability, and patellar tracking

placed into the defect to help supplement medial support of the tibial tray. Trial implants were placed and the patella prep was completed (Fig. 1.17).

The trial patella tracked in midline. All trials were removed, and after preparing the bone for cementation, the implants were cemented into appropriate position (Fig. 1.18).

Postoperative Result

The patient progressed well and at 3 months had regained all abilities for activities of daily living

with a walking tolerance of 2–3 miles. His knee was stable in all planes with 0–128° (Fig. 1.19).

Clinical Results

Primary total knee arthroplasty results in excellent outcomes for the majority of patients. While multiple techniques have been described to correct fixed varus deformities in primary total knee arthroplasty, there is little scientific evidence to support any one particular method over another. Krackow and Mihalko described the relative effects of releasing various structures on the

Fig. 1.18 Cementing of the final implants with meticulous removal of excess cement



Fig. 1.19 X-rays taken 3 months postoperatively show well-fixed cemented implants



medial side of the knee in cadavers [16], but comparative data has proven more difficult to describe in live postoperative patients with fixed deformity. Regardless of the technique chosen, it is

advisable to proceed in a stepwise fashion to obtain full intraoperative correction without over-releasing the medial side. Whiteside et al. showed that the anterior aspect of the MCL in the area of

the pes anserine tendons is particularly prone to over-release with significantly increased laxity on the medial side of the knee in 60° and 90° of flexion, predisposing to an asymmetrical gap in flexion [17]. A trapezoidal flexion gap can lead to internal rotation of the femoral component with subsequent patellofemoral issues when using a gap-balance technique [18] and has been associated with femoral condylar liftoff for total knees performed using measured resection [19].

Our preferred technique as currently described avoids release of the superficial MCL and pes anserine tendons in the large majority of patients. Occasionally, release of the deep MCL, posteromedial corner, posterior oblique ligament, posterior capsule, and the direct tibial insertion of the semimembranosus will not fully restore coronal balance in extension. In such knees, our next step is a tibial reduction osteotomy, which effectively loosens the medial side without affecting long-term implant survival [20–22]. Component design is another factor that may impact outcomes of primary total knee arthroplasty in patients with fixed deformities. While debate continues regarding posterior-stabilized (PS) versus cruciate-retaining (CR) designs, some studies have reported superior functional outcomes and implant survivorship for PS knees in patients with fixed varus deformity [23, 24]. Since the PCL is a deforming force in knees with fixed varus, we prefer to use PS components because it leads to more consistent and predictable soft tissue management.

Key Points

- Release of the pes anserine tendons or anterior superficial MCL can result in over-release leading to a loose medial flexion gap.
- Over-release of the medial side may lead to internal rotation of the femoral component when using a gap-balance method for establishing femoral rotation.
- If release of the deep MCL, posteromedial corner, and posterior oblique ligament (POL) and direct semimembranosus insertion do not fully equalize the medial and lateral extension gaps, medial tibial reduction oste-

otomy is our next preferred step before releasing into the pes anserine tendons and/or superficial MCL.

- For residual medial tibial defects less than 5 mm deep, components are cemented in standard fashion. For defects between 5 and 10 mm deep, we use screws to supplement cement augmentation. Defects deeper than 1 cm should have a tibial augment.

Option 3: Kinematically Aligned Total Knee Arthroplasty Corrects a Severe Varus Deformity and Flexion Contracture to Native Alignment Without Soft Tissue Release

Trevor J. Shelton and Stephen M. Howell

Case Presentation

History

A 58-year-old male presented with advanced post-traumatic, postsurgical osteoarthritis of his left knee with severe varus deformity and fixed flexion contracture. Patient sustained a motorcycle injury to his left knee at age 24. An arthrotomy was performed at that time, and an anterior cruciate ligament (ACL) tear was left unrepaired. A reinjury at age 48 resulted in a medial bucket-handle meniscal tear and subsequent arthroscopic meniscectomy. Ten years later, the patient presented with a severe varus deformity of 20° with 15° flexion contracture, inability to walk, and inability to do daily activities. Preoperatively, his Oxford Knee Score (OKS) was 11 (0 worst, 48 best), Knee Society Score (KSS) was 31, and Knee Society Function Score (KSFS) was 40.

A severe varus deformity with flexion contracture presents several potential challenges for kinematically aligned (KA) total knee arthroplasty (TKA) with manual instruments and generally without soft tissue release. One potential challenge is if the medial collateral ligament (MCL) is contracted. A second is that a medial augment might be needed. However, KA TKA that restores the native distal and posterior joint

lines of the femur and having the wellness to cut the tibia to restore negligible varus-valgus laxity in full extension generally overcomes these two challenges without the need for an augment or MCL release [25, 26].

Physical Examination

Patient had full active and passive range of motion (ROM) of the left hip without pain. The knee at rest had a fixed 20° varus deformity (Fig. 1.20) and 15° flexion contracture. His knee ROM was limited to 15°–90° of flexion. Patient had relatively normal varus-valgus laxity at 0° and 30° indicating an intact MCL and lateral collateral ligament (LCL). He had a positive Lachman and posterior drawer indicating chronic ACL and posterior cruciate ligament (PCL) insufficiency.

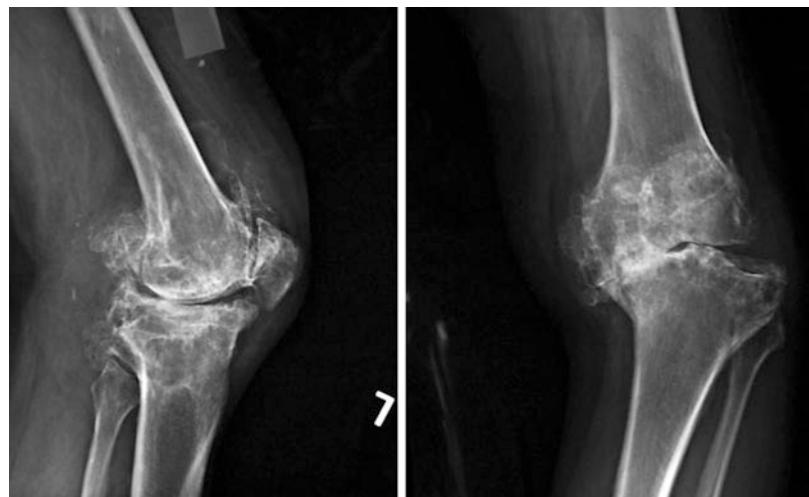
Radiographs and Advance Imaging

Standing anteroposterior and lateral radiographs of the left knee showed severe degenerative tri-compartmental arthritis including large osteophyte formation worse on the medial side, sclerosis, cystic changes, and definite bony deformity consistent with Kellgren-Lawrence grade 4 osteoarthritis (Fig. 1.21). Anterior and posterior osteophytes provided structural limitation to extend and flex his knee.



Fig. 1.20 Post-traumatic knee with severe flexion contracture and varus deformity with chronic posterior cruciate ligament insufficiency

Fig. 1.21 Standing lateral (left) and anteroposterior (right) preoperative radiographs of a post-traumatic left knee with severe flexion contracture and fixed varus deformity, large osteophyte formation, sclerosis, cystic changes, and definite bony deformity consistent with Kellgren-Lawrence grade 4 osteoarthritis



Surgical Approach

A mid-vastus approach exposed the knee. Osteophytes overgrew the notch, the ACL was absent, and the PCL is attenuated. First the femoral component was kinematically aligned by setting the femoral component tangent to the native distal and posterior joint line. Normally an offset caliper is used at this point to measure the anterior offset of the anterior tibia from the distal medial femur with the knee in 90° of flexion (Fig. 1.22); however, this was not done in this patient as his PCL was attenuated. Once the knee was fully exposed, the locations of cartilage wear were assessed on the distal femur. A ring curette was used to remove any partially worn cartilage to bone. The flexion-extension position of the femoral component was set by the insertion of a positioning rod 8–10 cm through a drill hole placed parallel to the anterior surface of the distal femur and perpendicular to the distal articular surface midway between the anterior cortex and the top of the intercondylar notch (Fig. 1.23) [27, 28]. The varus-valgus rotation and proximal-distal translation of the femoral component were set by using a

disposable distal referencing guide that compensates 2 mm when there is cartilage wear on the distal medial femoral condyle in the varus knee and 2 mm when there is cartilage wear on the distal lateral femoral condyle in the valgus knee. The anterior-posterior translation and internal-external rotation of the femoral component were set by placing a 0° rotation posterior referencing guide in contact with the posterior femoral condyles (Fig. 1.24). The positioning of the posterior referencing guide rarely requires correction because there is typically some normal cartilage thickness on the posteromedial/posterolateral femoral condyles where the posterior referencing guide rests even in the most arthritic knees [25, 27].

There are five intraoperative quality assurance steps that are used in sequence to confirm that the femoral and tibial components are placed following the principles of KA which are to place the components tangent to the native distal and posterior joint lines of the femur and tibia. The first intraoperative quality assurance step checks that flexion of the femoral component is minimized by positioning the starting hole for the positioning

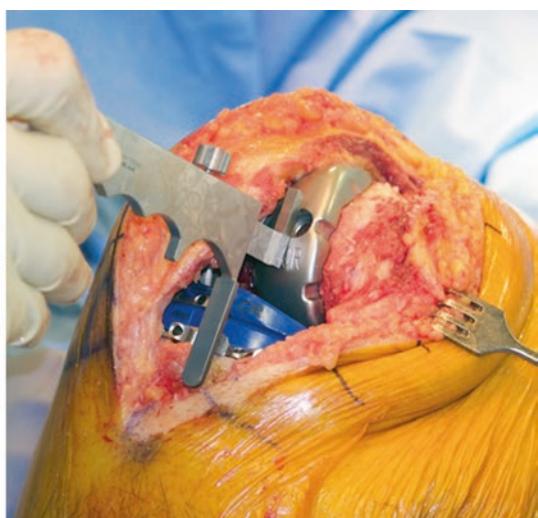


Fig. 1.22 Intraoperative photographs of a right knee with a varus deformity in 90° of flexion show the measurement of the native anterior offset of the tibia from the worn distal medial articular surface of the femur in a knee at the time of exposure (left) and at the time of reduction with the trial components (right). Compensating 2 mm for cartilage wear on the distal medial femur, adjusting the

anterior-posterior slope and the thickness of the tibial component until the offset of the anterior tibia from the distal medial femoral condyle with the trial components matches that of the knee at the time of exposure, and setting the internal and external rotations of the tibia approximately 14° restore the laxities of the knee in 90° of flexion

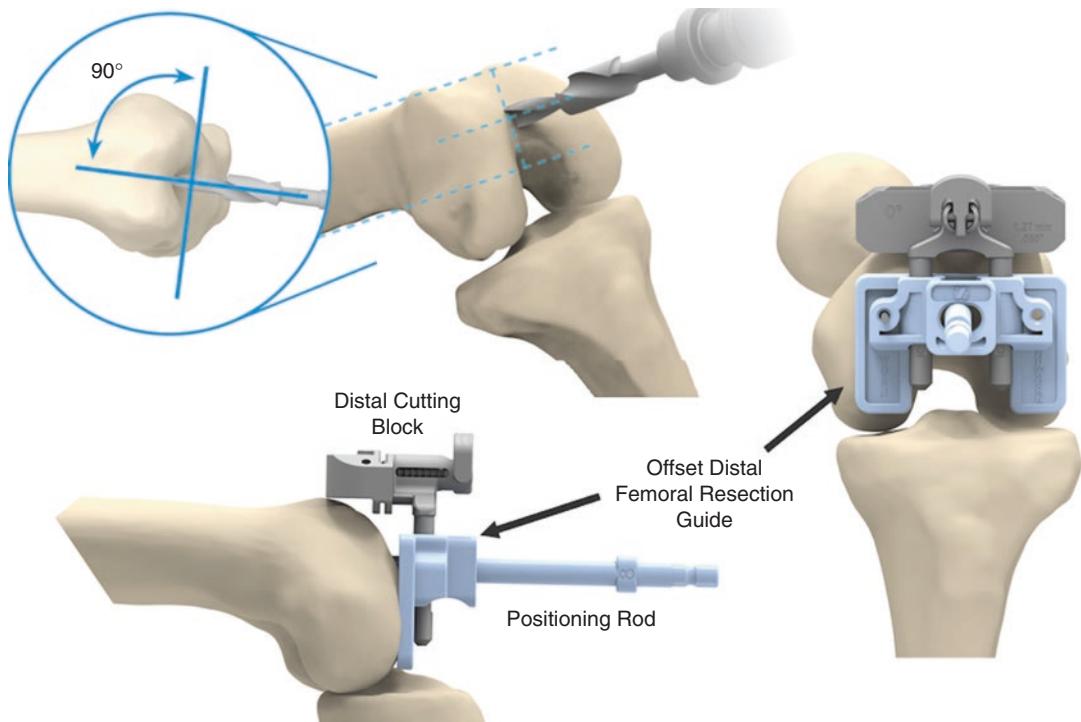


Fig. 1.23 Composite shows the method of setting the flexion-extension and varus-valgus rotations and the proximal-distal translation of the kinematically aligned femoral component with disposable instruments (blue). The insertion of a positioning rod 8–10 cm through a hole drilled midway between the top of the intercondylar notch and the anterior cortex and parallel to the anterior surface and perpendicular to the distal articular surface of the dis-

tal femur sets flexion-extension rotation of the femoral component. An assembly of the distal cutting block inserted into the offset distal femoral resection guide that compensates for 2 mm of cartilage wear on the worn condyle(s) is placed over the positioning rod in contact with the distal femur and sets varus-valgus rotation and proximal-distal translation of the femoral component (From Howell and Hull [28], with permission)

rod midway between the top of the intercondylar notch and aligning the positioning rod parallel to the anterior cortex of the femur (see Fig. 1.25). The second intraoperative quality assurance step checks the femoral component is kinematically aligned to the native femoral articular surface by performing a caliper measurement of the thickness of the distal and posterior femoral resections adjusting the thicknesses within ± 0.5 mm of the thickness of the condyles of the femoral component after compensating for cartilage wear and kerf from the saw blade (see Fig. 1.24). Alignment references used to position the femoral component in mechanically aligned (MA) TKA such as the femoral mechanical axis, intramedullary canal, transepicondylar axis, and anterior-posterior axis are neither of interest nor of use when performing KA TKA [25, 29, 30].

The following steps were used to align the tibial component tangent to the varus-valgus angle and posterior slope of the native tibial joint line. The tibial guide was applied and moved into varus about 2°. An angle wing was applied through the medial slot, and a conservative cut was made parallel to the varus-valgus slope after eliminating wear and kerf. The internal-external rotation can be set to either the major axis of the lateral tibial condyle or with the use of a kinematic tibial baseplate method [25, 31, 32]. The varus-valgus, flexion-extension, and proximal-distal positions are set with the use of an extra-medullary tibial guide (Figs. 1.25, 1.26, and 1.27) [25]. In this patient, a kinematic tibial baseplate was used to set internal-external rotation of the tibial component; the largest one of the seven available sizes that fit within the cortical contour

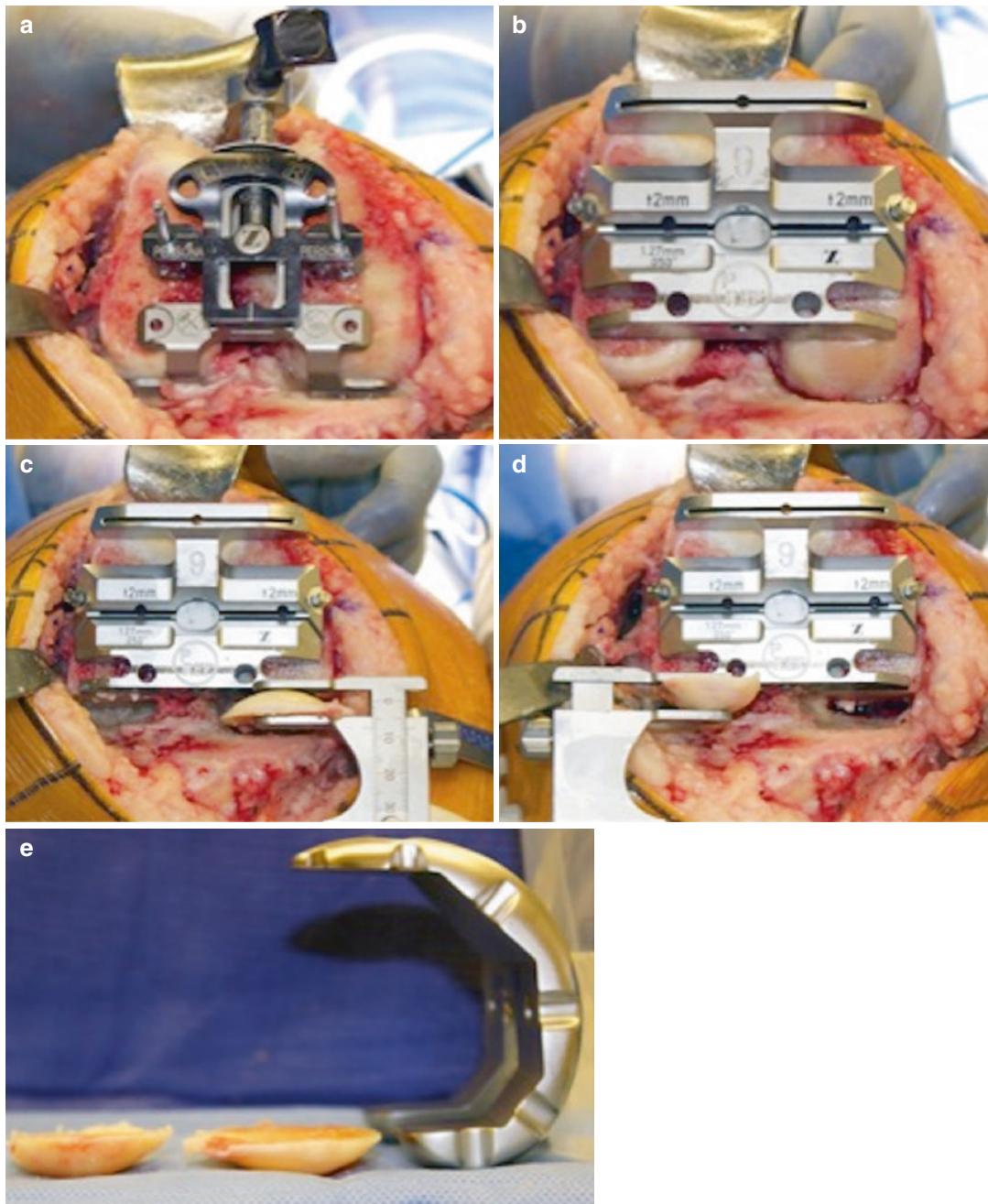


Fig. 1.24 Composite of a right varus osteoarthritic knee shows the steps for kinematically aligning the femoral component at 90° of flexion. A 0° rotation posterior referencing guide is inserted in contact with the posterior femoral condyles and pinned (a). The correct size chamfer guide is inserted into the pin holes (b). A caliper measures

the thickness of the posterior medial femoral condyle (c) and posterior lateral femoral condyle (d). These steps set internal-external rotation and anterior-posterior translation of the femoral component to the native articular surface of the posterior femur (e)

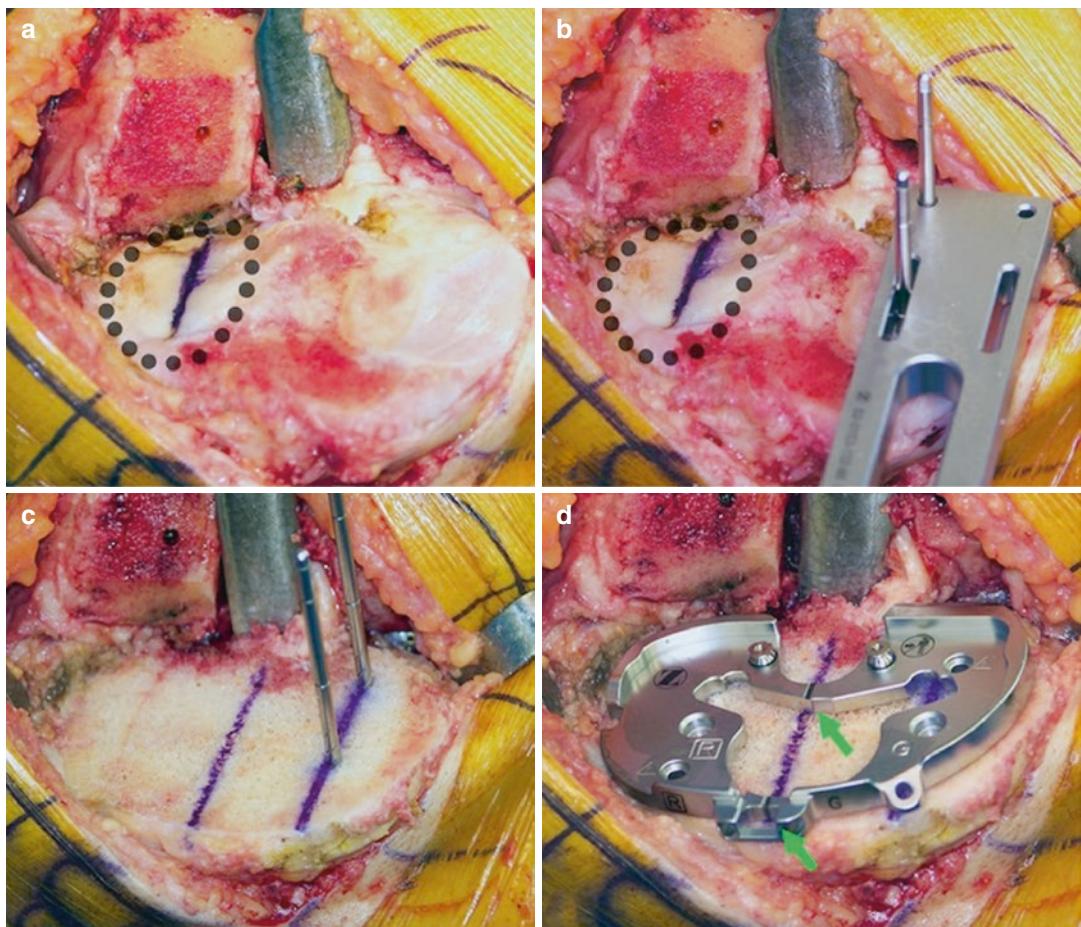


Fig. 1.25 Composite of a right knee shows the major axis of the lateral tibial condyle method for kinematically aligning the internal-external rotation of the trial tibial component to the anterior-posterior axis (blue line) of the nearly elliptical-shaped boundary of the articular surface of the lateral tibial condyle (black dots) (a). A guide is used to drill two pins through the medial tibial articular

surface and parallel to the major axis (b). The tibial articular surface is resected and removed, the two drill holes are identified (pins), and lines parallel to the drill holes are drawn (c). The score marks (green arrows) indicate that the anterior-posterior axis of the trial tibial baseplate is aligned parallel to these lines (d)

of the tibial resection was selected and best fit to the anterior and medial cortical edge (see Fig. 1.27). The in vitro reproducibility of the kinematic tibial baseplate was evaluated on 166 tibial resections by five arthroplasty surgeons, three orthopedic surgery fellows/residents, and three students and showed a negligible bias (0.7° external) and acceptable precision ($\pm 4.6^\circ$) between the anterior-posterior axis of the kine-

matic tibial baseplate and the flexion-extension plane of the knee. The in vivo reproducibility was evaluated in 63 KA TKAs by one arthroplasty surgeon and showed negligible bias (0.2° external) and acceptable precision ($\pm 3.6^\circ$) between the anterior-posterior axes of the tibial and femoral components (unpublished study).

The third intraoperative quality assurance step checks the internal-external rotation of the tibial

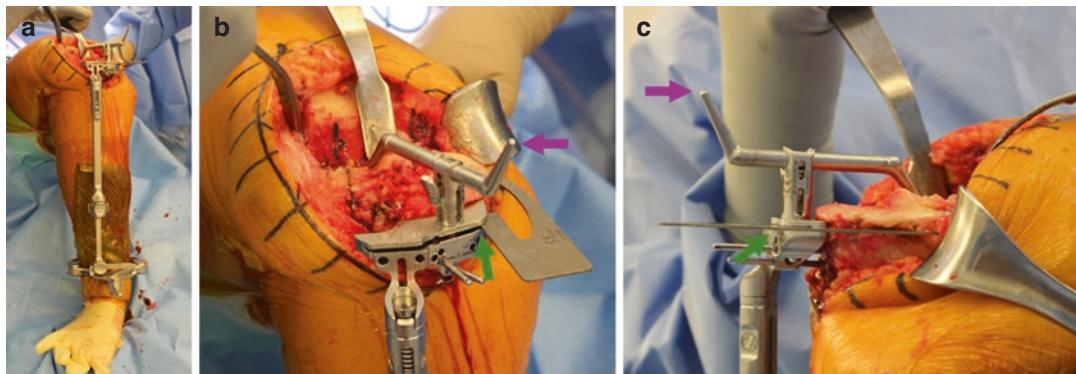


Fig. 1.26 Composite of a right knee shows the steps for kinematically aligning the tibial component. A conventional extramedullary tibial resection guide with a 10 mm offset tibial resection gauge (magenta arrow) and angel wing (green arrow) is applied to the ankle (a). The varus-valgus position of the tibial resection is set by adjusting the medial-lateral position of the slider at the ankle end of the guide until the saw slot is parallel to the tibial articular surface after visually compensating for cartilage and bone wear. The proximal-distal translation of the tibial compo-

nent is set by adjusting the level of the saw slot until there is contact between the 10 mm offset tibial resection gauge and the center of the unworn tibial condyle (b). The flexion-extension rotation of the tibial component is set by adjusting the inclination of the angel wing parallel to the slope of the medial joint line (c). These steps set the proximal-distal translation and the varus-valgus and flexion-extension rotations of the tibial component parallel to the native articular surface of the tibia

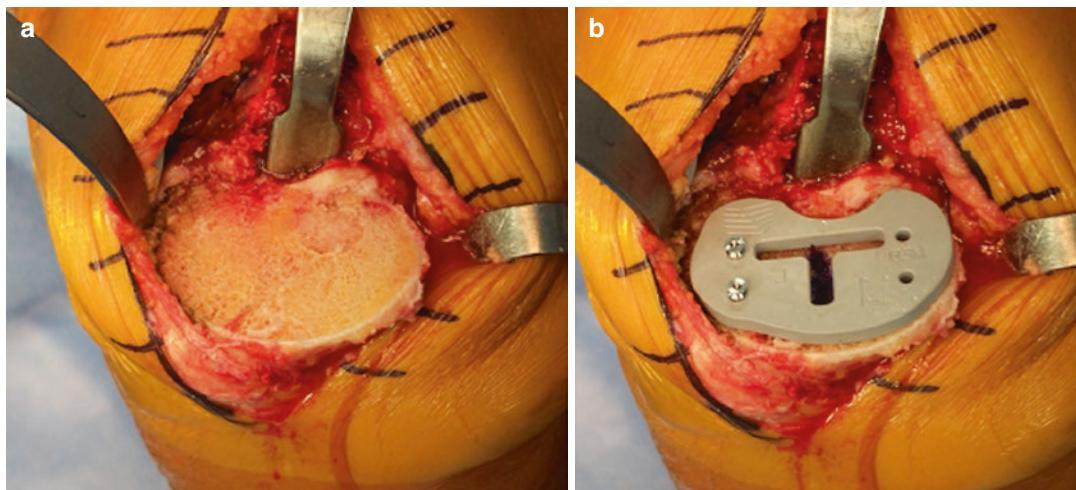


Fig. 1.27 Composite of a right knee shows the steps for aligning the internal-external rotation of the trial tibial component parallel to the flexion-extension plane of the knee with a kinematic tibial baseplate (gray). The cortical contour of the anatomic resection of the tibia is shown (a). The largest size kinematic tibial baseplate that fits within

the contour is selected from the seven kinematic tibial baseplates and is fit within the cortical contour (b). The anterior-posterior axis of the kinematic tibial baseplate is marked (blue line) (c). The score marks (green arrows) indicate that the anterior-posterior axis of the trial tibial baseplate is aligned parallel to the *blue line* (d)

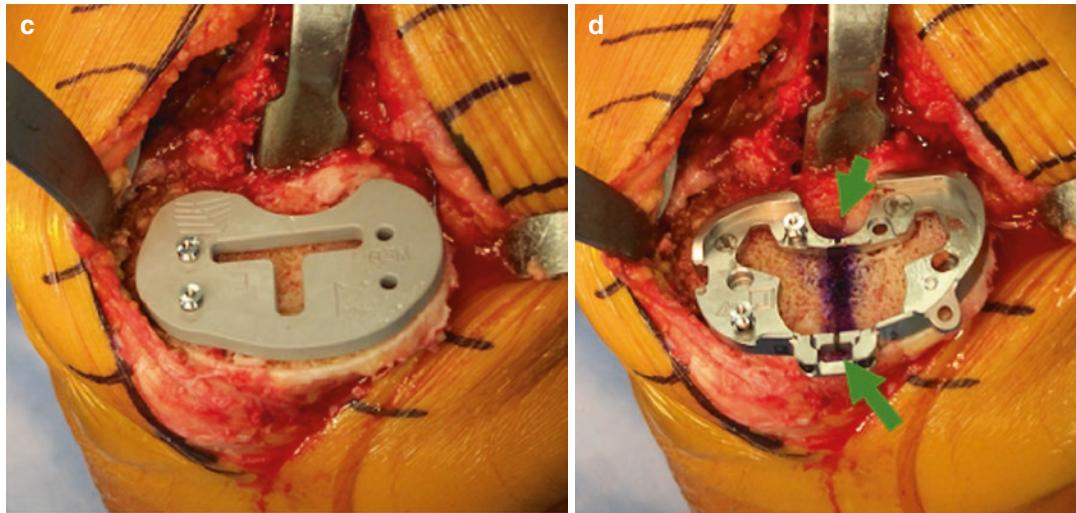


Fig. 1.27 (continued)

component is parallel to the flexion-extension plane of the knee by using either the major axis of the lateral tibial condyle or the kinematic tibial baseplate method. The fourth intraoperative quality assurance step checks the varus-valgus angle of the tibial resection until the varus-valgus laxity of the knee with trial components in extension is negligible which restores the native tibial joint line, knee alignment, and limb alignments [25, 26, 31, 32]. The final quality assurance step adjusts the anterior-posterior slope or flexion-extension of the tibial resection until the contact position of the femur on the tibia is centered which is measured by the anterior offset of the tibia on the femur (see Fig. 1.22) [25, 26, 32]. In this case, the PCL was insufficient, so the offset was estimated to be 15 mm based on the size of his knee.

When any of these conditions are not met, a stepwise alignment algorithm determines the corrective actions to achieve KA (Fig. 1.28). The underlying principle of this algorithm is that those corrections requiring a recut of bone are performed by fine-tuning the varus-valgus, flexion-extension or slope, and proximal-distal

positions of the tibial resection and not by recutting the femur nor by releasing collateral ligaments.

The patella was then prepared and the components were trialed before cementation. A PCL-substituting implant was used because of the torn PCL. The MCL was not contracted, no soft tissue releases were performed, and no medial augment was needed to restore the native tibial-femoral articular surface, the native knee and limb alignment, and the native knee laxities of this patient.

Postoperative Result

KA TKA corrected this severe varus deformity of 20° and flexion contracture of 15° without soft tissue release (Fig. 1.29). Postoperatively the patient had a 6° varus deformity, decreased from 20° preoperatively. The anteroposterior axis of the components was parallel to sagittal kinematic plane (Fig. 1.30).

Although the patient was not ambulatory before surgery, he was walking without any assistive devices 1 week after surgery. By 6 weeks, the patient's active ROM was from 5° to 110°

Step-Wise Algorithm for Balancing KA TKA					
Tight in Flexion & Extension	Tight in Flexion Well-Balanced in Extension	Tight in Extension Well-Balanced in Flexion	Well-Balanced in Extension and Loose in Flexion	Tight Medial & Loose Lateral in Extension	Tight Lateral and Loose Medial in Extension
Use thinner liner Recut tibia and remove more bone	Increase posterior slope until natural A-P offset is restored at 90° of flexion	Remove posterior osteophytes Reassess Strip posterior capsule	Add thicker liner and recheck knee extends fully When knee does not fully extend check PCL tension When PCL is incompetent consider PS Implants or UC liner	Remove medial osteophytes Reassess Recut tibia in 2° more varus Insert 2mm thicker liner	Remove lateral osteophytes Reassess Recut tibia in 2° more valgus Insert 2mm thicker liner

Fig. 1.28 Stepwise algorithm for balancing the kinematically aligned TKA. The top row lists six malalignments, and the bottom lists the corresponding corrective actions. Notice those corrections that require a recut of bone are

performed by fine-tuning the proximal-distal translation and the varus-valgus and flexion-extension (*slope*) rotations of the tibial resection and not by recutting the femur (From Howell and Hull [28], with permission)

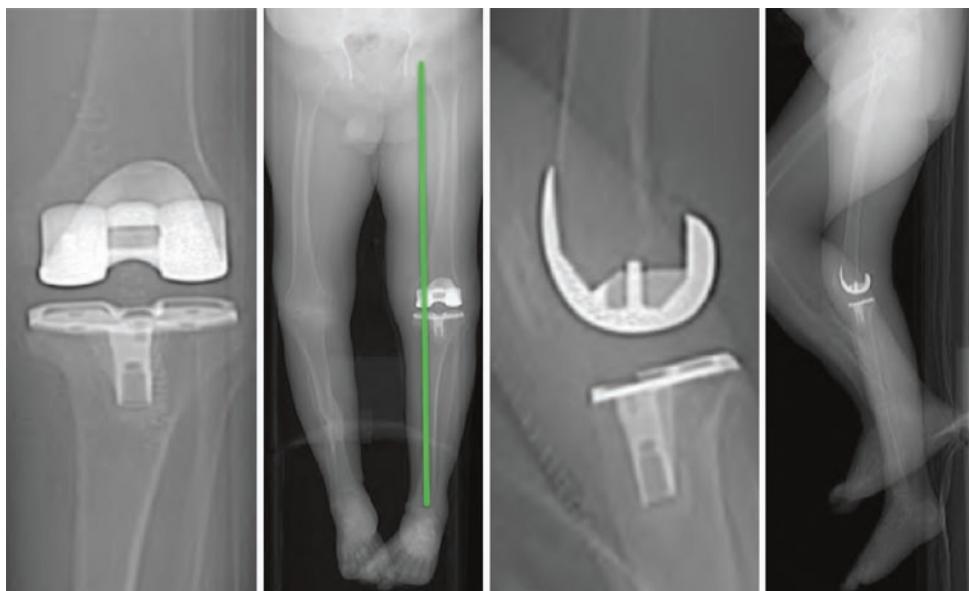


Fig. 1.29 Postoperative computer tomographic scanogram of the limb showing component alignment. Patient is in 6° of varus (green line represents a hip-knee-ankle angle of 0°) compared to the 20° of fixed varus preoperatively. The kinematically aligned TKA restored the native

alignment and laxities of the knee without a release of medial collateral ligament and was performed with posterior cruciate ligament-substituting implants because of the torn posterior cruciate ligament

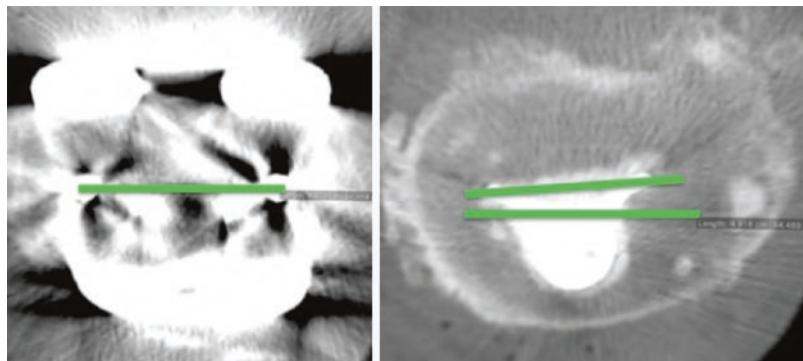


Fig. 1.30 Postoperative computer tomographic axial views of the femoral and tibial components. The kinematically aligned TKA restored the native alignment and laxities of the knee without a release of medial collateral

ligament and was performed with posterior cruciate ligament-substituting implants because of the torn posterior cruciate ligament

Table 1.1 Preoperative, 6 weeks postoperative, and 2 years postoperative extension, flexion, Oxford Knee Score, Knee Society Score, and Knee Society Function Score for patient with fixed varus deformity

	Preoperative	6 weeks postoperative	2 years postoperative
Extension	15°	5°	0°
Flexion	90°	110°	115°
Oxford Knee Score (0 worst, 48 best)	11	44	45
Knee Society Score	31	89	98
Knee Society Function Score	40	60	70

(preoperatively 15°–90°) (Table 1.1). His OKS improved to 44 (increase of 33 points), KSS to 89 (increase of 58 points), and KSFS to 60 (increase of 20 points).

Two years postoperatively the patient is doing very well and ambulating without difficulty or pain. The patient's active ROM has improved to 0°–115°, and his clinical outcome scores have increased (OKS 45, KSS 98, KFS 70).

Clinical Results

Kinematic alignment is a new technique in TKA that targets restoring the natural tibial-femoral articular surfaces, the natural knee and limb alignments, and the natural laxities of the knee rather than an overall postoperative neutral limb alignment [25, 27–35]. These goals are accomplished by aligning the components tangent to the native joint line which aligns them parallel and perpendicular to the three kinematic axes of the normal knee [25, 28, 34]. The first axis being the transverse axis in the femur about which the tibia flexes and extends. The second is the trans-

verse axis in the femur about which the patella flexes and extends. And the third is the longitudinal axis about which the tibia internally and externally rotates on the femur. These axes are either parallel or perpendicular to the tibial-femoral joint lines.

There is a growing interest in KA TKA as two randomized trials and a national multicenter study have shown that patient treated with kinematic alignment with patient-specific instrumentation reported significantly better pain relief, function, and flexion and a more normal-feeling knee than patients treated with MA TKA [27, 33–36]. Two other randomized trials showed similar clinical outcomes between KA TKA and MA TKA [35, 36]. There is a perception that the tibial component is predisposed to failure in KA TKA as 75–80% of the tibial components are set in varus with respect to a line perpendicular to the tibial mechanical axis; however, several studies have shown that KA TKA performed with patient-specific instrumentation has a high rate of implant survival at 6, 3, and 2 years [30, 34, 35, 37].

Key Points

- Quality Assurance Check 1: Minimize flexion of the femoral component by setting the flexion of femoral component to within 0° – 5° perpendicular to the anatomic axis of the femur [38].
- Quality Assurance Check 2: Set femoral component to restore the native distal and posterior joint lines by resecting the distal and posterior femoral condyles to within 0 ± 0.5 mm of the thickness of the femoral component after compensating for wear and 1 mm of kerf [25].
- Quality Assurance Check 3: Set internal-external rotation of the tibial component parallel to the flexion-extension plane of the knee by setting the internal-external rotation of the tibial component to within $0^\circ \pm 10^\circ$ of the femoral component [31].
- Quality Assurance Check 4: Minimize varus-valgus laxity in extended knee to restore native varus-valgus angle of tibial joint line by compensating for tibial wear by setting the varus-valgus angle of the tibial resection to match that of the native joint line [25, 26].
- Quality Assurance Check 5: Match anterior offset of the tibia at exposure to restore native slope of tibial joint line by compensating for tibial wear, and set the posterior slope of the tibial resection to match that of the native joint line [25].

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The Fixed Valgus Knee

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Introduction

Alfred J. Tria

The valgus knee is a challenging knee for total knee arthroplasty. The deformity is less common than varus and requires more releasing to correct the deformity. The medial approach is the more common one because it is familiar to the surgeon; however, the lateral approach affords excellent visualization [1]. The ligament imbalance can be approached both with tightening [2] and releas-

ing techniques [3], but releasing is once again more familiar to the operating surgeon. The cases describe the multiple-puncture technique [4] and the anatomic structure releases [5], which both have their advantages and dangers.

Option 1: Pie-Crust Technique for the Fixed Valgus Knee in Primary Total Knee Arthroplasty

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Case Presentation

History

A 69-year-old female presents with years of progressive lateral-sided left knee pain that is exacerbated with activity. She has a progressive knock-knee deformity that causes her to ambulate with a limp and a lurch. She had a prior left knee arthroscopy 25 years ago. She has no major medical problems.

Physical Examination

Body mass index is 28. Range of motion of the left knee demonstrates a 15° flexion contracture and flexes to 115°. Clinical limb alignment is approximately 20° valgus deformity that is not correctable with manual varus stress. There is 2–3 mm of medial laxity with valgus stress but a

Fig. 2.1 Anteroposterior (AP) standing radiograph demonstrating valgus deformity of the left knee with medial soft tissue attenuation



solid end point. The skin is intact and the limb is neurovascularly intact. Hip range of motion is pain-free.

Radiographs and Advanced Imaging

Anteroposterior (AP) radiograph of the knees demonstrates valgus deformity of the left knee with medial soft tissue attenuation as evidenced by medial joint space widening (Fig. 2.1). A pre-operative photograph demonstrates the valgus deformity of the left leg that is not correctable with varus stress (Fig. 2.2).

Surgery

Total knee arthroplasty was performed using the “pie-crust” technique for lengthening the lateral structures. However, due to the significant fixed deformity, this technique was insufficient to

allow full correction of the lateral side contractures. Therefore, an additional popliteus release was performed. Even though the knee was stable following extensive releases, the surgeon elected to use a constrained articulation to prevent late acquired lateral instability. Postoperatively, the patient recovered well with a limb that was neutrally aligned and stable. The case is presented in detail in the subsequent figures.

Surgical Approach

Operative Pie-Crust Technique for the Fixed Valgus Knee in Primary Total Knee Arthroplasty [6]

We prefer a standard medial parapatellar approach. The lateral approach has been described [7] and offers the advantages of



Fig. 2.2 Preoperative photo demonstrating valgus deformity left leg. The deformity was not correctable with a varus stress

releasing the contracted lateral structures as part of the soft tissue dissection. Furthermore, if additional releases are required, the lateral soft tissue structures are directly accessible. Disadvantages include lack of surgeon familiarity with operating from the lateral side of the knee, instrumentation designed for the medial side, and concerns regarding soft tissue closure if the fat pad is poorly preserved.

During dissection, the subperiosteal elevation of the proximal medial soft tissues from the tibia is limited to 3–4 cm to avoid exacerbating pre-existing MCL attenuation.

Basic bone cuts are performed with mechanical guides or computer navigation.

If lateral femoral condyle hypoplasia and erosion are noted, it is common that resection of the distal, lateral femoral condyle will be minimal (1–2 mm).

Deficiency in the posterolateral aspect of the tibial plateau should also be noted.

Femoral component rotation should be set parallel to the transepicondylar axis since lateral femoral condyle hypoplasia would lead to an internally rotated component if referencing the posterior femoral condyles. Similarly, the AP axis (Whiteside line) may be difficult to accurately identify due to abnormalities of the trochlea in the valgus knee; therefore, use of this anatomical reference may lead to malrotation in the valgus knee.

In general, in the valgus knee, the transepicondylar axis is the primary rotational landmark with the posterior femoral condylar axis and AP axis used as secondary references.

A thin spacer block with axial load is used to evaluate the tibial cut and mechanical axis of the leg prior to any soft tissue releases (Fig. 2.3).

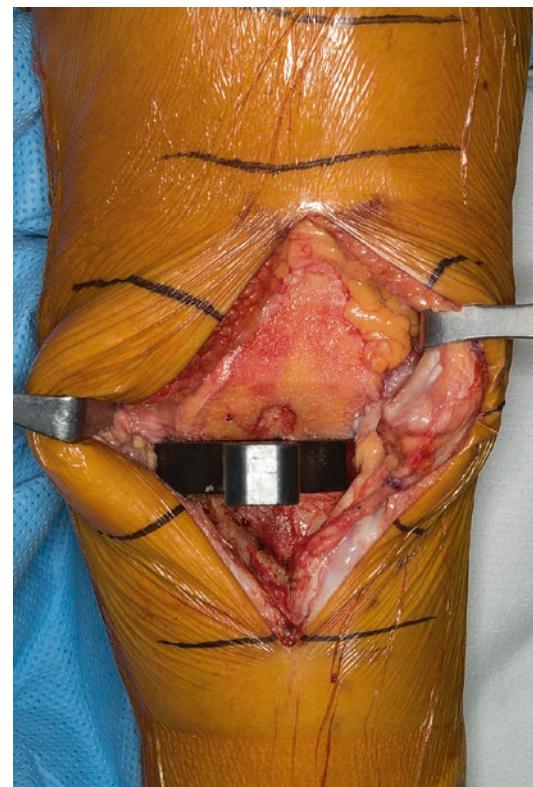


Fig. 2.3 The basic distal femoral and proximal tibial bone cuts have been performed. A thin spacer block has been inserted, and an axial load is applied to the foot to allow overall alignment to be inspected and approved

Medial and lateral soft tissue tension is then evaluated with a spacer block in extension and then flexion (Figs. 2.4 and 2.5, respectively) with a varus and valgus stress applied.

If the lateral side is tight as compared to the medial side, it is our preference to use the so-called “pie-crust” or multiple-puncture technique of lateral soft tissue release as described below. Other techniques, including MCL imbrication or advancement, have also been described [8].

Pie-Crust Technique

A laminar spreader is inserted in the medial femorotibial space with the knee in extension (Fig. 2.6).

The popliteus tendon is protected during the entire procedure as it provides an important stabilizer throughout the range of motion but most importantly in flexion [9]. Similarly,

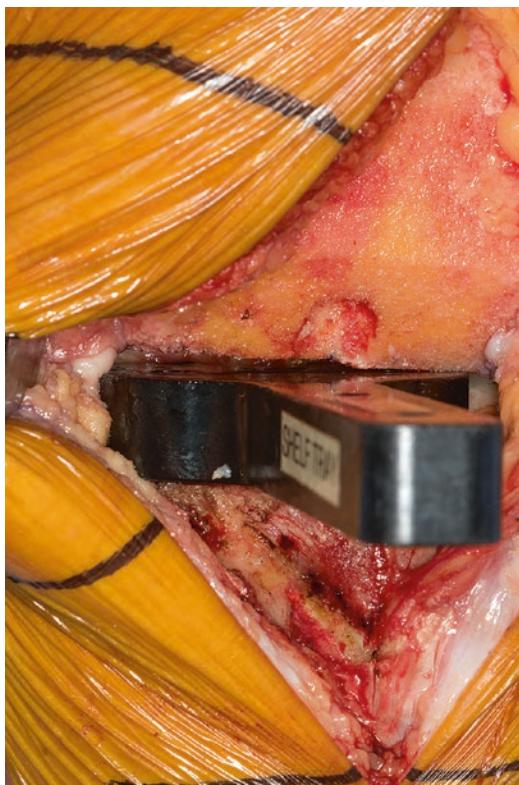


Fig. 2.4 With the knee in extension, a valgus stress has been applied. The medial knee opens up and the lateral side is tight

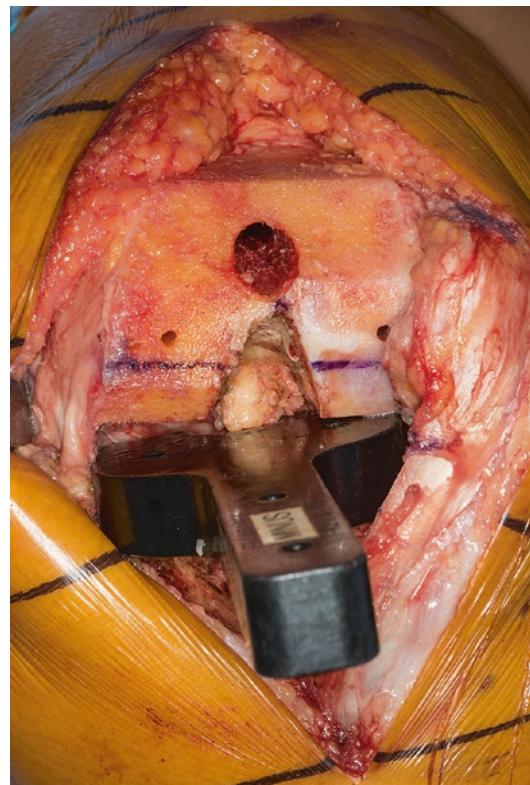


Fig. 2.5 The knee is placed in flexion and a valgus stress is applied. In flexion the medial laxity is more pronounced than in extension. The lateral side of the knee remains tight

while portions of the lateral collateral ligament (LCL) and posterolateral corner of the knee are also often lengthened during the pie-crust technique, care is made to prevent full transection (Fig. 2.7).

First, at the level of the tibial bone cut, a #15 surgical blade is used to make a transverse incision through the posterolateral capsule, beginning anterior to the popliteus tendon (Figs. 2.8 and 2.9).

Next, multiple horizontal stab incisions are made through the iliotibial band (ITB), LCL, and lateral capsule at the level of the joint line and proximal to the joint line until medial-lateral soft tissue balance is achieved. It is important to note that during this process, the tip of the blade should not penetrate the soft tissues by more than 5 mm to minimize risk to the peroneal nerve [10]. After the lateral side of the knee has

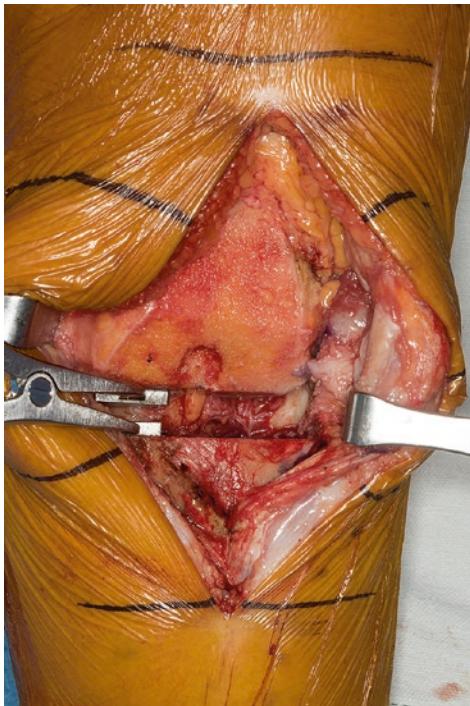


Fig. 2.6 The knee is placed in extension, and a laminar spreader is inserted medially and tensioned in anticipation of performing a lateral soft tissue release using the pie-crust technique



Fig. 2.8 With a #15 blade, the posterolateral capsule is horizontally cut at the level of the tibial bone cut, beginning anterior to the popliteus tendon and proceeding anteriorly to the iliotibial band



Fig. 2.7 The popliteus tendon in the posterolateral corner of the knee is identified



Fig. 2.9 The horizontal incision of the posterolateral capsule has been completed



Fig 2.10 Next multiple “pie-crust” punctures are performed with the tip of the knife blade through the tight lateral structures that include the lateral capsule, the iliotibial band, and often the lateral collateral ligament (LCL), to gradually titrate the required lateral soft tissue release. The tip of the index finger on the contralateral hand is used to palpate and identify the tightest lateral soft tissues that are sequentially released

been lengthened, a second laminar spreader is inserted into the lateral joint space and is used to gently stretch and tension the soft tissue structures (Figs. 2.10, 2.11, and 2.12).

Following the lateral side lengthening, an appropriately sized spacer block that fills the extension space is used to evaluate the medial and lateral balance (Fig. 2.13). Typically this spacer block will be 2–4 mm thicker than the initial block that was used prior to soft tissue releases but is dependent on the initial asymmetry and magnitude of the valgus deformity and whether the deformity is correctable on initial evaluation under anesthesia.



Fig 2.11 The final result of the pie crusting of the lateral structure is demonstrated in another case

The knee is then flexed and the symmetry of the flexion and extension gaps is assessed (Fig. 2.14).

If soft tissue tension is not symmetric (difference greater than 1–2 mm), additional “pie crusting” is performed in the same way as described above.

In the case presented in this chapter, the lateral tightness in flexion exceeded that in extension, and the operating surgeon believed that further pie crusting would be insufficient to correct the mismatch. Therefore, the popliteus tendon, which acts a lateral stabilizer throughout the range of motion but has a greater relative effect in flexion, was released from the femur using the electrocautery (Fig. 2.15). It is important to note that in cases with greater valgus deformity (typically exceeding about

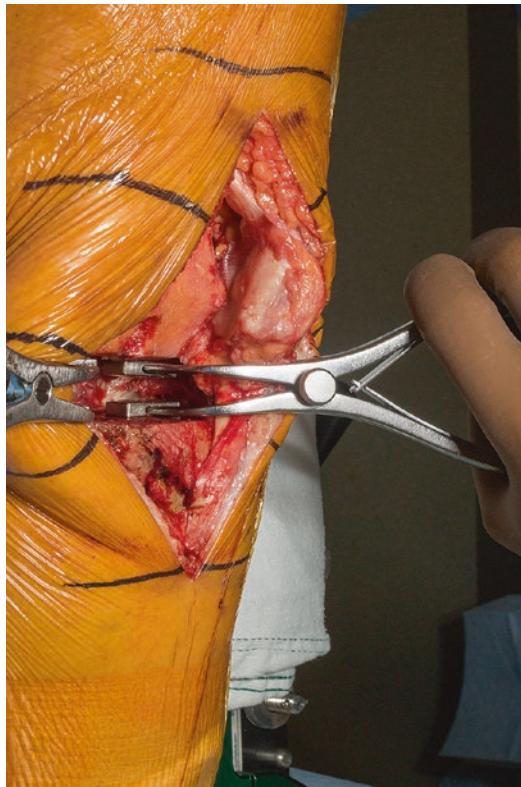


Fig 2.12 After the lateral pie-crust release has been performed, a second laminar spreader can be inserted laterally, and gradual tension can be applied to stretch the remaining lateral structures. If a rectangular space has been created, a thicker spacer block can be inserted, and the medial and lateral soft tissue tension and overall flexion versus extension gap symmetry can be evaluated. If further release is required, the medial laminar spreader is reinserted and additional pie crusting performed

15°–20°), additional releases, such as lateral femoral epicondyle osteotomy, or sequential release of the LCL and popliteus tendon from the lateral femoral condyle, followed by the posterior capsule and lateral head of the gastrocnemius, may be required.

Following popliteus release it was possible to insert a larger spacer block. The increase from initial spacer thickness to final spacer once soft tissue releases were performed is demonstrated (Fig. 2.16).

After pie crusting, incision of the posterolateral capsule, and popliteus release, the flexion and



Fig 2.13 After the lateral pie-crust release has been performed, a larger spacer is inserted, and with valgus stress, the medial gap opens up less than a millimeter

extension gap (Figs. 2.17 and 2.18, respectively) is now symmetric medially and laterally. Neutral limb alignment is achieved through bone preparation and soft tissue releases (Fig. 2.19).

When extensive releases are performed, the lateral side of the knee may be unstable, especially in the figure-4 flexed position with a varus stress. In these circumstances, a constrained prosthesis may be required [11].

There are no restrictions postoperatively.

Postoperative Result

Postoperative photograph (see Fig. 2.19) and radiograph (Fig. 2.20) demonstrate correction of the valgus deformity in appropriate limb alignment with a constrained articular insert in place.

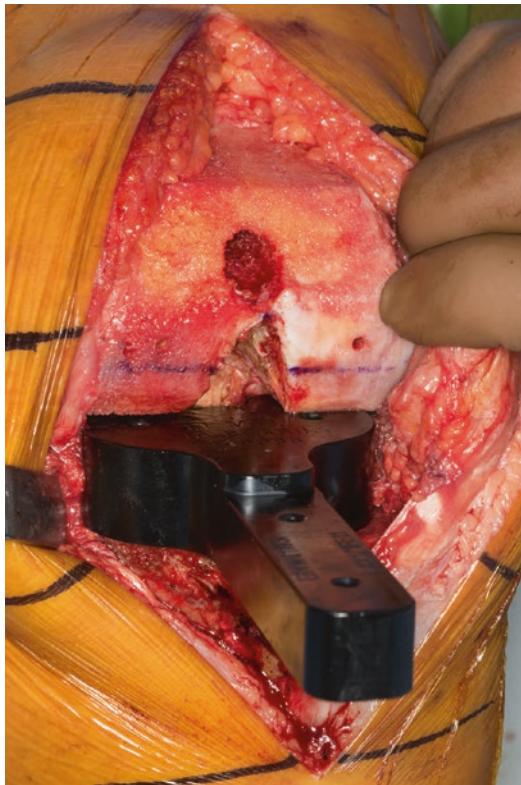


Fig 2.14 With the same larger spacer block and the knee in flexion with valgus stress applied, the medial side remains looser than the tight lateral side

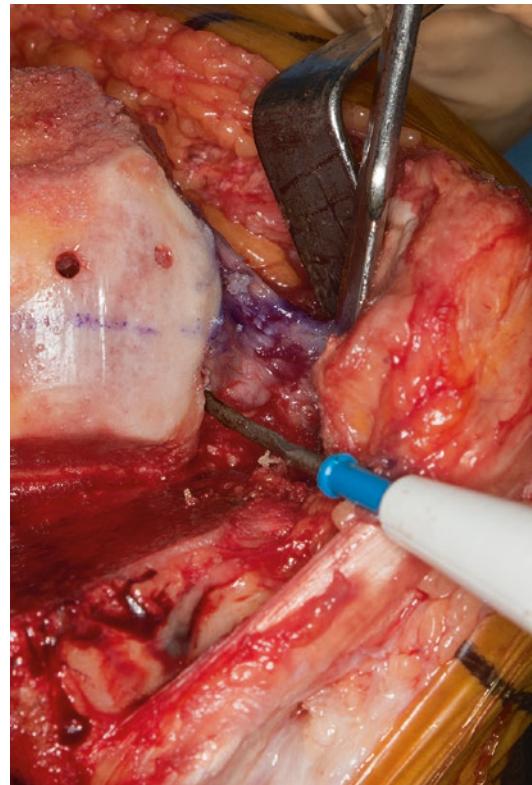


Fig 2.15 With greater lateral tightness in flexion versus extension, the decision was made that further pie crusting would not achieve gap symmetry, and the decision was made to proceed with an alternative type of lateral soft tissue release. As the knee was tighter laterally in flexion than extension, the surgeon elected to next release the popliteus tendon, which acts a lateral stabilizer throughout the range of motion but has a greater relative effect in flexion. The popliteus tendon was released from the femur using the electrocautery



Fig 2.16 Following popliteus release it was possible to insert a larger spacer block. The increase from the initial spacer thickness to final spacer after soft tissue releases were performed is demonstrated

Clinical Results

In total knee arthroplasty (TKA) for valgus knees, correction of the deformity and accurate soft tissue balancing are critical for the functional

outcome and survival of the prosthesis [12–14]. Soft tissue contractures are often part of the pathology present in arthritic knees. These contractures are addressed during surgery to create symmetric and balanced flexion and extension gaps. In valgus knees, the lateral soft tissues including the ITB, LCL, popliteus tendon, and posterolateral capsule contract; with increasing deformity the corresponding medial soft tissues may also become attenuated [12, 15]. Although numerous methods and sequences of soft tissue balancing have been described to manage the valgus knee during TKA [3, 9, 12, 14–23], all have the final goal of producing a stable and balanced

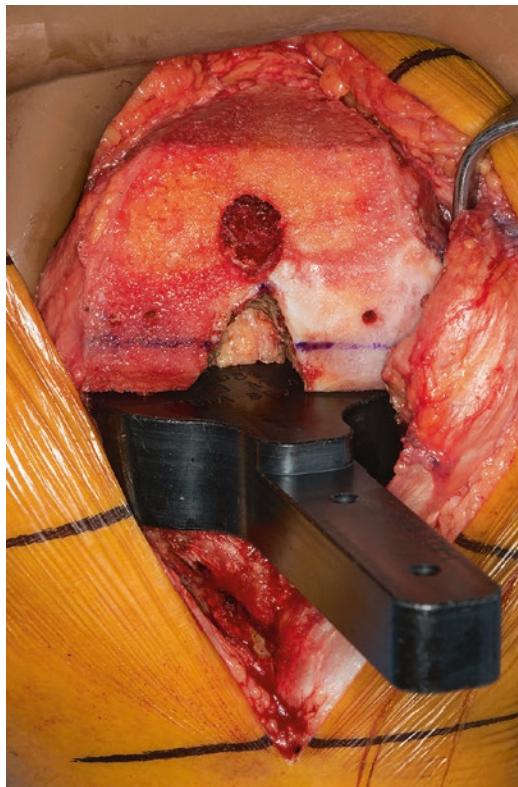


Fig 2.17 After pie crusting, incision of the posterolateral capsule, and popliteus release, the flexion gap is symmetric medially and laterally

knee [13]. We prefer the above-described pie-crust type of release. This preserves the popliteus since it has a greater relative contribution to stability in flexion [9, 15], which prevents lateral lift off and reduces the risk of PS cam and post-dislocation in the figure-4 position.

The pie-crust (or multiple-puncture) technique for releasing the tight lateral structures was described separately by Insall and Ranawat [12, 24]. The goal of this technique is to systematically lengthen the lateral soft tissue contractures in a controlled fashion through multiple transverse stab incisions as described above in the surgical approach. This technique gradually releases the tight structures, which are tensioned in distraction using laminar spreaders, until gap symmetry is obtained.

Clarke et al. reported their clinical outcomes of 24 consecutive valgus knees treated with pie-crust technique in conjunction with a cemented poste-

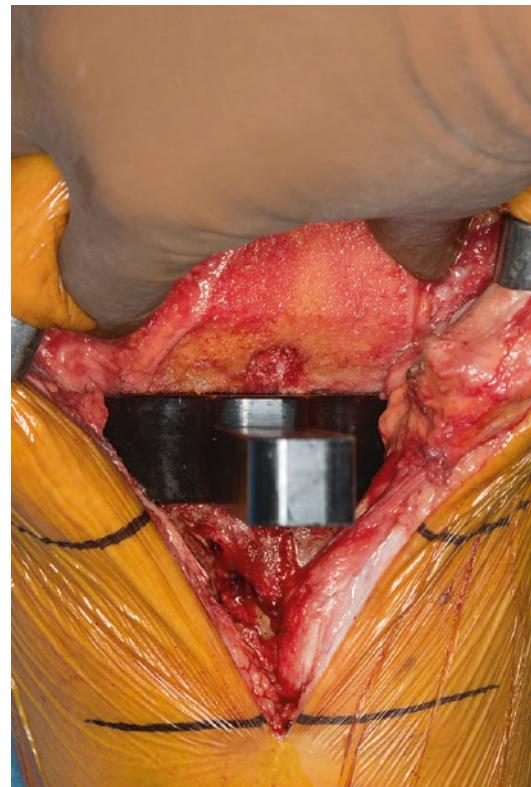


Fig 2.18 The extension gap is also symmetric. Due to the extensive lateral soft tissue releases performed with sacrifice of the popliteus tendon, which is usually preserved in the pie-crust technique to provide lateral stability, the surgeon elected to use a constrained articulation, even though the joint was stable, in order to prevent late postoperative lateral instability

rior-stabilized TKA [18]. At follow-up (mean of 54 months, range 24–69 months), there were no clinical failures, no cases of radiographic loosening or wear, and no cases of residual instability. The knees functioned well with a mean Knee Society score of 97 (range 87–100) and mean range of motion of 121° (range 100°–145°).

In a study by Miyasaka et al. who employed a similar surgical technique, only 3 (6%) of 52 knees demonstrated a mild degree of postoperative mediolateral instability at a mean of 7 years postoperatively [20].

Elkus et al. demonstrated excellent results in patients undergoing pie-crust technique during TKA for valgus knees [14]. Of the 42 knees that were followed for a minimum of 5 years, the



Fig 2.19 Postoperative limb alignment

mean coronal alignment was corrected from 15° of valgus preoperatively to 5° of valgus postoperatively with zero cases of delayed instability. In their series, there were a total of three revisions unrelated to the multiple-puncture technique (one each for delayed infection, premature polyethylene wear, and patellar loosening). Similar results were reported by Aglietti et al. who followed 48 patients with 53 valgus knees for a mean of 8 years (range 5–12 years) [4]. Excellent postoperative alignment within 5° from neutral was achieved in 51 of 53 (96%) patients. They had zero revisions, one postoperative complication of a transient peroneal nerve palsy that completely recovered spontaneously, and one case of varus instability greater than 10° in extension when assessed with stress radiographs.

Whereas the above studies were with PS knees, McAuley et al. [25] employed a similar technique to Elkus et al. [14] they termed “inside-out” in conjunction with a cruciate-retaining



Fig 2.20 Postoperative X-ray demonstrates correction of the valgus deformity. A constrained articular insert is noted

prosthesis. They found that preservation of the popliteus or LCL using the “inside-out” technique was associated with 97% revision-free survivorship at 10 years as well as a Knee Society score of 89 ± 13 at a minimum of 5 years postoperative.

One theoretical concern of pie crusting the posterolateral capsule at the level of the joint is the proximity to the peroneal nerve and potential for iatrogenic injury during puncturing. In a cadaveric study of 20 specimens, Bruzzone et al. showed that the average distance from the peroneal nerve to the posterolateral corner of the tibia was 1.35 cm [26]. They described the “danger zone” as a triangle defined by the popliteus tendon, the tibial cut surface, and the most posterior

fibers of iliotibial band where extra care should be taken. Similarly, Clarke et al. demonstrated in an MRI study that the peroneal nerve is on average 1.49 cm (range 0.91–2.18 cm) from the tibial corner but always separated from the bone by the lateral gastrocnemius [10]. They concluded that while the peroneal nerve is adequately protected, the pie-crust technique should nevertheless be performed carefully. One variation, as advocated by Ranawat, is to use electrocautery at the posterolateral capsule [12]. Electrocautery may stimulate the peroneal nerve as the surgeon brings the tip of the device in close proximity, thus alerting the surgeon and possibly avoiding iatrogenic injury [12]. However, heat from the electrocautery may extend beyond the tip of the device and cause thermal injury to the nerve or skin in thin patients before direct contact occurs. No definitive study has demonstrated whether a knife or electrocautery is safer in clinical practice, and use of either should be in a controlled manner with precise knowledge of the posterolateral anatomy of the knee.

Key Points

- The pie-crust technique facilitates controlled lengthening of the lateral soft tissue contractures in a systematic fashion through multiple transverse stab incisions at the level of the joint.
- According to the literature, use of the pie-crust technique in valgus knees is associated with excellent clinical outcomes and a low risk of symptomatic postoperative instability.
- The popliteus tendon is protected during the entire procedure as it provides an important stabilizer in flexion. It is released when there is excessive tightness in flexion as compared to extension with varus stress.
- Use of the pie-crust technique does not result in postoperative instability when the popliteus tendon and muscle are preserved.
- The close proximity of the peroneal nerve to the posterolateral corner of the knee should be understood during lateral soft tissue releases.

- When preoperative femorotibial alignment exceeds 15°–20°valgus, consider alternative techniques such as lateral femoral epicondyle osteotomy or sequential release of the LCL and popliteus tendon from the lateral femoral condyle followed by the release of the ITB, posterior capsule, and lateral head of the gastrocnemius.
- If the joint is unstable following soft tissue releases and correction of the valgus deformity, especially if all three primary lateral stabilizers (LCL, popliteus, and posterolateral capsule) have been released, consider the use of a constrained prosthesis. In addition to varus-valgus laxity in extension, the knee should be evaluated in flexion with a varus stress (figure-4 position) to make sure that the knee is not unstable in this position. This is particularly important when a posterior-stabilized implant is used as lateral instability in flexion places the knee at risk for dislocation due to the potential for the cam riding up and over the post in this position.

Option 2: Lateral Femoral Epicondylar Osteotomy for Correction of Fixed Valgus Deformity in Total Knee Arthroplasty

Jacob M. Conjeski and Giles R. Scuderi

Case Presentation

History

A 75-year-old male presented with persistent right knee pain with weight-bearing activities that continued even at rest. He had a right knee surgical arthroscopy and partial lateral meniscectomy several years prior and several intra-articular cortisone injections. There was no relief with nonsteroidal anti-inflammatory medication, and he found the knee to be a functional disability with limited motion, sense of instability, and swelling.

Physical Examination

On examination he walked with a right medial thrust. The right knee had a 15° fixed valgus deformity and 15° flexion contracture with a mild joint effusion. The active range of motion was 15°–120° with pain and crepitus through the arc of motion. The knee was stable with good quadriceps strength.

Radiographs and Advanced Imaging

The preoperative radiographs (Fig. 2.21) revealed a valgus deformity with lateral joint space narrowing, osteophyte formation, and patellofemoral arthritis.

Surgical Approach

Based upon this patient's history, physical examination, and radiographic findings, it was determined that he would require a total knee arthroplasty (TKA) with a lateral epicondylar osteotomy to correct the valgus deformity and flexion contracture.

Once regional anesthesia was obtained, the left knee was prepped and draped in a sterile fashion for a TKA. An anterior midline skin incision was used and extended through the subcutaneous layer exposing the extensor mechanism. A medial parapatellar arthrotomy was performed carefully protecting the medial collateral ligament, and the knee was exposed. Following lateral subluxation of the patella, the proximal tibia and distal femur were prepared with conventional instrumentation. Following femoral and tibial bone resection, the flexion and extension gaps were checked with spacer blocks. Asymmetry of gaps was noted with contracture of the lateral supporting structures consistent with a flexed valgus deformity.

With the knee in 90° of flexion and the patella retracted, the lateral femoral epicondyle is identified (Fig. 2.22a). A three-fourths-inch osteotome is placed at the distal leading edge of the lateral epicondyle (Fig. 2.22b). A shingle of bone is osteotomized from the lateral epicondyle that includes the popliteus tendon, lateral collateral ligament, and posterior capsule (Fig. 2.23). This releases that contracted lateral supporting structures and allows lengthening of the lateral side of

the knee joint. Once released, the flexion and extension gaps are checked for balance and alignment (Fig. 2.24). Satisfied that the deformity has been corrected and the knee is stable, final preparation is undertaken to prepare the knee for a posterior-stabilized prosthesis.

The final components are cemented in place, and the appropriate tibial polyethylene articular surface is inserted. The osteotomized lateral femoral epicondyle does not require internal fixation. The knee is then closed in a routine fashion.

Postoperative Result

Postoperatively, the patient underwent a routine rehabilitation program with no complications and was discharged home on postoperative day 3. At 2-year follow-up, he was doing well with an active range of motion 0°–130°, no instability, and good strength. Radiographs show the components in good position and alignment with a fibrous union of the lateral femoral osteotomy (Fig. 2.25).

Clinical Results

Correction of fixed valgus deformity during primary TKA presents with a unique and challenging task and has produced variable clinical results with correction of deformity and instability. Multiple techniques to balance and align the knee have been described including utilizing a lateral parapatellar arthrotomy, an inside-out pie crust of the lateral supporting structures, reconstruction of the medial collateral ligament, and use of a constrained condylar implant [5, 10, 12, 27–31]. While release of the contracted lateral supporting structures with an inside-out pie-crust technique has proven to be a safe and effective technique for restoring limb alignment with a valgus deformity [10, 12, 27], it has been observed that this technique may not be adequate to restore the limb alignment in cases with severe fixed valgus deformities or those associated with flexion contractures.

Insall initially described correction of a fixed valgus deformity with release of the ligamentous, capsular, and fascial attachments from the lateral femur in contrast to soft tissue release from the medial tibia for varus deformities [32].



Fig. 2.21 Preoperative radiographs show a valgus deformity: anteroposterior (AP) view (a), lateral view (b), Merchant view (c)

In this original technique, the lateral capsule, lateral collateral ligament, and popliteus tendon are sharply cut from the lateral femoral condyle, sometimes with division of the lateral head of

the gastrocnemius muscle. In severe cases with an associated external rotation deformity, the iliotibial band was also divided. While this release of the lateral structures corrected the

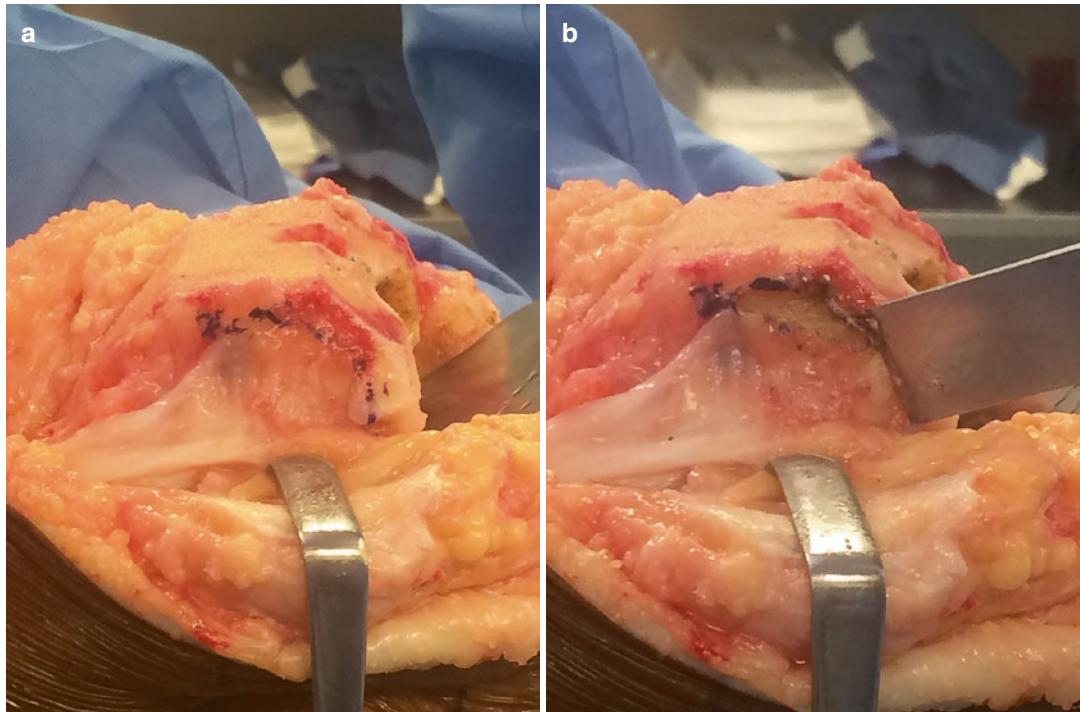


Fig. 2.22 The lateral epicondyle is with outlined (a); a 3/4-inch osteotome is placed distal to the lateral epicondyle (b)

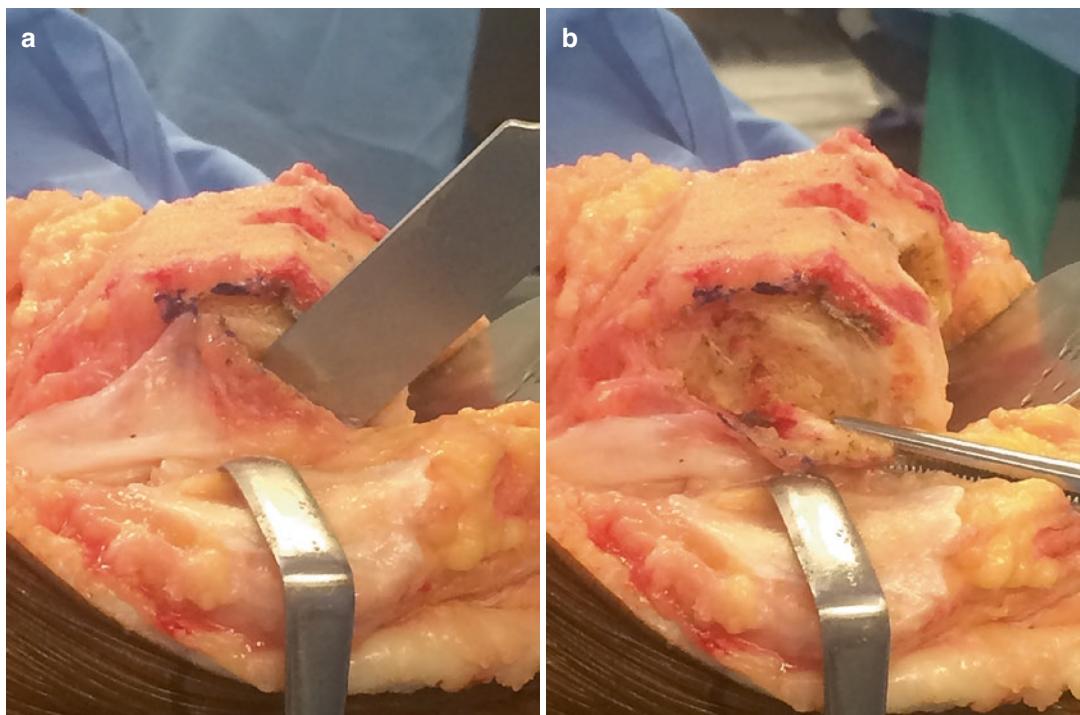


Fig. 2.23 The lateral epicondylar osteotomy is begun distally and extends proximally (a), releasing the attached soft tissue with a shingle of bone (b)

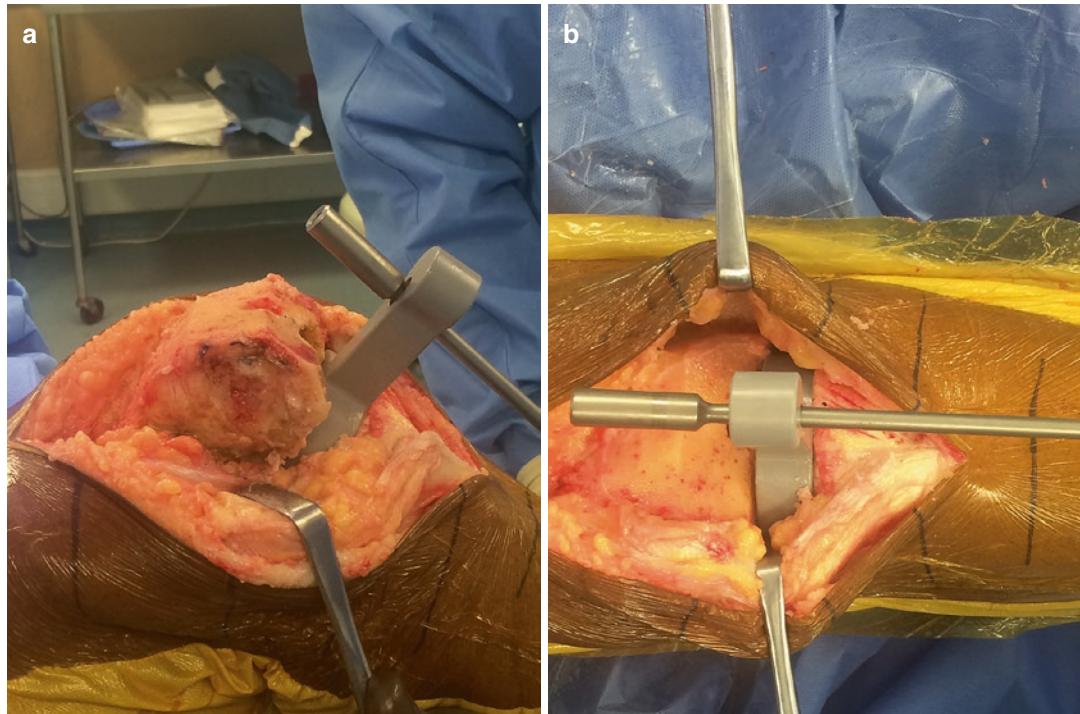


Fig. 2.24 Following release of the lateral structures, the flexion gap (a) and the extension gap are balanced (b)

valgus deformity, there was unpredictable healing of the lateral soft tissues with occasional cases of rotatory instability or flexion instability. When these conditions were observed intraoperatively, a constrained implant was recommended. Scuderi and Insall first described the lateral epicondylar osteotomy in 1995 for non-correctible fixed valgus deformities greater than 20° [33]. They also observed that stiff valgus knees with a flexion contracture with lesser deformity may require a lateral epicondylar osteotomy to restore limb alignment. The technique releases the tight contracted lateral supporting structures, including the lateral collateral ligament, popliteus tendon, and posterior lateral capsule with a shingle of bone osteotomized from the femoral lateral epicondyle. Occasionally in the presence of an associated flexion contracture, the posterior capsule and lateral head of the gastrocnemius require release. As the flexion and extension gaps are balanced, the shingle of bone will slide distally, allowing a lengthening of the lateral side of the knee. This technique does not

require fixation of the osteotomized lateral epicondyle, and the choice of implant constraint is dependent upon the ability to balance the flexion and extension gaps. In a recent review of 13 knees in 12 patients (5 male and 7 female) with valgus deformity requiring a lateral femoral epicondylar osteotomy, we were able to restore the limb alignment and appropriate stability. The implants used included a posterior-stabilized prosthesis in seven knees, a mid-level constrained condylar prosthesis in four knees, and a constrained condylar knee prosthesis in two knees. There was improvement in the Knee Society objective and functional score in all cases. No patient demonstrated postoperative instability. Radiographic analysis revealed well-positioned components with restoration of the mechanical alignment and fibrous union of the osteotomized epicondylar bone. There was one transient peroneal nerve palsy that occurred in a patient with a preoperative fixed valgus deformity of 28°, which completely resolved by her 6-month follow-up visit.



Fig. 2.25 Postoperative radiographs with the implants in place: anteroposterior (AP) view (a), lateral view (b), Merchant view (c)

This technique of releasing the lateral supporting structures with a shingle of bone from the femoral epicondyle to correct a fixed valgus deformity is less complicated and severe than techniques describing a sliding osteotomy of the lateral

femoral condyle. These techniques require a calculated osteotomy of the distal lateral femoral condyle that is slid distally, lengthening the lateral soft tissue structures, and secured in the chosen position with internal screw fixation [34–36].

In summary, the lateral femoral epicondylar osteotomy is a safe and effective technique for correcting severe fixed valgus deformities or valgus deformities associated with a flexion contracture.

Key Points

- When encountering a fixed valgus deformity, a decision should be made as to whether a pie crusting of the lateral side will provide a sufficient release or if a lateral epicondylar osteotomy will be needed, since we prefer not to perform both procedures in combination.
- A fixed valgus deformity $>20^\circ$ or a non-correctable valgus deformity with an associated flexion contracture usually requires a lateral epicondylar osteotomy.
- The lateral epicondylar osteotomy lengthens the lateral supporting structures and does not need internal fixation or a postoperative brace.
- If there is any intraoperative evidence of coronal or rotatory instability, then a constrained implant should be implanted.

Option 3: Alignment and Ligament Balancing in the Valgus Knee Done Through the Medial Parapatellar Approach

Leo A. Whiteside

Case Presentation

History

A 68-year-old patient presented with a 15° valgus right knee. She had pain with ambulation and at rest for more than 10 years. Medications, physical therapy, intra-articular injections, and bracing all had been tried.

Physical Examination

The patient ambulated using a cane and had an antalgic gait on the right side with a medial thrust of the femur on the tibia through the stance phase of gait. The knee hyperextended a few degrees

and flexed to 130° with the patella tracking slightly lateral but not dislocating. The clinical valgus was 15° with the lateral side tight in full extension and the medial side lax but with a detectable end point to valgus stress. The neurovascular status of the leg was normal and the hip examination was normal.

Radiographs and Advanced Imaging

The standing X-ray showed an anatomic alignment of 15° with a mechanical axis of 8° . The medial aspect of the knee was slightly open on the standing view. The lateral X-ray showed patella alta (Fig. 2.26).

Surgical Approach

Bone Resection

The medial parapatellar approach is easy and safe with a modest incision along the medial border of the patella, extending proximally between the vastus medialis and vastus intermedius muscles and distally to the attachment of the patellar tendon into the tibial tubercle, allowing the patella to sublux laterally over the lateral femoral condyle.

Whereas the normally aligned knee usually can be managed simply by using an intramedullary rod for femoral alignment and an extramedullary instrument for the tibia, the valgus knee usually has a valgus curvature in the shaft of the femur (Fig. 2.27) [37], and this must be addressed



Fig. 2.26 The standing X-ray showed an anatomic alignment of 15° with a mechanical axis of 12° . The medial aspect of the knee was slightly open on the standing view. The lateral X-ray showed patella alta

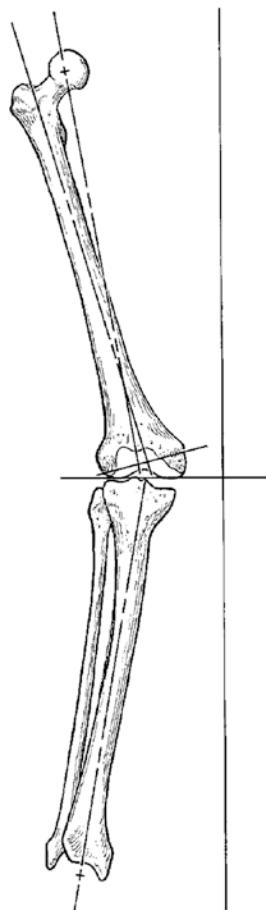


Fig. 2.27 Valgus angulation of the femoral shaft places the central axis of the bone medial to the patellar groove at the joint surface (From Whiteside [37], with permission)

in choosing the position of the entry point for the intramedullary alignment rod in the femur. The central axis of the femur, when extended to the joint, crosses the surface medial to the deepest part of the patellar groove (see Fig. 2.27). An entry point medial to the deepest part of the patellar groove allows the alignment rod to access the medullary canal of the femur in direct alignment with the long axis of the diaphysis (Fig. 2.28) and allows correct valgus alignment for distal femoral resection. The intramedullary alignment rod lies slightly medial to the center of the patellar groove, and the cutting guide is set at a 5° valgus angle to align the joint surface perpendicular to the mechanical axis of the femur and parallel to the epicondylar axis. The thickness of the implant

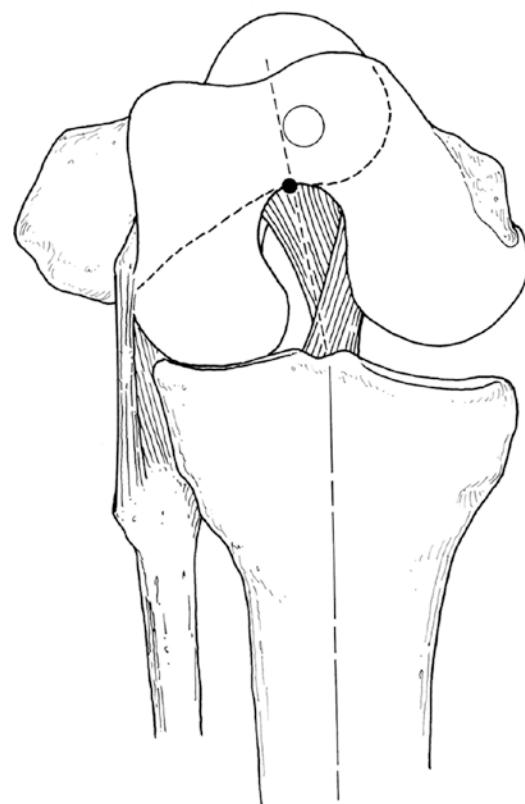


Fig. 2.28 Entry just medial to the center line of the patellar groove and intercondylar notch places the alignment rod in alignment with the long axis of the femur

is resected distally from the medial side with minimal or no resection from the lateral side of the distal femur (Fig. 2.29) [5, 38, 39].

Following selection of the appropriate sized femoral component, the femoral anteroposterior (AP) cutting guide is aligned so the surfaces are resected perpendicular to the femoral AP axis and parallel with the epicondylar axis, resecting the thickness of the implant from the intact medial femoral condyle and much less from the deficient lateral side (Fig. 2.30). This places the joint surfaces in anatomic position to correct the valgus position in flexion and places the patellar groove correctly with the mechanical axis of the lower extremity. With a fixed valgus deformity, the lateral ligaments are still tight, and the femur is held in an externally rotated position by the ligament contractures after the femoral surfaces are resected and the bone fragments removed (Fig. 2.31) [40].

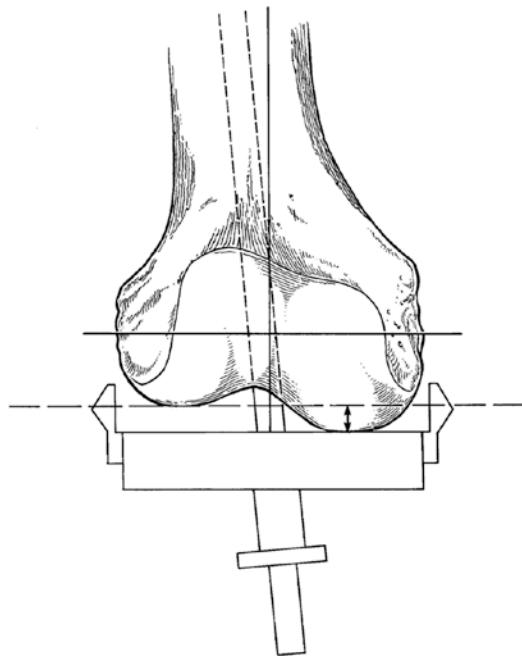


Fig. 2.29 Correct valgus angle of resection is facilitated by this slight medialization of the entry point. Thickness of resection is measured from the intact medial side of the distal surface of the femur (From Whiteside [5], with permission)

The tibial surface is resected perpendicular to the long axis of the tibia in the coronal plane and sloped 4° posteriorly in the sagittal plane. Because the foot often is externally rotated relative to the tibia in the valgus knee (Fig. 2.32), the distal end of the tibial cutting guide should not be aligned with the foot, but instead should be aligned directly over the anterior ankle surface, which may be medial to its usual position in a normal lower extremity (Fig. 2.33). As is done for the femur, the thickness of the implant is resected from the intact side.

Ligament Assessment and Balancing

Following bone resection, the trial components are inserted and stability is evaluated in flexion and extension. To understand the significance of the stability tests, a clear concept is needed to understand how the ligaments of the lateral side of the knee work to achieve stability. The anterior and posterior portions of the iliotibial (IT) band and its extensions function differently in flexion and

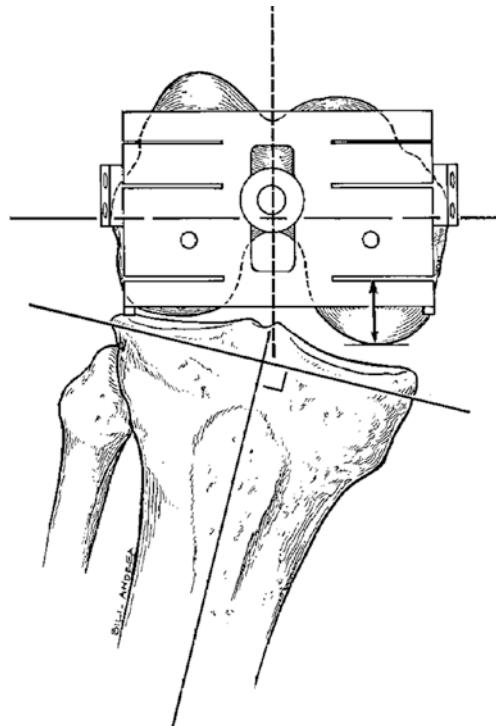


Fig. 2.30 Application of the cutting guide is done so the femoral bone cuts are perpendicular to the anteroposterior axis of the femur, and the thickness of the posterior condylar portion of the femoral component is resected from the posterior medial condylar surface so that less than the thickness of the femoral component is resected from the lateral surface. This corrects the angular deformity of the anterior and posterior surfaces of the femur in the coronal plane (From Whiteside [5], with permission)

extension [40]. The posterior portions tighten in extension, while the anterior portions loosen. In flexion the anterior portions are held forward by attachments to the patella and quadriceps mechanism, and they tighten as the knee flexes [40]. The lateral collateral ligament (LCL), popliteus tendon (PT), and the posterolateral corner (PLC) fibrous capsule (which is conjoined with the lateral gastrocnemius) are attached to the femur near the center of rotation of the tibia, so they have an effect both in flexion and extension [40]. However, they are not attached to the femur all at the same point, but form an oblique line from front to back on the lateral femoral epicondylar surface. In the extended knee position, the PT is relatively slack because its femoral attachment is close to the joint surface. In this position the LCL is tensioned, and the PLC and

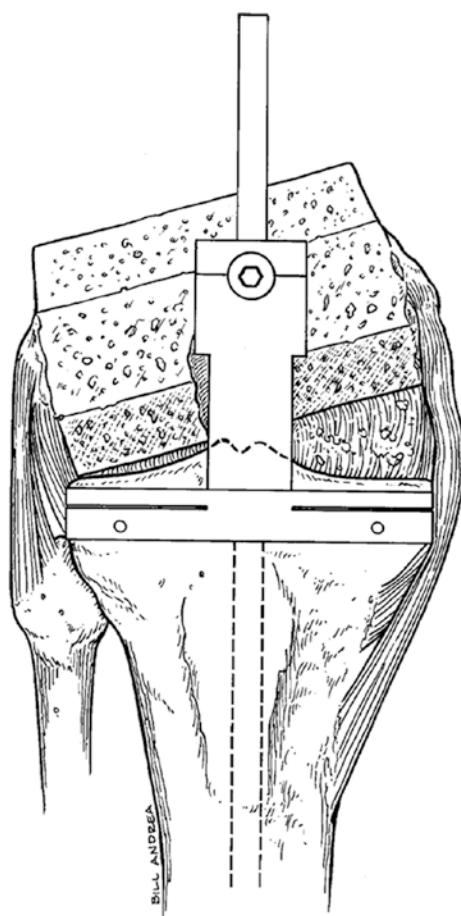


Fig. 2.31 After the femoral surfaces are resected, the deformity remains due to the lateral contracture and medial stretching of the collateral ligaments. Next the tibial surface is resected perpendicular to the long axis of the tibia (From Whiteside [40], with permission)

gastrocnemius are tensioned along with the posterior capsule (PC) (Fig. 2.34). When the knee is flexed, the PT attachment moves away from the joint surface, so the PT is tensioned, and the LCL is loosened, and the PLC is loosened further because its attachment moves closer to the joint surface (Fig. 2.35). Thus the LCL and PLC are more effective in extension, and the PT is more effective in flexion, but they all have some effect throughout the flexion arc [9, 40]. The PC is effective only in extension as a valgus stabilizer of the knee.

The knee is evaluated in flexion and extension to assess varus, valgus, rotational, anterior, and posterior stability. To test the knee in flexion, the

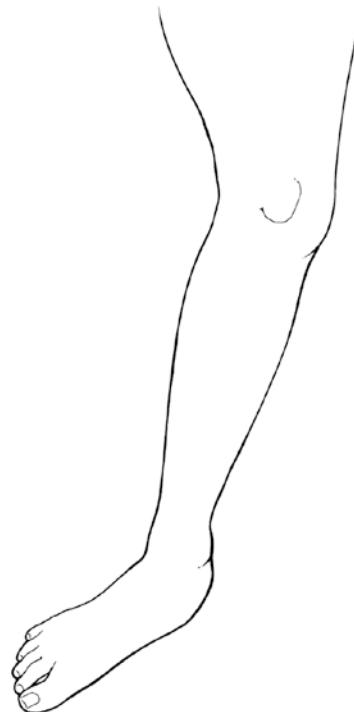


Fig. 2.32 Typical valgus malalignment includes valgus angulation of the femur and tibia as well as valgus and external rotation of the foot

ankle is grasped with one hand, while the other hand steadies the knee. The extremity then is rotated externally through the hip until the lateral ligament structures are stressed (Fig. 2.36) and then rotated internally until the medial ligament structures are stressed (Fig. 2.37).

In this case the knee is tight laterally and gaps medially in flexion (Fig. 2.38). It also pivots around the lateral ligament structures. This indicates that either the LCL or popliteus complex, or both, is tight. Nothing can be determined yet about knee stability in extension because these structures are highlighted in flexion. Next the knee is placed in full extension, and the varus-valgus, rotational, and AP stability tests are repeated. In this case the knee is tight laterally and loose medially (Fig. 2.39). The LCL, PT, IT band, and lateral posterior capsule (LPC) all may be involved in the extended position. It is already known from the flexion stability tests that the LCL, PT, posterolateral corner, or all three are

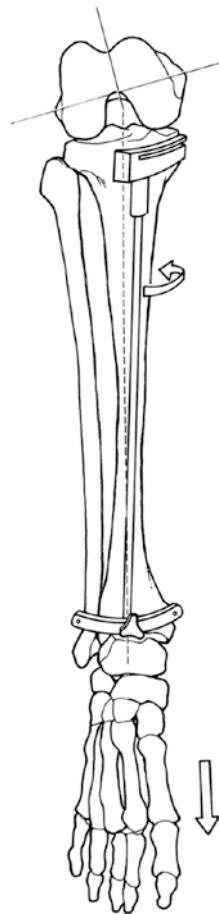


Fig. 2.33 The tibial cutting guide is rotationally aligned with special care to align with the anterior surface of the tibia. If the cutting guide is aligned with an externally rotated foot, as in this illustration, the surface will be cut in varus malposition

tight. In fact, these three structures, which are effective both in flexion and extension due to their attachment location near the femoral epicondyle, may be the only tight structures in the knee, so addressing the tightness in flexion should be done first since release of the IT band and PC may not be necessary.

To release the lateral epicondylar structures, the knee is flexed to 90°. The PT is evaluated first by palpation. If it is extremely tight and holds the tibia in internal rotation, it should be released. The PT is released directly from the femur with a knife blade and allowed to retract (Fig. 2.40).

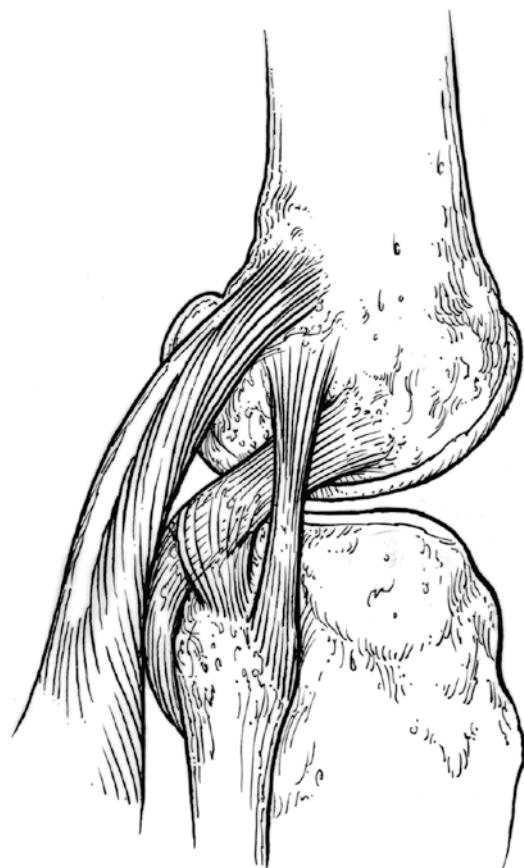


Fig. 2.34 The three stabilizing structures that attach to the lateral epicondylar area behave differently in flexion and extension. The posterior lateral corner capsular tissue and the lateral collateral ligament tighten in extension, while the popliteus tendon loosens

Because of its secondary attachments to the capsule and LCL, the PT retracts only about 5–10 mm. The knee should be tested again to evaluate the effect of release of the PT. If the knee is still tight on the lateral side in flexion, the LCL should be evaluated and released if it is tight. The LCL is easily visible and may be released by pie crusting with an 18-gauge needle, or it can also be released directly from its bone attachment, leaving intact the capsular attachments just behind it. If this is not sufficient, the PLC capsule is released (Fig. 2.41) [16]. This structure sometimes is the last remaining ligament attached to the epicondylar surface and therefore seldom should be completely released. Very conservative pie crusting is more appropriate.

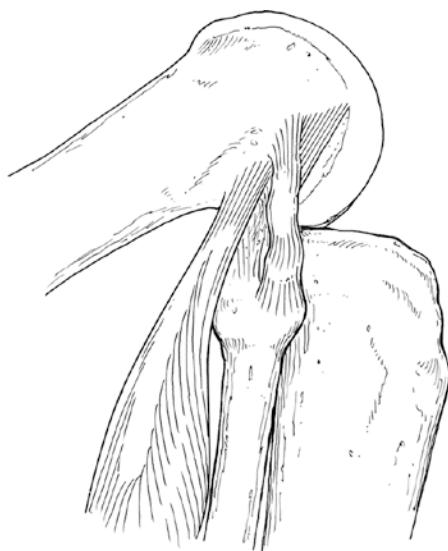


Fig. 2.35 When the knee flexes, the popliteus tendon tightens, the lateral collateral ligament slackens slightly, and the posterolateral corner capsule slackens further

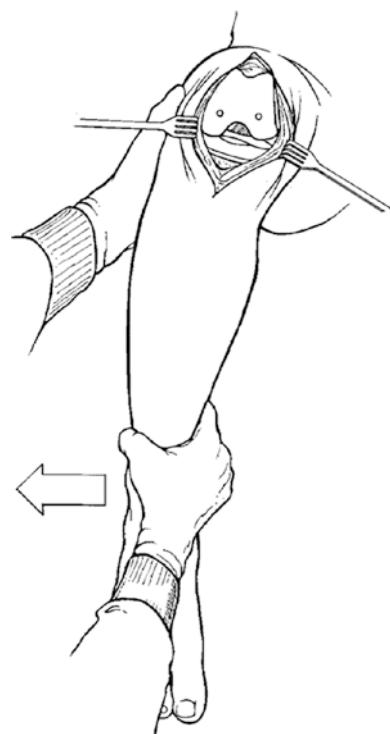


Fig. 2.37 Then to test valgus stability, the hip is fully internally rotated and valgus torque is applied (From Whiteside [40], with permission)

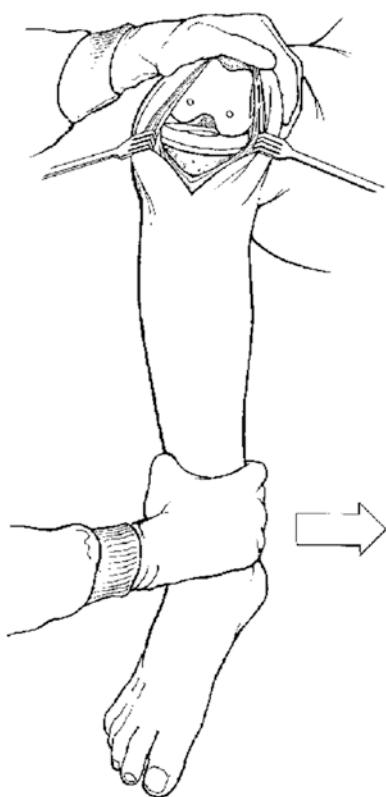


Fig. 2.36 With the trial components in place, knee stability is evaluated while flexed 90°. It is stressed toward varus, rotating the hip to full external rotation and then applying torque in an attempt to open the lateral side of the knee. From Whiteside [40], with permission)

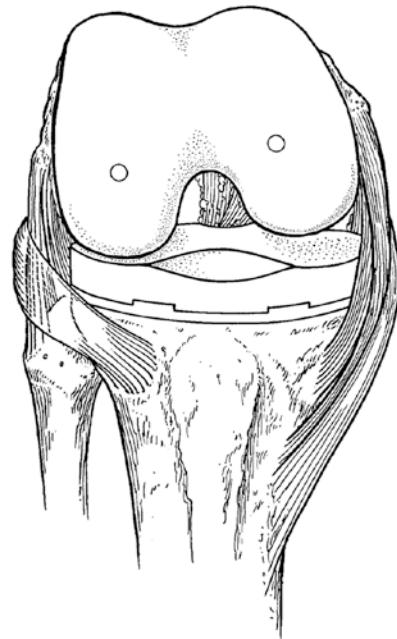


Fig. 2.38 The knee is tight laterally and loose medially in the flexed position. When stressed, the medial gap is about 10 mm and the lateral is zero (From Whiteside [40], with permission)

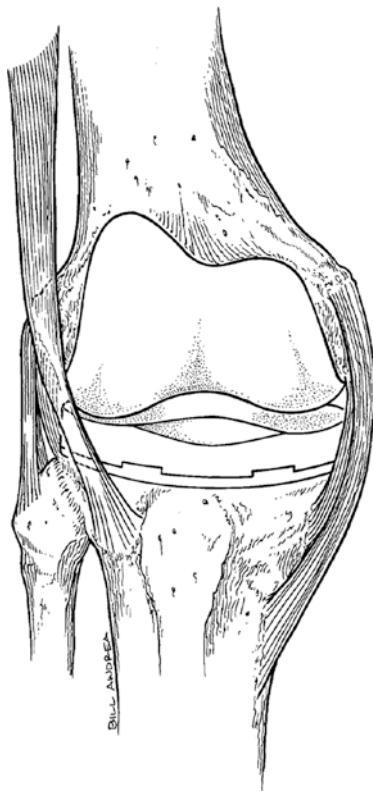


Fig. 2.39 Next the knee is extended and the joint stability to varus and valgus stress is evaluated. The medial gap is 8 mm and the lateral is zero (From Whiteside [40], with permission)

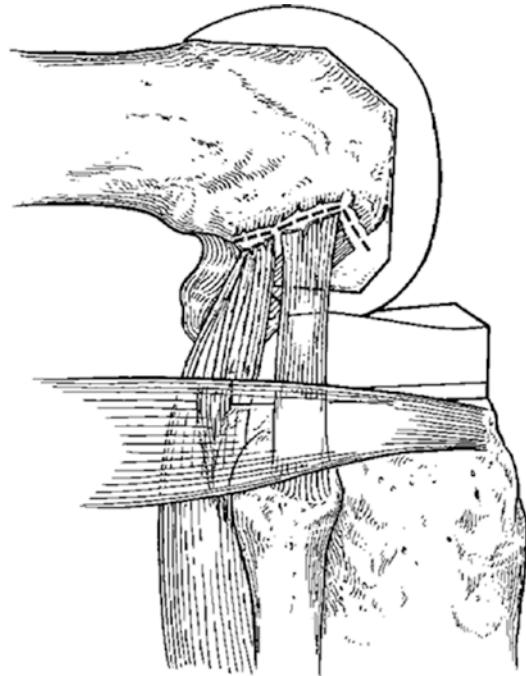


Fig. 2.41 The lateral collateral ligament and posterolateral corner can also be released, but very conservatively, preferably with pie-crust technique (From Whiteside [16], with permission)

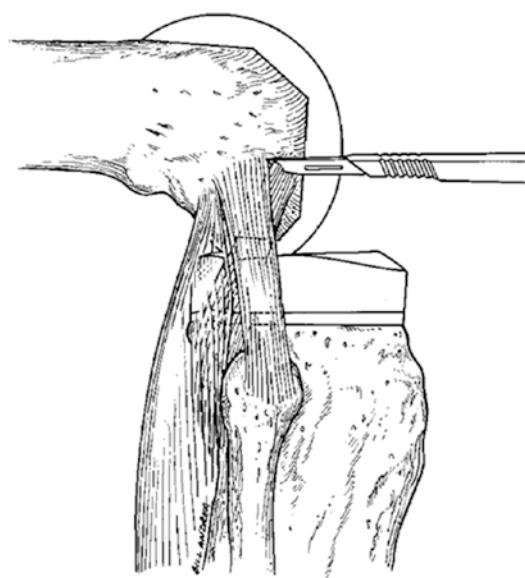


Fig. 2.40 The popliteus tendon is released with a knife blade directly from its bone attachment (From Whiteside [40], with permission)

Now that the LCL, PT, and PLC have been released, they retract partially, but remain attached to the surrounding capsule and dense overlying synovial membrane, and so continue to function as lateral stabilizers. Release of the PT, LCL, and PLC always corrects lateral ligament tension in flexion because these are the only structures that stabilize the lateral side of the knee in flexion. With the knee in flexed position, the IT band can still act as a lateral stabilizing structure because it is held anteriorly by its attachment to the patella. The IT band and PC remain as stabilizers in extension, and still may apply deforming forces, but only in the extended knee.

If the knee remains tight laterally in extension, the posterior portion of the IT band should be released. In this case the release is done just above the joint line, extrasynovially. To expose the IT band, subcutaneous dissection is done over the patella. The tight posterior portion is identified by palpation, and a longitudinal incision is made in the IT band at about the midpoint. Then blunt dissection is done between the IT band and synovial membrane, and the posterior portion of

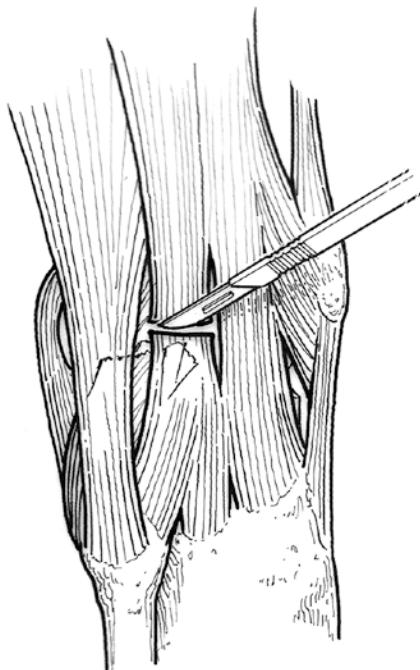


Fig. 2.42 For knees that remain tight in extension, the posterior portion of the iliobial band is exposed and released extrasynovially, leaving the synovial membrane intact if possible

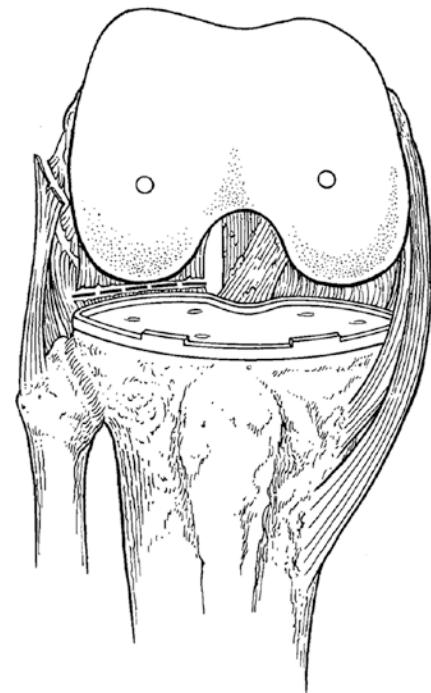


Fig. 2.43 Posterior capsule release can be done under direct vision with the knee flexed and distracted (From Whiteside [37], with permission)

the IT band is transected, leaving the upper and lower portion still attached to the synovial membrane so that a gap forms and functional elongation occurs (Fig. 2.42) but allows the ligament to continue supporting the lateral side of the knee in extension. This release also can be done percutaneously with pie-crusting technique using an 18-gauge needle. The PC and biceps femoris remain as lateral stabilizers in extension.

When the PC must be released, access is achieved by removing the tibial spacer and distracting the joint with the knee flexed 90°. The capsule either can be transected at the joint line (Fig. 2.43) or released from the posterior surface of the femur with a curved osteotome (Fig. 2.44). Release of the posterior lateral capsule from the tibia should not be done because of risk of damage to the peroneal nerve. The knee now is balanced in flexion and extension, but is likely to be loose both medially and laterally due to medial ligament stretching and lateral ligament release, and therefore will require a thicker tibial polyeth-

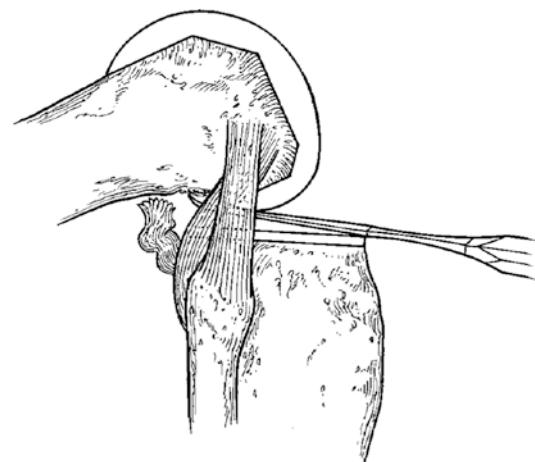


Fig. 2.44 In a few cases, the posterior capsule may be released from the posterior femoral surface with the knee flexed and a sharp curved one-half-inch osteotome applied to the tendon attachment to the bone. The posterior capsule must be released to fully correct the knee in extension, especially if a flexion contracture persists after iliobial band release (From Whiteside [40], with permission)

ylene component. In rare cases the knee remains tight laterally in extension and requires release of the LPC, the last remaining lateral ligamentous structure.

Following release of the lateral supporting structures, a thicker tibial spacer is added to tension the medial ligaments. The lateral ligaments are lengthened to match the medial structures in flexion and extension.

In flexion the ligaments remain well balanced and are tensioned appropriately by the thicker spacer. The AP axis now passes through the center of the femoral head and aligns precisely with the long axis of the tibia (Fig. 2.45).

Occasionally a knee is found to be tight on the lateral side in flexion and extension but more so in extension. The LCL is most effective in extension, and the PT is most effective in flexion. In these cases, similar to this illustration, only the LCL is released. This release is done with a knife, detaching the ligament directly from the bone, but leaving

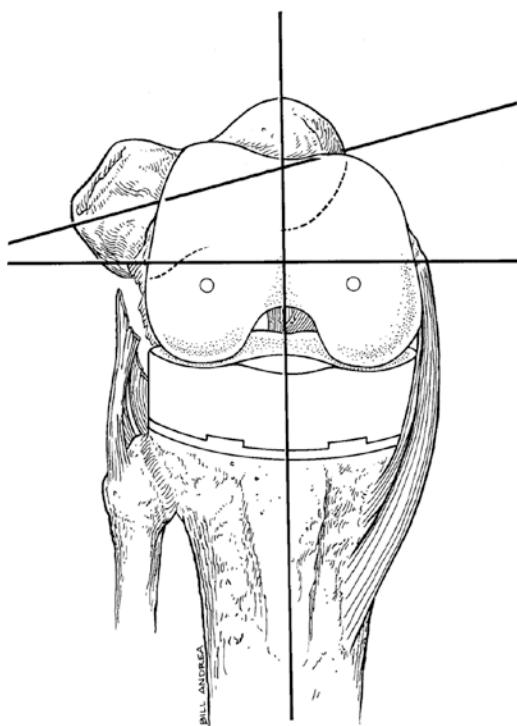


Fig. 2.45 Alignment is correct in flexion. The anteroposterior plane passes through the femoral head, center of the patellar groove, and down the central axis of the tibia with the knee flexed 90° (From Whiteside [5], with permission)

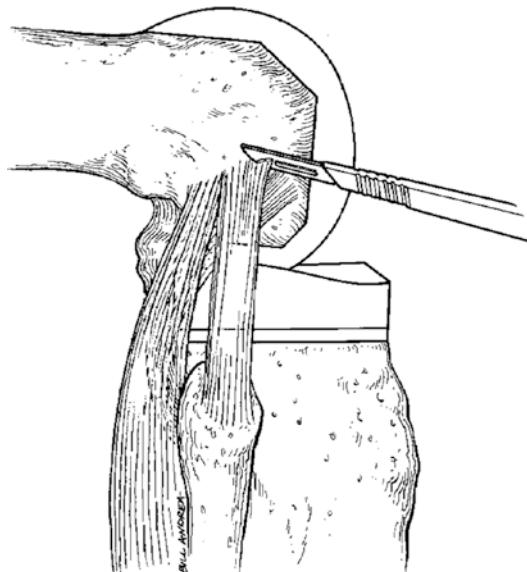


Fig. 2.46 The lateral collateral ligament is released with a knife directly from its femoral attachment. This can be done while leaving the popliteus tendon and lateral posterior capsule intact (From Whiteside [40], with permission)

it attached to the surrounding capsule and PT (Fig. 2.46). This also may be done with pie-crusting technique while distracting the joint with a curved osteotome to tension the ligaments.

In extension the knee is still supported laterally by the IT band, PC, PT, and the posterolateral corner. The IT band, PT, and PC maintain stability in extension.

In flexion, LCL release may have less effect because the LCL normally is somewhat slack in the flexed position. The PT, posterolateral corner, and PCL continue to provide lateral stability in flexion.

In many cases after correct resection and insertion of spacers or trial implants, the knee is found to be tight laterally in extension but to have normal stability in flexion.

However, when the knee is flexed to 90°, the joint surfaces seat normally, and the joint opens normally medially and laterally with valgus and varus stress, demonstrating that the epicondylar ligaments are normally tensioned.

The initial step in correcting the knee that is tight laterally in extension only is to release the

posterior portion of the IT band. The IT band is exposed subcutaneously and the tight posterior portion is identified. A knife is used to incise the IT band in line with its fibers, the synovial membrane is bluntly dissected from the undersurface of the IT band, and the IT band is transected from anterior to posterior until the muscle fibers of the biceps are encountered. This also can be done by pie crusting percutaneously. Occasionally the biceps femoris also is tight in full extension and can be released partially under direct vision with this exposure. The peroneal nerve lies directly behind the biceps muscle and tendon, so care should be taken not to extend the dissection posterior to the muscle fibers of the biceps. Now the knee no longer gaps spontaneously on the medial side in full extension, and the tendency for the tibia to rotate externally has been corrected.

In a few cases, the knee remains tight laterally only in full extension after release of the IT band and may even have a slight flexion contracture. In this situation, the LPC is the next structure to be released. The polyethylene spacer trial is removed, the knee is flexed to about 90°, and the femur and tibia are distracted. A curved one-half-inch osteotome is placed firmly against the femoral bone attachment of the LPC, and the osteotome is tapped gently with a hammer or the heel of the hand to completely release it from the bone (see Fig. 2.44).

Now the knee is correctly stabilized in extension. The LCL, PT, PLC, and PC all have been released so that they remain attached to their surrounding soft tissue structures and still maintain lateral stability. In rare cases, further release in extension is necessary, and the PLC capsule is released using pie-crusting technique (*arrow*) (Fig. 2.47).

In some cases the knee is tight laterally in flexion but normally stable in extension. When the knee is tested while flexed 90°, the joint space opens medially with valgus stress, but does not open at all laterally to varus stress. In full extension the knee opens normally medially, opening slightly with valgus stress, and also is normal laterally, opening a bit more with varus stress.

Because the PT is more effective in flexion than in extension, it is released first. This is done

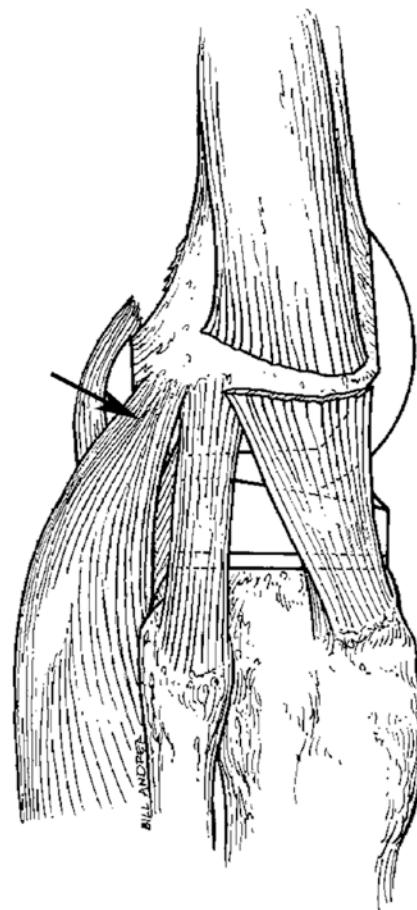


Fig. 2.47 Rarely the posterolateral corner (*arrow*) must be pie crusted to correct persistent lateral tightness in extension (From Whiteside [40], with permission)

with a knife, releasing the fibers directly from their attachments to the bone, leaving the tendon attached to the surrounding synovial membrane, capsule, and LCL.

The PT slides distally after the release but remains functional as a lateral stabilizing structure. The knee should be tested again, and if release is not sufficient to achieve correct lateral laxity in flexion, the LCL can be released partially. This can be done by releasing its bone attachment at the femoral epicondyle and letting it slide distally or by pie crusting the ligament and its surrounding fibrous capsular attachments. Finally, if the knee is not lax enough laterally, the PLC capsule and conjoined lateral head of the gastrocnemius can be released using pie-crusting

technique, which is done by penetrating the ligament multiple times with an 18-gauge needle as the condyles are separated with a laminar spreader or with a curved osteotome wedged between the lateral condyle of the femoral trial component and trial polyethylene component. Release of these epicondylar structures should be done conservatively by pie crusting or leaving them partially attached to their bone attachments. As with the PT, the LCL and posterolateral corner, when released individually directly from their attachments to the lateral femoral condyle, remain attached to the surrounding dense fibrous capsule and synovial membrane. Of course, the knee will still be stabilized laterally in flexion by the anterior attachments of the IT band and its attachment to the patella. Because the epicondylar structures are the only ones that stabilize the lateral side of the knee in flexion, this release always corrects the lateral ligament contracture in flexion. It is important, of course, to release the three lateral epicondylar ligaments carefully, using fractional release techniques that allow the ligaments to elongate and maintain lateral stabilizing function.

In full extension the knee is stabilized by the IT band and LPC. If the anterior portion of the IT band has not been released, it can provide substantial stability in flexion as well.

Because the posterior cruciate ligament (PCL) is a medial structure, it often is stretched and deformed, and the PCL is deficient in these cases. The PT, the LCL, and to a certain extent the PLC are secondary posterior stabilizing structures, so the tibia may sag posteriorly after ligament balancing in the valgus knee. This places the quadriceps at a disadvantage.

If the lateral epicondylar ligaments have been released, further abnormality in knee kinematics will be caused by loss of the external rotational stabilizing effect of the LCL, PT, and PLC, allowing the tibia to rotate externally under loadbearing, causing rotational instability. This can lead to symptomatic instability of the knee and lateral tracking of the patella (Fig. 2.48). One of the simplest solutions for this combined insufficiency of the PCL and lateral epicondylar ligaments is to use the highly conforming polyethylene compo-

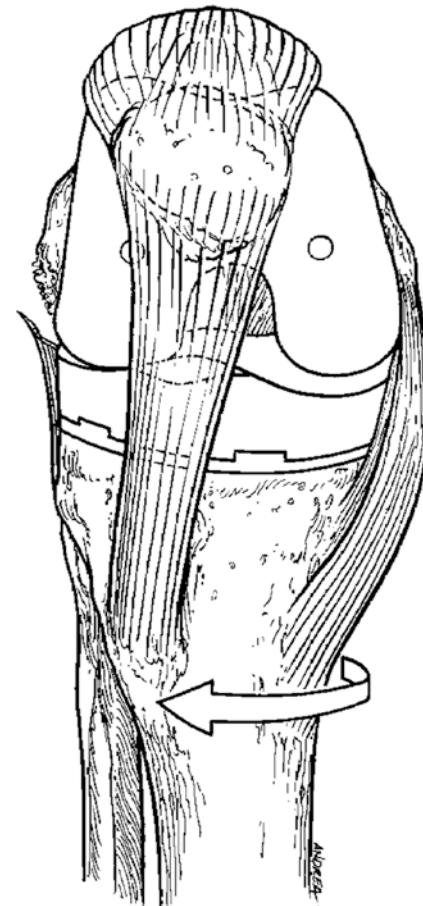


Fig. 2.48 External rotational instability also may occur due to loss of the epicondylar ligaments and can lead to lateralization of the tibial tubercle and thus cause patellar problems (From Whiteside [40], with permission)

nent. This deep-dish polyethylene component holds the tibia forward and prevents posterior tibial subluxation, so it improves the quadriceps advantage. The rotational stabilization provided by the conforming polyethylene component prevents lateral tibial rotational subluxation, and allows the tibial tubercle to track in its normal central position, and thus normalizes patellar tracking. As the tibia rotates externally, the femoral condyle climbs the anterior slope of the conforming polyethylene component and thus produces separation of the bone attachments of the lateral ligaments, which tensions the remaining portions of the ligaments and IT band and therefore improves lateral stability of the knee

after extensive release of contracted and deformed ligaments.

Patellar ligament balance often is a major part of soft tissue management of TKA in the valgus knee. Since the lateral femoral condyle is commonly deficient anteriorly as well as distally in the valgus knee, adding structure to achieve normal contour to this portion of the knee often creates abnormally high tension in the lateral ligaments of the patella, causing lateral tracking and tilt. This problem cannot be overcome by tightening the medial ligaments and quadriceps attachment of the patella, but only can be solved by restoring normal ligament tension to the lateral and medial patellar ligament structures. This requires lateral release of the patellar retinacular structures and often requires partial release of the patellar attachment of the vastus lateralis. These structures are approached by dissection over the patella to expose the lateral patellar retinaculum. Often the patellar branch of the superior lateral genicular artery can be identified and preserved during release of the retinaculum (Fig. 2.49) [41]. Beginning with minimal release of the patellofemoral ligament, the patellar retinaculum is released, and patellar tracking is tested repeatedly until the patella drops into the patellar groove automatically at 20° knee flexion and stays in the track through the rest of the flexion arc without tilting upward on the medial side.

Postoperative Result

The right knee was approached with a medial arthrotomy and only required release of the iliotibial band. The implant that was used had intramedullary stems, but the tibial polyethylene insert was non-constrained because of the limited release that was required (Fig. 2.50).

Clinical Results

Alignment is of paramount importance in total knee arthroplasty, and the peculiarities of the valgus knee should be accommodated meticulously during the alignment process. The valgus knee is best approached from medial to the patella so that the patella and quadriceps mechanism can be displaced in the same direction that the vectors pull them. Sizing, measured resection, and position-

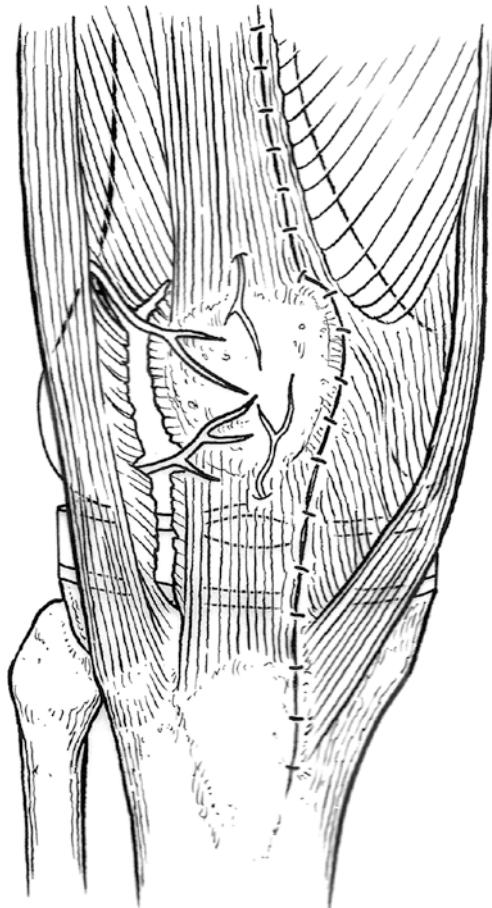


Fig. 2.49 Extensive release of the lateral patellar retinaculum should preserve as much of the lateral vasculature as possible (From Whiteside [41], with permission)

ing based on reliable bone landmarks place the joint surface in the optimal position for achieving correct ligament balance through the entire range of motion. Once this set of conditions has been established, the ligaments are assessed and managed (released or maintained) based on their function.

The ligaments attaching near the lateral epicondyle are effective through the entire arc of flexion, but all three behave somewhat differently in flexion and extension. The LCL is regarded as a stabilizing structure both in flexion and extension but is usually tighter in full extension than in flexion, and it has rotational as well as valgus stabilizing effects. The PT complex also has passive varus stabilizing effects and is especially tight in

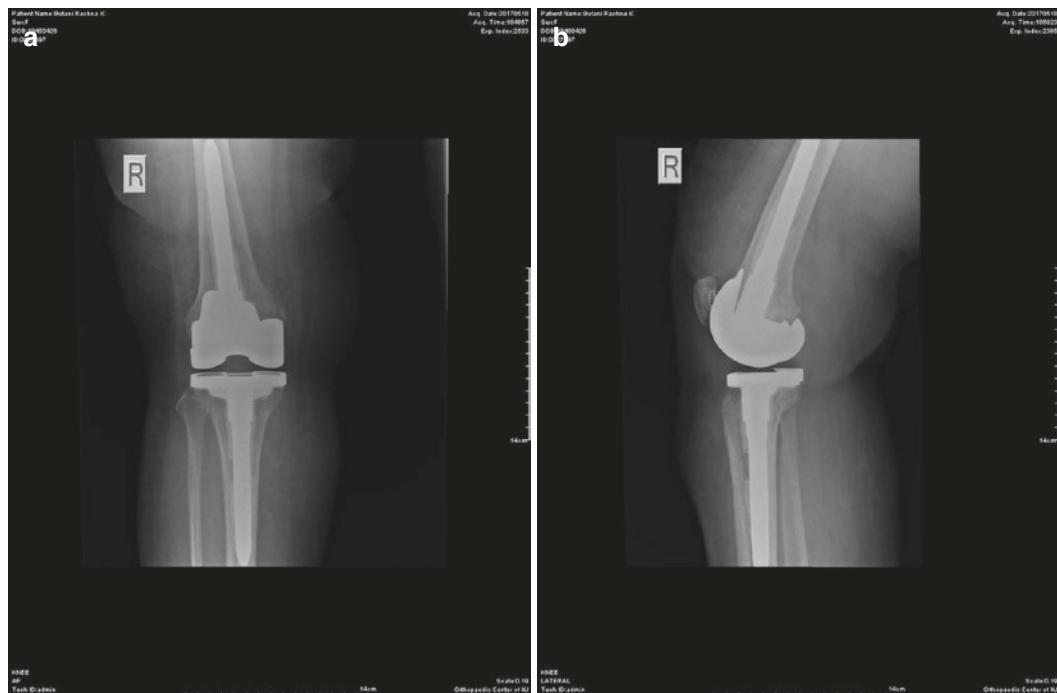


Fig. 2.50 The postoperative anteroposterior and lateral X-rays of the patient in Fig. 2.26, showing the total knee arthroplasty with intramedullary stems in good alignment

flexion. It also has a prominent role in external rotational stabilization of the tibia on the femur. The PLC capsule, which is joined to the lateral gastrocnemius tendon, is tightest in extension, but also has some effect in flexion, especially when the other two epicondylar-attaching structures have been released. After careful assessment, these three structures can be released from their bone attachments or elongated by pie crusting to achieve correct balance in flexion and extension.

The ligaments that attach to the tibia posteriorly and to the femur far from the center of rotation of the knee are effective only in extension. The posterior portion of the IT band is aligned perpendicular to the joint surface when the knee is extended and therefore can provide lateral knee stability when the knee is extended. But when the knee is flexed to 90°, the posterior IT band is slackened and cannot stabilize the knee to varus stress. The anterior portion of the IT band is held taut by its attachment to the patella and quadriceps mechanism and can be an effective second-

ary lateral stabilizer in flexion. The lateral posterior capsular structures are tight only in full extension and are slack when the knee is flexed. Release of either the PC or the IT band would have a rational basis only for a knee that is tight laterally in extension or has a persistent flexion contracture after lateral ligament balance is achieved. Release of either would have little effect on lateral knee stability in the flexed position.

Thus, after total knee arthroplasty, the knee that is tight laterally in flexion and extension will be almost completely corrected in flexion by release of the LCL and PT. No other structures afford lateral stability in flexion, so release of these two structures is all that is needed to correct the effects of the lateral ligament contracture in flexion. However, in extension the IT band and the LPC are effective lateral stabilizers and may still need release. Because the IT band is easily accessible, it is the next lateral stabilizing structure to be released if the knee remains tight laterally in extension. If the knee remains tight

laterally even after the IT band release, then the PC can be released to finish correcting lateral ligament tightness.

Knee stability in extension is absolutely necessary for good function, so these two extension stabilizers (IT band and LPC) should be released only as a last resort. If they are released first, before lateral laxity is tested in flexion, and the LCL and PT are released to achieve ligament balance in flexion, then nothing will remain to provide crucial extension stability.

For reasons probably related to differences in deformity of the lateral side of the knee, the knee sometimes is tight laterally only in extension after the trial implants have been inserted or tensioners applied. In these cases the LCL and the PT should not be released, but only the posterior IT band and the LPC should be released to achieve ligament balance. Uncommonly, valgus knees require all static lateral stability structures to be released to adequately correct the deformity and ligament imbalance. In these cases the anterior portion of the IT band, biceps femoris muscle, gastrocnemius muscle, and deep fascia provide support for the lateral side of the knee until capsular healing occurs.

Key Points

- Resect the bone surfaces to accommodate the implants in their correct position and in correct alignment, and then balance the ligaments to accommodate the implant in this correct position.
- The anterior and posterior portions of the IT band and its extensions function differently in flexion and extension.
- The LCL, the PT, and the PLC fibrous capsule (which is conjoined with the lateral gastrocnemius muscle) are attached to the femur near the center of rotation of the tibia, so they have an effect both in flexion and extension.
- Knees that are tight in extension only should have release of the posterior IT band first and then release of the posterior lateral corner, and the posterior capsule, if necessary, to correct the imbalance.

- Knees that are tight laterally in flexion and extension should have the popliteus tendon and lateral collateral ligament released first. If that does not correct the problem in extension, then the extension structures should be released.

Option 4: Total Knee Arthroplasty for Fixed Valgus Deformities Through a Lateral Parapatellar Approach

David Rodriguez-Quintana and Brian S. Parsley

Case Presentation

History

The patient is a healthy 5'9", 220-lb 71-year-old male patient with global dull and aching right knee pain. He has a history of previous surgeries to his right knee in the early 1980s but cannot recall the exact procedures performed. The patient walked into the clinic without the use of any assistive devices and with an obvious limp complaining of 5/10 right knee pain with ambulation that reaches 7–8/10 during attempted exercise or prolonged activity. He has failed conservative measures including anti-inflammatory medications and several corticosteroid injections.

Physical Examination

Upon examination, there were two previous incisions present. The first was anterolateral and longitudinal, which was used as our surgical incision, and the other was located over the anteromedial aspect of the knee (Fig. 2.51). Moderate swelling was noted on gross examination together with a 12° fixed valgus deformity. Arc of motion evaluation showed crepitus throughout the entire arc, a 15° flexion contracture, and flexion of 78° with a firm end point. Lachman and anterior drawer signs were negative and a posterior sag was noted. Patellofemoral grind was painful on exam.

Radiographs

Weight-bearing anteroposterior (AP), 90° flexion lateral, and sunrise views (Figs. 2.52) showed



Fig. 2.51 Clinical picture of the right knee showing previous anterior incisions. An anterolateral longitudinal incision used as our surgical incision and a second midline anteromedial incision

advanced tricompartmental osteoarthritis with complete loss of joint space in the lateral and medial tibiofemoral compartments as well as subchondral sclerosis and multiple osteophytes. Valgus deformity measured 12°. Moderate to severe patellofemoral osteoarthritis was also noted on the sunrise view. The 90° flexion lateral view showed excessive rollback of the femur on the tibia.

Surgical Approach/Technique

Preoperative Planning

Dynamization of the lateral anatomical structures in the knee when approaching both flexible and

fixed valgus knee deformities utilizing a lateral parapatellar approach is a technique that must be considered by orthopedic surgeons. Preoperatively, the surgeon has the option of performing standing long views of the leg for calculation of the true valgus angle for a perpendicular resection to the mechanical axis of the femur (MAF). Due to the hypoplasia commonly seen in the distal lateral and posterolateral femur, the amount of resection of the distal femur and valgus angle of resection is important to avoid postoperative hyperextension while allowing for restoration of the patient's joint line. The valgus knee is commonly associated with hyperextension preoperatively and should be avoided postoperatively. It is therefore critical to initially perform conservative resections of the distal femur and proximal tibia.

Preoperative clinical evaluation should also focus on the flexibility of the valgus deformity. In contrast to the more common varus deformity, valgus deformities are heralded by different patterns of bone deficiency. Together with the above-mentioned defects in the distal lateral and posterolateral femur, resection of the tibia must account for the deficient lateral surface, and a conservative resection is also recommended. The lateral distal femoral and lateral tibial defects, together with pliable lateral soft tissues, contribute to a flexible deformity. When the lateral structures become unyielding (contracted), a fixed deformity ensues, and the need for release of lateral structures such as the iliotibial (IT) band may be necessary. A lateral parapatellar approach with Z-plasty of lateral retinaculum combined with a Gerdy tubercle (GT) osteotomy will assist in dynamization of the tight lateral structures while providing adequate and safe exposure for knee replacement.

Surgical Exposure: Lateral Arthrotomy with Z-Plasty of Lateral Retinaculum and Gerdy Tubercl Osteotomy

After spinal anesthesia and with the knee in about 70°–90° of flexion, a longitudinal surgical incision is made in the lateral midline centered over the lateral third of the tibial tubercle and the lateral third of the patella. A full thickness lateral flap is developed without violation of the medial

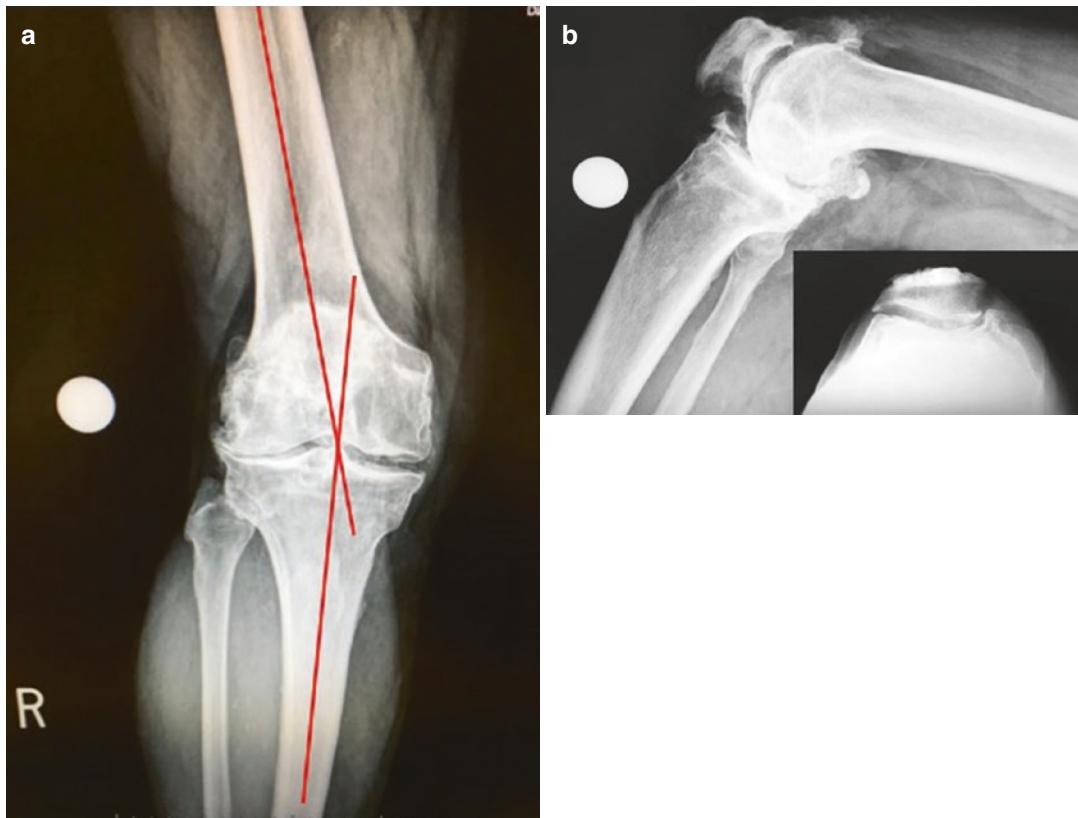


Fig. 2.52 Weight-bearing anteroposterior (AP) (a), 90° flexion lateral, and sunrise (b) views of the patient's knee show evidence of severe tricompartmental osteoarthritis with valgus deformity

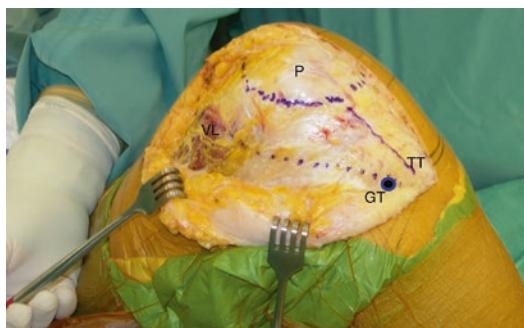


Fig. 2.53 Initial exposure of the knee with development of a lateral skin and subcutaneous tissue flap and maintenance of an intact medial skin flap. The patella (P), tibial tubercle (TT), Gerdy tubercle (GT), vastus lateralis (VL), and the planned incision of the capsular layer are marked

skin flap (Fig. 2.53). The lateral retinaculum is then incised 3–4 cm from the lateral border of the patella. This interval varies based on the severity and flexibility of deformity. The lateral

retinacular layer is incised with care taken to preserve the underlying synovial membrane layer. The synovium will “pop open” as the capsule is incised from the interval between GT and the tibial tubercle up to the vastus lateralis, exposing the underlying synovial layer (Fig. 2.54a). Once the synovial layer is exposed, a Z-plasty is performed between the capsular/retinacular layer and the synovium itself until the lateral border of the patella is reached (Fig. 2.54b, c). Once the Z-plasty reaches the lateral border of the patella, the knee is entered by incising the synovial layer just lateral to the patellar border, leaving a superficial/anterior layer of capsule and a posterior deep layer of the synovial membrane for later closure (Fig. 2.55). During the arthrotomy, it is important to preserve the lateral fat pad with the lateral synovial envelope, critical for closure at the end of the case (Fig. 2.56).

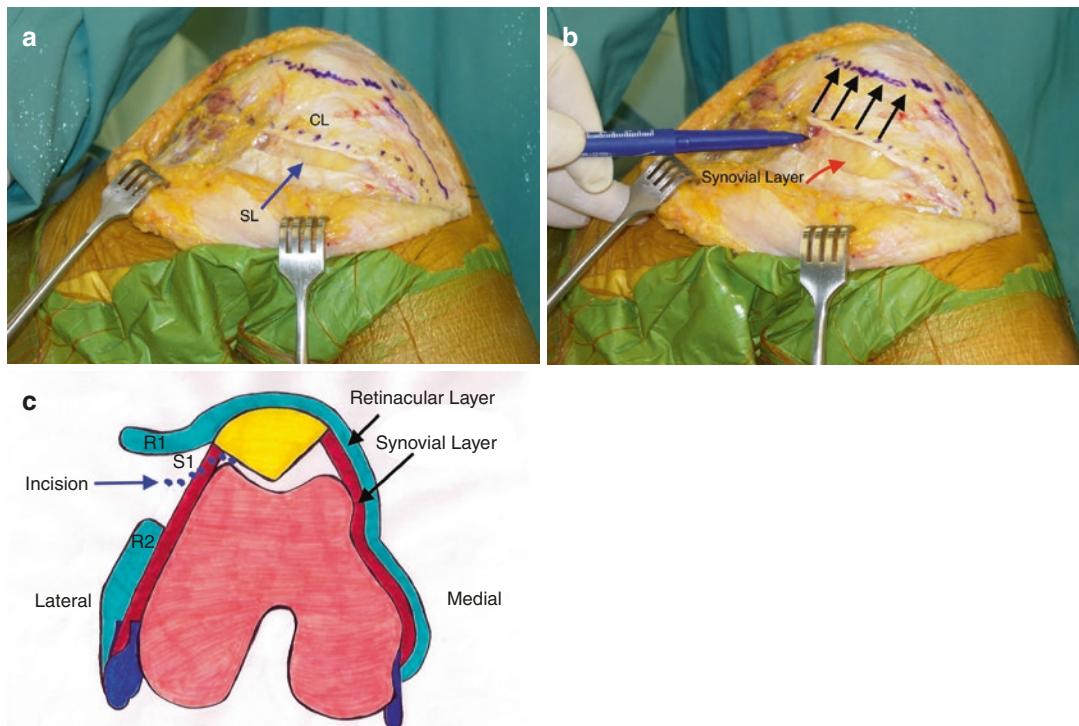


Fig. 2.54 (a) Utilizing the belly of the knife incises the lateral capsular layer (CL), allowing exposure of the underlying synovial layer (SL). (b) Demonstration of the Z-plasty performed between the capsular layer (R1) and the synovial layer (S1). (c) Medial dissection is carried

out posterior to the capsular layer until the lateral border of the patella is reached. Arthrotomy is performed by incising the synovial layer just lateral to the patellar border

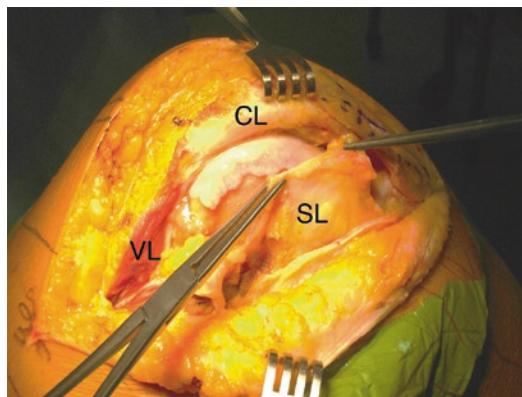


Fig. 2.55 The knee is entered through synovial layer adjacent to the patellar border. The arthrotomy leaves a superficial capsular layer (CL) and a deep synovial layer (SL). Notice how the lateral fat pad is retained together with the synovial layer. This is critical for later closure. In this figure, the 3–4 cm of capsular layer is retracted medially

The Z-plasty is important when approaching the valgus knee through a lateral approach due to the convex nature of the deformity and the degree of correction obtained. Restoration of the patella-femoral articulation is also eased by the relaxation of the lateral retinaculum, which is achieved utilizing this technique (see Fig. 2.56b). Next, the distal portion of the incision is extended down into the interval between GT and the tibial tubercle into the lateral compartment. Proceed to expose GT and the fascia of the lateral compartment. A half-inch osteotome is used to perform a wafer osteotomy of GT, leaving the lateral muscular fascia and the IT band attached to the wafer. Elevate the osteotomy laterally including the lateral compartment musculature toward the fibular head (Fig. 2.57). This elevates but does not directly release the static contracture of the lateral structures (analogous to the medial proximal

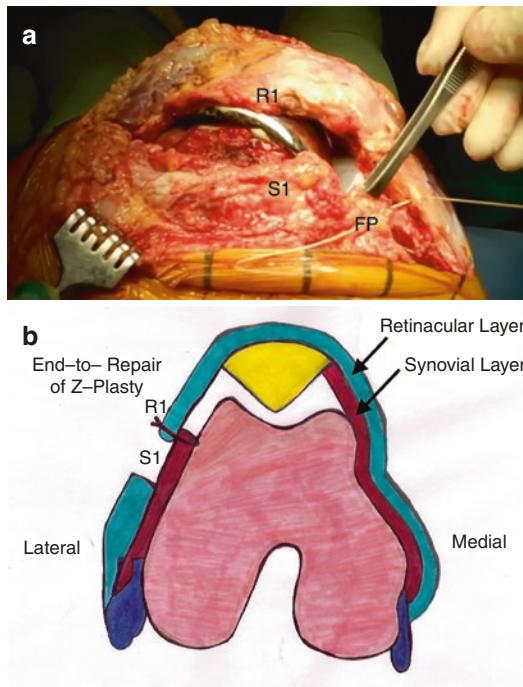


Fig. 2.56 (a, b) Notice the remaining superficial/anterior layer of capsule and a posterior deep layer of synovial membrane. Both layers are closed end to end during arthroscopy closure (R1 to S1). Fat pad (FP), synovial layer (S1), capsular layer (R1)

tibia exposure in medial parapatellar approaches) but still maintains a dynamic lateral stabilization with the IT band and the lateral compartment fascia. Proximally, complete the lateral arthroscopy by incising the vastus lateralis tendon along its lateral aspect of the patella and into the direct rectus fascia. At this time, mobilize the lateral gutter soft tissue envelope, and fine-tune the tibia exposure by releasing any patellar tendon attachment proximal to the tibial tubercle if necessary. The patella can then be safely everted or subluxed medially while exposing the entire distal femur and protecting the patellar tendon insertion (Fig. 2.58).

Distal Femur and Proximal Tibia Cuts

After adequate exposure is achieved, proceed with a conservative distal femur resection in 5°–6° of valgus. Depending on the amount of valgus deformity and lateral femoral hypoplasia, the lateral distal femur resection is variable and often

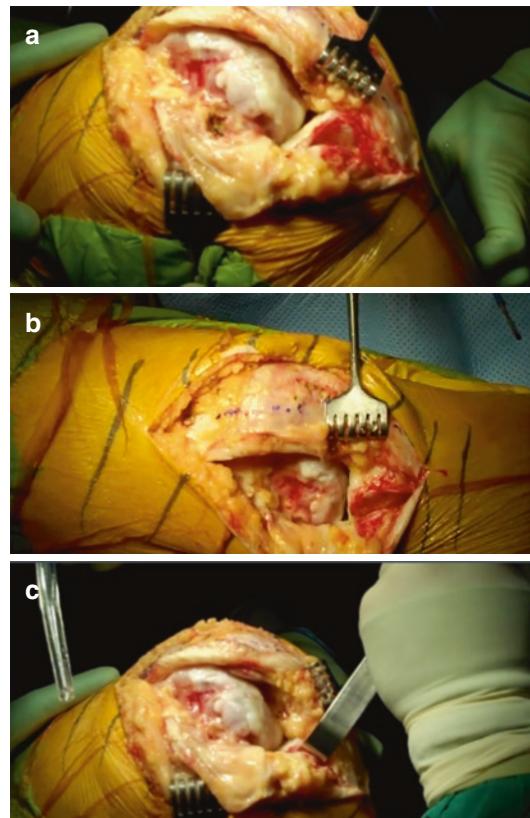


Fig. 2.57 (a, b) Lateral views of the knee following Z-plasty and joint arthroscopy. A wafer osteotomy of Gerdy tubercle is done with a half-inch osteotome and elevated off the lateral tibial plateau together with part of the lateral compartment musculature. (c) Elevation of the IT band/lateral compartment and resulting partial correction of a fixed deformity

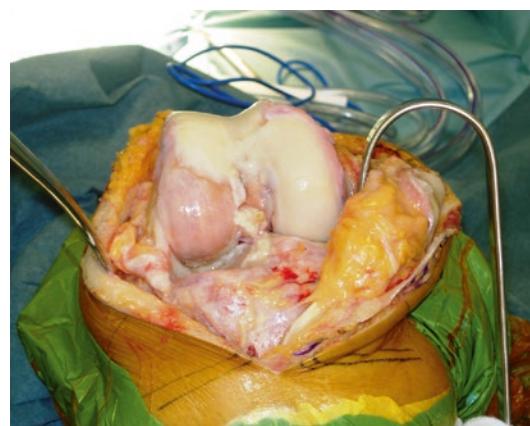


Fig. 2.58 Excellent and safe exposure is obtained with medial subluxation or eversion of the patella without the need for tibial tubercle osteotomy or quadriceps snip

wafer thin. It is important not to over-resect the distal femur due to possible postoperative hyperextension. A minus 2 mm resection of the distal femur based on the medial femoral condyle is routinely utilized. After the distal femoral cut is completed, proceed with anterior subluxation of the tibia for adequate exposure. Perform a conservative resection of the proximal tibia perpendicular to its anatomic axis with attention placed on the abovementioned lateral defect and in avoiding a varus resection. The amount of slope to be given to the tibial cut should be dependent on the implant of choice, whether cruciate-retaining (CR) or posterior-stabilized (PS) is utilized. If both cruciates are intact, the posterior cruciate ligament is of normal length, and a CR knee design is an excellent choice. If utilizing a CR implant, match the patient's anatomy and slope. With a PS implant, perform a resection with less slope given the expected increased flexion laxity after the posterior cruciate ligament (PCL) is resected. A 3° slope is typical.

Following distal femoral and proximal tibial resections, spacer blocks are utilized to assess extension balance and ensure sufficient bony resection. Restoration of coronal mechanical alignment is also evaluated. Typically, a long rod passed through the spacer block should point proximally toward the femoral head and distally along the long axis of the tibia. Ensure adequate ligament balancing is achieved in extension. Sequential releases of the tight concave structures can be performed until similar mediolateral balance is achieved. By utilizing this approach with an osteotomy of GT, rarely are additional releases necessary for achieving adequate balance in extension. If needed in more severe deformities, the typical sequential lengthening of the tight lateral structures is performed with an 18-gauge needle. A laminar spreader in the lateral compartment allows for identification of the structures in need of lengthening. The tightest structures are fractionally lengthened first followed by additional structures as needed to achieve coronal balance.

Femoral Rotation and Flexion Gap Balancing

Femoral component sizing should be performed as per surgeon preference. Attention to the femo-

ral component rotation is critically important due to the hypoplasia of the lateral femoral condyle. Multiple references should be used for determination of appropriate rotation. The Whiteside and transepicondylar axis lines should be drawn, and, together with the tibial resection line, femoral rotation should be set to obtain a rectangular flexion gap. Sizing should be determined off the medial femoral condyle following determination of the proper rotation for the AP block. Once adequate sizing and rotation are set, make the anterior cut first while avoiding anterior cortical notching. The posterior medial and lateral cuts should then be performed with adequate protection of the collateral ligaments. Often the posterior resection of the lateral femoral condyle is minimal. After removing the cuts, utilize a spacer block to ensure a rectangular flexion gap. Fine-tuning the flexion balance can be obtained by performing posterolateral and lateral releases as needed.

Arthrotomy and Wound Closure

With the lateral plateau having less inherent soft tissue attachments than the medial plateau, adequate closure technique of the lateral arthrotomy is critical to minimize the potential for postoperative drainage. This is especially critical at the distal portion of the incision near the joint line, the most common location of potential leakage. The arthrotomy is normally closed with the knee in 30°–50° of flexion, and attention must first be directed to the distal closure between the anterior tibial fascia and lateral compartment fascia. The interval between GT and the tibial tubercle is addressed first. A single- or double-suture anchor is placed just inferior to the tibial baseplate and is used to help secure the lateral compartment fascia, retropatellar fat pad, and retinaculum into the proximal tibia. This suture anchor adequately seals an area with no soft tissue attachments. The addition of a suture anchor has become a critical step to seal the inferior arthrotomy. The inferior patellar fat pad is then advanced to the lateral patellar tendon, and the interval is then closed proximally in a running fashion between the previous Z-plasty ends. This is an end-to-end repair of the capsular layer and the medial edge of the

synovial layer of the Z-plasty (see Fig. 2.56b). A typical end-to-end closure of the lateral retinaculum at this level of the arthrotomy is not possible due to the correction of the valgus deformity, but closing the Z-plasty layers allows for a watertight seal. The vastus lateralis and rectus femoris portions of the arthrotomy are then closed utilizing interrupted figure of eight suture repairs.

It is important to note that GT is not directly reattached and is allowed to scar back into place in its modified position while providing dynamic stabilization to the lateral aspect of the knee. Next, the knee is taken through a range of motion to assess for any potential areas of leakage, and these are addressed accordingly. A drain is utilized in all patients with lateral surgical approaches in order to prevent any fluid pressure buildup and minimize the potential for early wound leakage.

Postoperative Result

Postoperative radiographs demonstrate adequate alignment of components and restoration of the mechanical axis (Fig. 2.59). Clinical evaluation shows excellent wound healing, clinical alignment, and significant improvement from preoperative arc of motion. Given our preoperative flexion contracture of 15°, our results of full extension without quadriceps lag and 110° of flexion are optimal.

Clinical Results

Total knee arthroplasty for valgus knee deformities has historically been a more technically demanding procedure. Achieving optimal balance when approaching the knee from the “lax” medial side can sometimes lead to iatrogenic instability. The lateral parapatellar approach (LPA) for total knee replacement has been described in the literature utilizing different techniques to protect the extensor mechanism. More historical techniques describe the use of a quadriceps snip or a tibial tubercle osteotomy (TTO), while newer alterations avoid them by introducing a lateral capsular Z-plasty and even an osteotomy of the Gerdy tubercle. The rationale of a LPA is to facilitate a more direct exposure of the tight lateral structures. The exposure itself provides release of the tightest structures and allows for direct fine-tuning during the final knee balancing steps. This includes release of both the capsular and lateral retinacular layers, the latter also allowing for easier realignment of the extensor mechanism. The approach avoids violating the medial soft tissue structures that are often attenuated and prevents the higher incidence of lateral retinacular release typically needed in valgus knees. When a medial parapatellar approach is utilized for valgus knees, over 35% of the cases can require the addition of a lateral retinacular release [42]. This results in the violation of the



Fig. 2.59 Postoperative radiographs showing adequately aligned components

medial and lateral soft tissue envelopes and increases the potential for vascular compromise to the extensor mechanism.

Comparison studies of medial and lateral parapatellar approaches show similar postoperative alignment, clinical results, and functional postoperative scores [43–45]. With this in mind, the ability to achieve coronal alignment and extensor mechanism realignment can be more easily achieved through a lateral parapatellar approach utilizing a Z-plasty and a wafer osteotomy of GT. Problems described in the literature with the lateral parapatellar approach include a high technical difficulty level, inconsistent lateral closure of the prosthetic joint, and need of a sometimes undesirable TTO [46]. With the use of the lateral approach together with a TTO, authors have shown excellent results with minimal complications including low rate of osteotomy non-union [47, 48].

In order to avoid TTO and its possible complications, addition of a lateral retinacular Z-plasty protects the extensor mechanism while releasing the tight lateral structures [49, 50]. These techniques often utilize a quadriceps snip instead of the TTO in case the extensor mechanism is still potentially compromised during exposure. Utilizing the techniques mentioned in this case, a TTO is not indicated, and the soft tissue envelope is relaxed with the lateral capsular Z-plasty. Wound closure is also facilitated by the availability of the lateral soft tissue envelope created by the Z-plasty, allowing a watertight closure. This technique also effectively allows for relaxation of the lateral soft tissue envelope and realignment of the patellofemoral articulation. Lastly, the addition of a Gerdy tubercle elevation provides for dynamization without transection of the iliotibial band, avoiding iatrogenic instability and loss of the muscle function. Previous studies have described elevation of the IT band off the Gerdy tubercle and the lateral compartment without osteotomy [51].

In conclusion, the lateral parapatellar approach with a coronal Z-plasty and osteotomy of the Gerdy tubercle provides an adequate and reproducible approach for joint arthroplasty of both flexible and fixed valgus deformities. Although

still technically demanding, avoidance of TTO and quadriceps snip together with ease of balancing and improvement of patellofemoral tracking are excellent benefits of this approach. The long-standing concern of inefficient closure of the arthrotomy is also greatly improved with the use of a suture anchor at the Gerdy tubercle osteotomy site, providing watertight closure of the knee without prolonged drainage concerns.

Key Points

- Incision over lateral third of the tibial tubercle maintaining an intact medial skin flap
- Lateral capsulotomy and Z-plasty with Gerdy tubercle elevation
- Preservation of retropatellar fat pad
- Bone resection sequence
Bone preserving distal femur cut in 6° of the valgus
- Conservative tibial cut
- Close attention to arthrotomy closure
Suture anchor just distal to tibial baseplate for re-approximation of IT band and lateral compartment fascia
- End-to-end closure of lateral retinacular edge to synovial edge of Z-plasty

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Fixed Flexion Contracture

3

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Introduction

Fred D. Cushner

Fixed deformities are common when approaching the arthritic knee. While often most attention is placed to treat the varus or valgus deformity, both of these degenerative arthritis deformities can be associated with flexion deformity. Correction of these flexion deformities is necessary to obtain a successful total knee arthroplasty [1, 2].

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The orthopedic literature once supported the concept that complete correction of flexion deformities was not required at the time of surgery, and it was felt that the knee envelope would “stretch” during the postoperative period, allowing for full extension to be achieved. This concept should be abandoned; it is necessary to obtain full extension prior to leaving the operating theater. If the knee is tight in extension, then postoperative knee extension is often limited and full extension difficult to obtain. While limited flexion can be improved with a postoperative manipulation under anesthesia, the benefit in achieving improved extension is limited.

These case presentations will discuss how to handle the fixed flexion contracture, and surgical pearls will be provided so full extension is achieved [3]. Certainly, while evaluating extension in the operating room, the surgeon must critically evaluate the extension achieved as well as the effort required to achieve that extension. Since the extension is evaluated at the end of the case, often with trial in place, one must make sure that significant force is not required for this extension to be achieved. The surgeon must remember that the patient is under anesthesia and once awake with the element of pain introduced, it may be even more difficult to obtain that full extension. One must also consider that the arthrotomy is open at the time of final extension evaluation and once closed could add to the inability of getting full extension in a tight knee.

Therefore, prior to final component placement, full extension must easily be achieved with little force. Knees tight prior to closure with the patient under anesthesia will be even more tight on post-operative day 1.

If full extension is achieved in the operating room, the surgeon must remain vigilant in making sure the patient keeps that full extension. Often this begins with patient as well as staff education. During the immediate postoperative period, patients often find it more comfortable to place the knee in a flexed position. It should strongly be encouraged that this position be avoided. In fact, a pillow or rolled up towel can be placed just proximal to the heel so that active extension is encouraged.

The ability to obtain full extension must be evaluated daily while in the hospital, and if the flexion contracture appears to be increasing, intervention is required. While this may start with just simple patient education, often further intervention is needed. One simple preventive measure is to place the patient in a knee immobilizer at night. During the day patients are encouraged to sit with the knee flexed, to perform the drop and dangle maneuver, but at night extension is held with the knee immobilizer as needed. With earlier hospital discharges, often the flexion contracture is seen later in the post-operative period. While extension exercises can still be prescribed, this is often not enough and dynamic knee splinting may be required. It is important that pain is well controlled to aid in range of motion improvement. A multimodal approach to pain management is required so that appropriate exercises and stretching can be performed.

Despite all of the above, residual flexion contractures remain difficult to treat postoperatively and must therefore be avoided at the time of the indicated knee procedure.

Option 1: Implant Choice: Cruciate-Retaining Femoral Component

Andrew A. Freiberg and Tiffany N. Castillo

Achieving a stable and well-balanced total knee arthroplasty in patients with a fixed flexion contracture can present a unique set of challenges. The following two case examples illustrate how such deformities can be adequately treated with the use of a cruciate-retaining femoral component and a posterior cruciate ligament (PCL) sacrificing polyethylene insert.

Case 1

History

A 70-year-old male retired executive presented with several years of progressive bilateral knee pain, right worse than left. He was treated with a series of Synvisc injections 4 months prior to presentation without any improvement in his symptoms. His past medical history was only remarkable for an episode of high-altitude pulmonary edema and hyperlipidemia. Given the failure of nonoperative treatment modalities and limited function and pain secondary to his knee osteoarthritis, the patient desired to proceed with staged total knee arthroplasty beginning with the right knee.

Physical Examination

His right knee had a trace effusion, and knee range of motion was notable for a 10° fixed flexion contracture and active flexion to 120°. He had patellofemoral crepitus as well as medial and lateral joint line tenderness and a correctable varus deformity. His knee exam was also notable for a firm, non-tender mobile mass at the lateral joint line.

Radiographs and Advanced Imaging

Preoperative knee radiographs demonstrated advanced tricompartmental osteoarthritis with varus deformities (Fig. 3.1). A magnetic resonance image (MRI) of the right knee was also performed to further evaluate the mass at the lateral joint line, which revealed a small tear of the posterior aspect of the iliotibial band, a complex posterolateral meniscus tear, and a homogenous fluid collection contiguous with the joint space (Fig. 3.2).

Fig. 3.1 Preoperative weight-bearing (a) anteroposterior and (b) lateral radiographs demonstrating tricompartmental osteoarthritis with varus deformity and posterior osteophytes

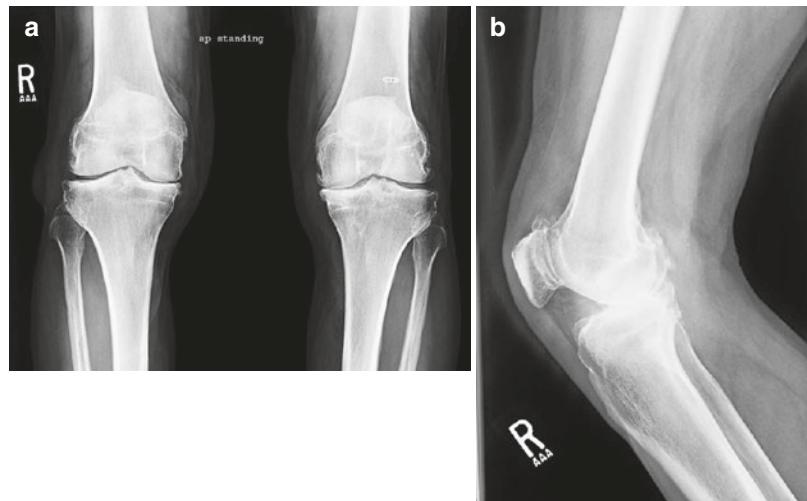
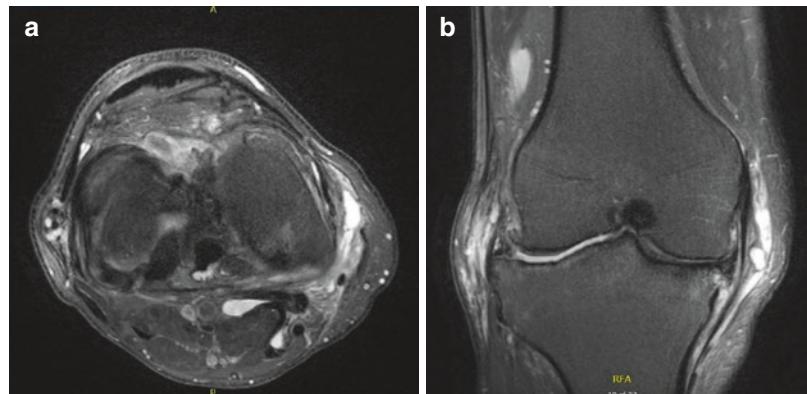


Fig. 3.2 Representative T2-weighted magnetic resonance (MR) (a) axial and (b) coronal images demonstrating complex posterolateral meniscus tear with associated parameniscal cyst extruding into the lateral soft tissues and through a torn portion of the posterior aspect of the iliotibial band at the level of the joint line



Surgical Approach

After induction of spinal anesthesia, a photograph was taken to demonstrate patient's mild fixed flexion contracture (Fig. 3.3). A standard midline incision and abbreviated medial parapatellar arthrotomy were used for exposure followed by medial tibial exposure and removal of a portion of the retropatellar fat pad and suprapatellar synovium. After subluxation of the patella, the distal femur was cut in 5° of valgus utilizing an intramedullary guide and the tibia with 7° of posterior slope utilizing an extramedullary guide. The most critical step in managing flexion contracture is to confirm that when the distal femoral and proximal tibial resections are done, there is full extension. After this step, sizing, rotation, and finishing cuts are made. This sequence pre-

vents inadequate distal femoral resection and excessive need for capsular stripping or osteophyte removal, which without adequate distal resection does not work to resolve fixed contractures. The extension gap was checked utilizing a 10 mm block and found to have excellent balance. The knee was then brought into flexion for final sizing and preparation of the femur using a cruciate-retaining cutting block for the femur and standard drill and keel punch after appropriate sizing and position of the tibial component were established. The PCL was resected, and a series of polyethylene inserts were trialed to determine appropriate soft tissue tension. The patella was resurfaced to remove the same amount of bone as replaced by the appropriately sized patellar button. Tracking and soft tissue tension proved to be

Fig. 3.3 Intraoperative photograph demonstrating mild fixed flexion contracture (after spinal anesthesia)



very well balanced without any additional soft tissue release or bone removal; thus final implants were sequentially cemented in place.

Postoperative Results

Patient had standard postoperative care with extra attention paid to having a pillow beneath the leg for 30 min at least three times a day to allow the knee to go into full extension and prevent recurrence of a flexion contracture. One-month postoperative radiographs demonstrated well-fixed components (Fig. 3.4).

Case 2

History

A 76-year-old male presented with 4 years of progressive severe right anterior knee pain. He had history of right medial meniscus surgery 12 years prior for a locked knee. In the years prior to presentation, he noted progressive varus deformity and loss of range of motion of his right knee. His past medical history was significant for rectal cancer treated with chemotherapy and radiation and history of right lower extremity deep vein thrombosis on chronic anticoagulation.

Physical Examination

His right knee had no effusion and active assisted range of motion was from 30° of fixed flexion to 80° of flexion. There was patellofemoral crepitus, medial joint line tenderness, and a partially correctable varus deformity.

Radiographs

Preoperative knee radiographs demonstrated advanced tricompartmental osteoarthritis with varus deformity of the right knee (Fig. 3.5).

Surgical Approach

Preoperative right knee range of motion was confirmed to be unchanged from patient's clinic visit, and a photograph was taken to document his severe fixed flexion deformity (Fig. 3.6). Surgical treatment in this case required additional steps to achieve full extension and soft tissue balance. Given the severity of his flexion contracture, an additional 2 mm was immediately resected from the distal femur to increase the extension gap. It is our practice to remove distal femoral bone in 2–3 mm increments and to check the gaps after each cut to prevent excessive bony resection. To facilitate soft tissue balance, all osteophytes were removed from the suprapatellar region, the medial joint line, and the posterior

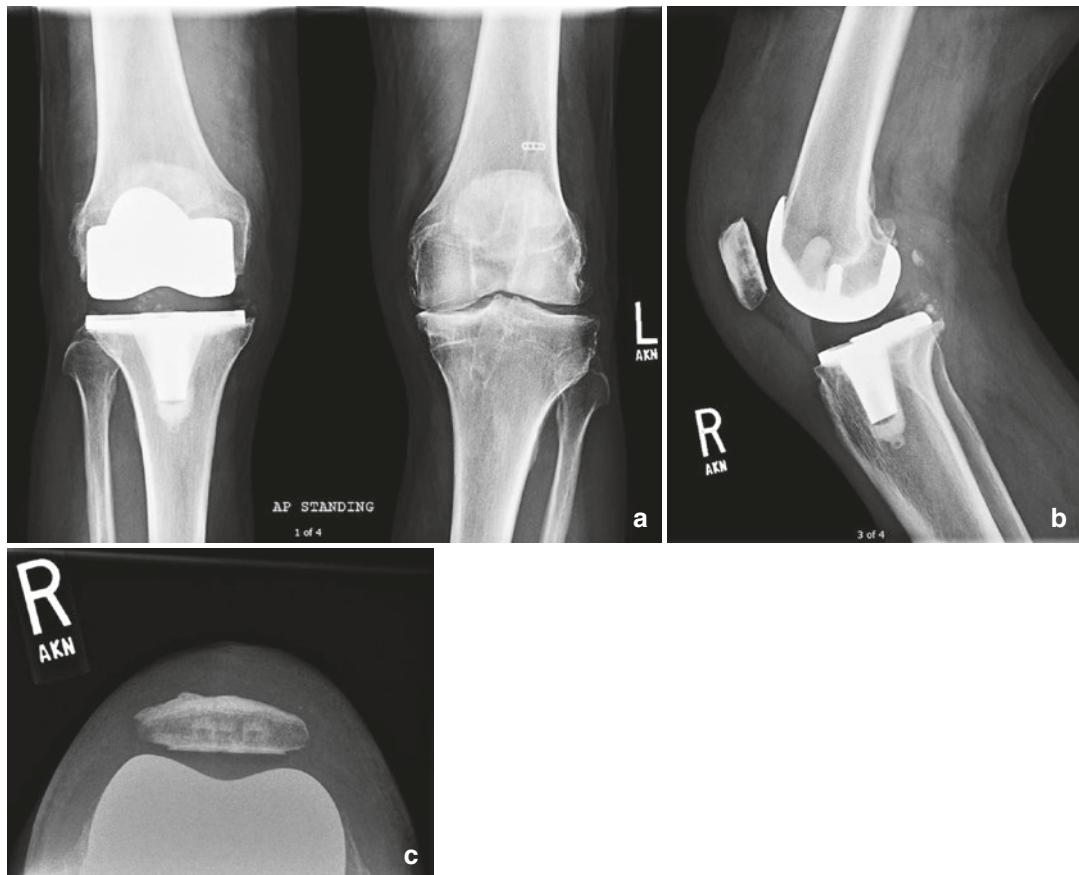


Fig. 3.4 One-month postoperative (a) anteroposterior, (b) lateral, and (c) sunrise radiographs demonstrate well-fixed right total knee arthroplasty

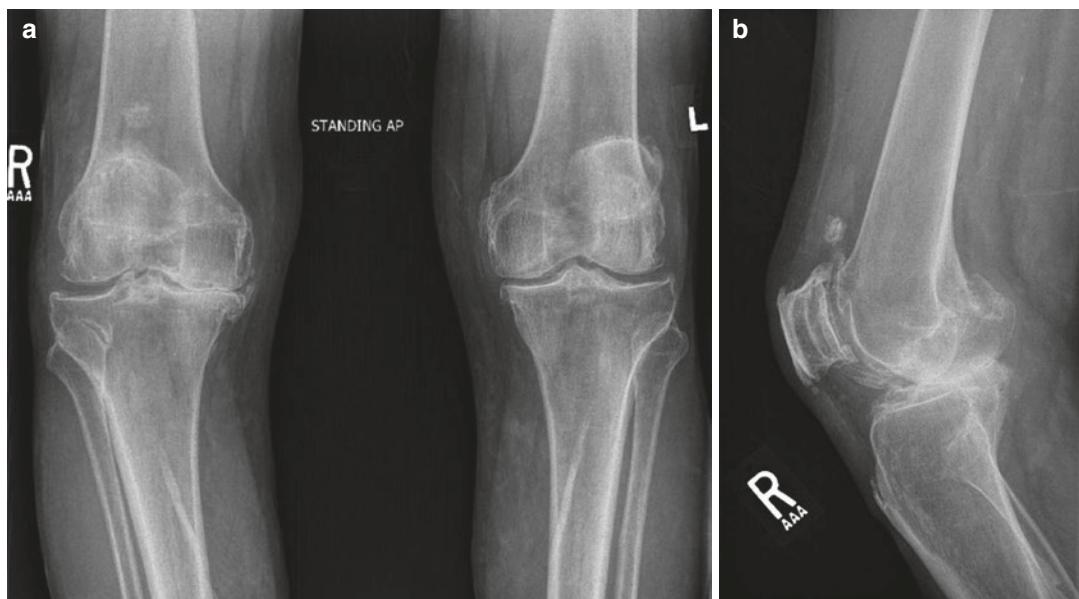


Fig. 3.5 Preoperative weight-bearing anteroposterior (a) and lateral (b) radiographs demonstrating advanced tricompartmental osteoarthritis with varus deformity and posterior and suprapatellar osteophytes

Fig. 3.6 Intraoperative photograph demonstrating a severe fixed flexion contracture



femoral condyles. Although this improved the balance, additional release of the posterior capsule from femur utilizing a cobb and release of a portion of the deep MCL were required to obtain a soft end point in full extension and balance in the coronal plane.

Postoperative Results

Patient underwent standard postoperative care with emphasis on the attainment of full extension. One-month postoperative radiographs demonstrated well-fixed components (Fig. 3.7).

Clinical Results

Both of these cases illustrate how mild to severe fixed flexion contracture deformities can be adequately addressed with the use of a cruciate-retaining femoral component and a PCL sacrificing ultracongruent polyethylene insert. As discussed by Berend et al., the use of ultracongruent or deep-dish anterior-stabilized-type inserts in the setting of flexion contracture provides excellent postoperative range of motion and, as seen in their series, may in fact result in improved range of motion and lower rates of postoperative manipulation under anesthesia compared to traditional cruciate-retaining designs [4]. As illustrated by the severe flexion contracture case, it is sometimes necessary to address such deformities with additional femoral

resection and sequential release of tight posterior structures followed by tight collateral structures. This algorithm has been well described in the literature [5–7], and it has been emphasized that the inability to achieve full extension at the time of surgery will inevitably result in inability to achieve full extension postoperatively and is associated with poor patient satisfaction and outcomes [8]. Nonetheless, controversy remains about the necessary amount of distal femoral resection. Some authors advocate for 2 mm for every 10° of fixed flexion, and others caution never to resect more than an additional 3 mm [9]. It has been our experience that cautious sequential removal of 2 mm with evaluation of the extension gap after each cut is a safe method to obtain adequate resection without experiencing over-resection. Moreover, it has been our experience and is well-documented in the literature that avoiding a tight extension gap and adequate release of posterior structures is equally important in achieving and maintaining full extension in patients with fixed flexion contractures [10–12].

Key Points

- Remove distal femoral osteophytes before placing resection guide.

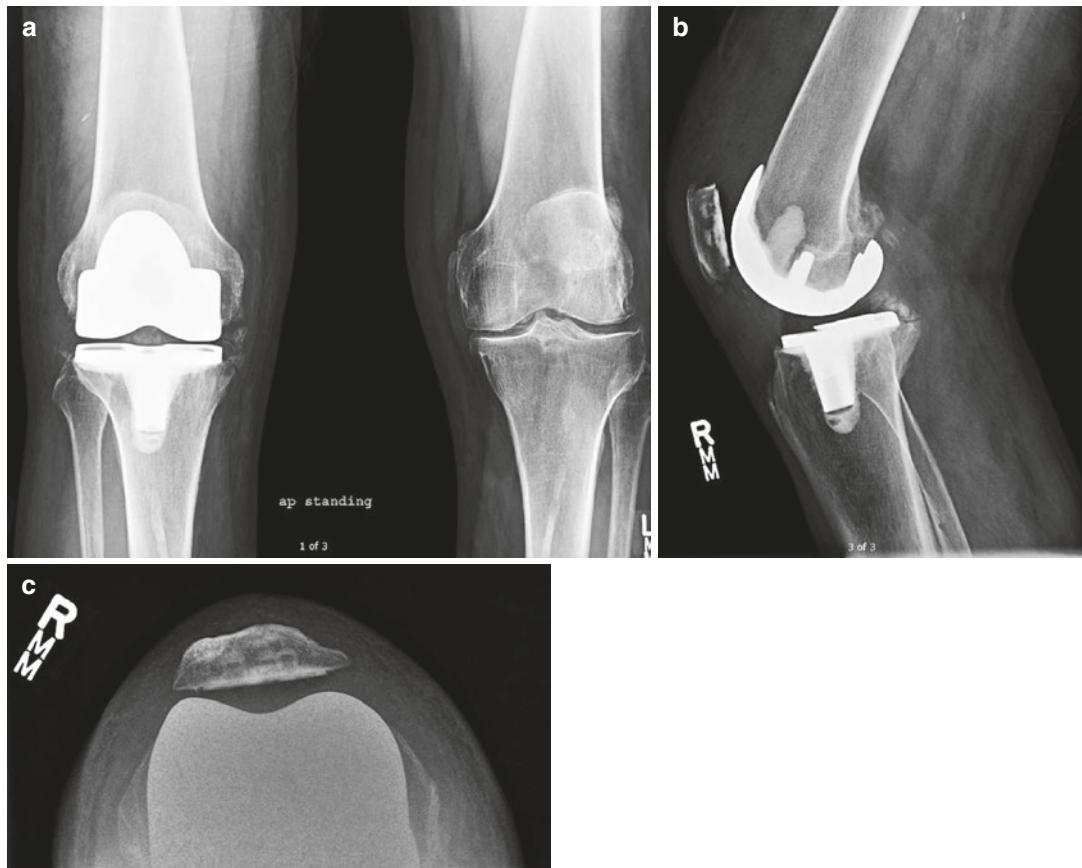


Fig. 3.7 One-month postoperative (a) anteroposterior, (b) lateral, and (c) sunrise radiographs demonstrate well-fixed right total knee arthroplasty and interval resection of the majority of the posterior osteophytes

- Perform standard distal femoral and proximal tibial cuts, and then check the extension gap with a spacer block.
- Resect additional distal femur in 2 mm increments, and confirm the gap with a spacer block after each cut—acceptable to aim for 12 mm poly.
- Remove posterior osteophytes and perform capsular release *after* adequate bony resection.

Case Presentation

History

The patient is an 81-year-old female with the chief complaint of right knee pain for more than 10 years. She has been treated with oral NSAIDs, physical therapy, hyaluronic acid injections, and bracing. She has not had any previous surgical procedures and her left knee is minimally symptomatic.

Option 2: Fixed Flexion Contracture Treated with a Posterior-Stabilized Total Knee Design

Jared S. Preston, Dexter K. Bateman, Bertrand W. Parcells, and Alfred J. Tria

Physical Examination

The patient ambulates with a cane for support and has a short leg, antalgic gait on the right side. The examination of the lumbar spine is negative with no evidence of sciatica. The hip and ankle examinations are normal with full range of

motion and no pain with passive motion. The knee has a range of motion from 20° to 125° with a fixed flexion contracture of 20° (Fig. 3.8). There is a small effusion and all areas of the knee are tender. There is no anterior or posterior drawer sign, and the anterior and posterior Lachman tests are both negative. Both collaterals are stable to varus and valgus stress. There is a five degree fixed varus deformity.

Radiographs and Advanced Imaging

The standing anteroposterior X-rays show a varus knee of 5° with mild lateral subluxation of the tibia beneath the femur (Fig. 3.9). All three compartments are arthritic and the medial compartment is the most narrowed. The lateral X-ray does not reveal significant osteophytes posteriorly.

Surgical Approach

Following the administration of preoperative antibiotics, the patient was taken to the operating room and placed in a supine position on the operating room table. The knee was prepped and draped in the customary fashion. The extremity was exsanguinated and the tourniquet elevated.

A midline incision was made followed by a median parapatellar arthrotomy. The patella was subluxed laterally. The intercondylar notch was

cleared, excising both the anterior and posterior cruciate ligaments. The early resection helps with femoral visualization and establishes the flexion gap size for later balancing. The anteroposterior (AP) axis was drawn. The femoral intramedullary hole was made and evacuated, and the first guide pin placed parallel to the AP axis. With this particular system, the anterior resection of the femur is completed first. The standard distal femoral cut resects 9 mm of the bone that will be replaced by 9 mm of the implant thickness. When the flexion contracture is less than 5°, the standard cut is made, and any residual contracture can be corrected with release of the posterior capsule on the femoral side. If the contracture is 5°–15°, 2 mm additional distal resection is planned (Fig. 3.10). If the contracture is greater than 15°, 3 or more mm of the bone may need to be resected, and that should be determined later in the procedure.

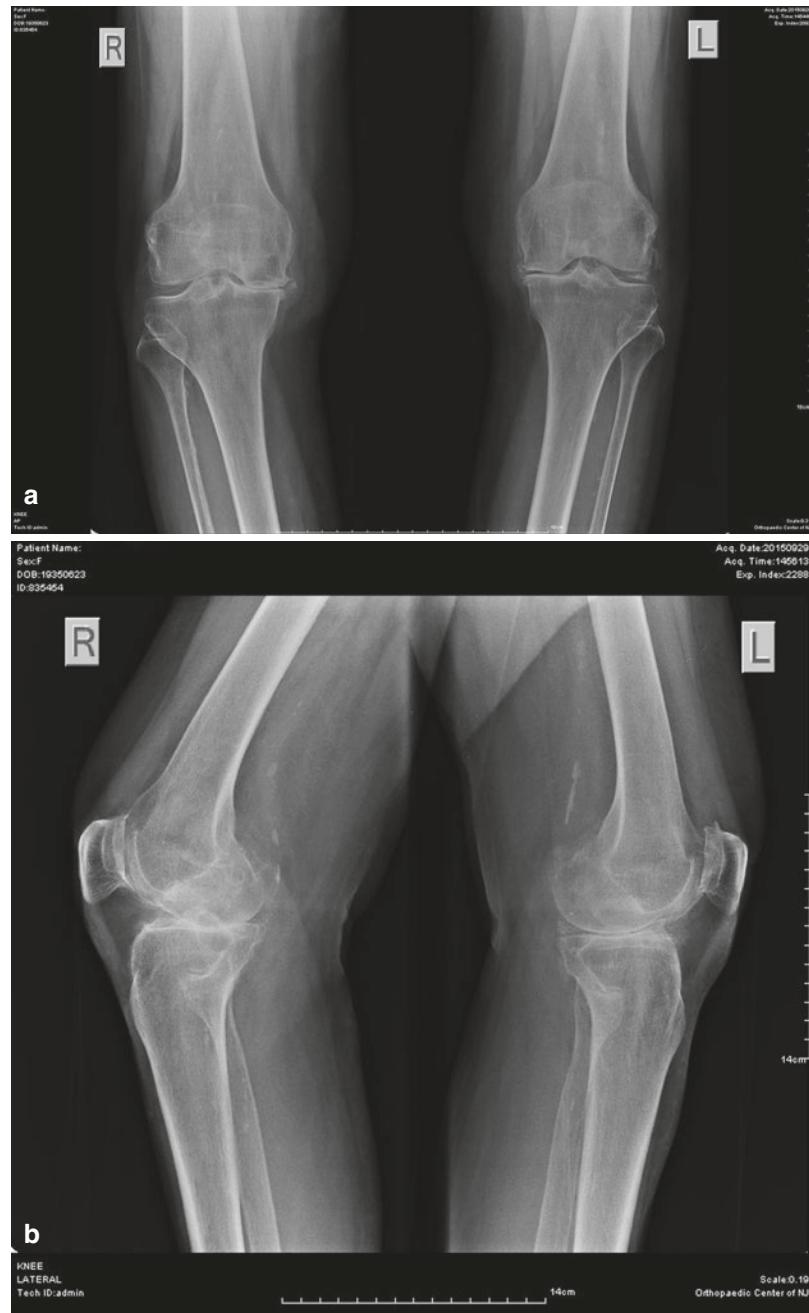
After completing the distal femoral resection, the bone surface can be sized and the appropriate finishing block is used to fashion the final surfaces.

The extramedullary tibial guide was used to complete the plateau resection considering proper varus/valgus, slope, and depth of the cut. The flexion gap technique was used confirming the ligamentous balance in full extension and



Fig. 3.8 Two views (a, b) of the knee on the operating table after the anesthetic has been established

Fig. 3.9 The standing anteroposterior (**a**) and lateral (**b**) X-rays of both knees



90° of flexion before completing the cut. The deep and superficial medial collateral ligaments were released without releasing the reflection of the ligament over the soleus. This release allows proper balance without destabilizing the medial side. The spacer block was inserted to confirm balanced gaps and full extension (Fig. 3.11). In

this case the knee still lacked full extension, and the posterior osteophytes and capsular releases were performed. After resecting the marginal and posterior osteophytes (Fig. 3.12), the posterior capsule can be visualized better and released using a periosteal elevator (Fig. 3.13). It is safest to use a blunt instrument for this step to

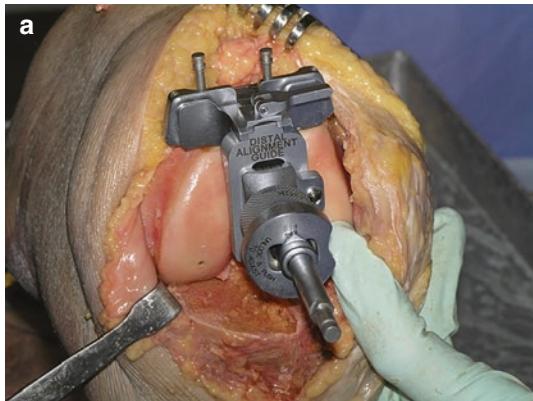


Fig. 3.10 (a) The intramedullary distal femoral resection guide is set against the articular surface of the femur. (b) The guide can be adjusted to resect additional bone in 2 mm segments



Fig. 3.11 The spacer block inserted in full extension evaluates the alignment of the knee with reference to both the ankle and the anterior superior iliac spine of the pelvis. It also confirms if the knee comes to full extension

avoid injury to the posterior vessels and nerves. If the knee is still flexed greater than 5°, further distal femoral resection should be considered. Extreme flexion contractures up to 90° will require significant resection and may sometimes approach the level of the epicondyles, where collateral ligament preservation is the final limit. The additional bone resections will elevate the joint line and may lead to decreased total range of motion and/or increased patellofemoral discomfort. Thus, the surgery must take into consideration the extent of the remaining flexion contracture versus the elevation of the joint. The authors prefer obtaining as much extension as possible and accept the joint line elevation as long as this does not lead to ligamentous instability of the knee.



Fig. 3.12 (a) The curved osteotome resects the posterior osteophytes allowing greater extension of the knee. (b) The marginal osteophytes should also be resected to aid in visualization and in extension

After the releases and the balancing were confirmed, the trial components were inserted and the range of motion, balance, and stability of the knee documented. In some cases it may be necessary to add additional constraint to the implant (either a CCK-type device or, in rare cases, a hinge). Thus, the preoperative planning should consider the appropriate prostheses to address the extent of the flexion contracture.

After confirming the alignment, balance, and full extension, the final finishing of the femur and tibia was completed and the patella was resurfaced. All components were cemented, and the knee was closed in the standard fashion after release of the tourniquet. The patient was transferred to the postanesthesia care unit where final X-rays were completed (Fig. 3.14).

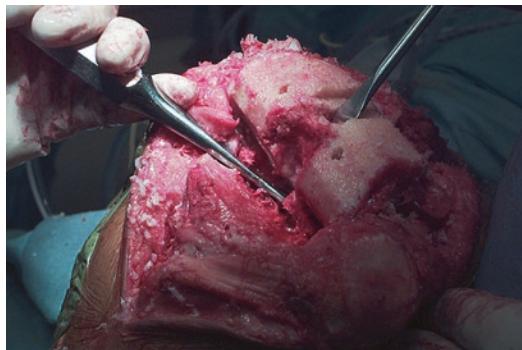


Fig. 3.13 The periosteal elevator is used to release the posterior capsule from the distal femur

Postoperative Result

The patient underwent standard postoperative rehabilitation with full weight-bearing ambulation on the day of surgery and range of motion both active and passive on the next day. The knee gradually increased in range of motion, and at 3 months after the surgery, the range was 5°–125° and at 6 months it was 0°–125°.

Clinical Results

Knee flexion contractures are one of the most common deformities dealt with in total knee arthroplasty, with estimates of up to 60% of TKA patients having some degree of a fixed flexion contracture [5]. A knee fixed flexion contracture is a knee that is unable to fully extend, both actively and passively. There is a multifactorial etiology of these fixed flexion deformities. Bony impingement, posterior capsular contracture, hamstring shortening, and ligament contracture may all contribute to the inability to fully straighten the knee [5].

Fixed flexion contractures (FFCs) force the quadriceps to continually contract to avoid buckling, leading to greater energy expenditure and early fatigue. Perry et al. demonstrated that a 15° flexion contracture forced the quadriceps to contract with 22% more force when compared to a fully extended knee. As the contracture approaches 30°, the quadriceps force must increase 50% [13]. Thus, a residual flexion con-



Fig. 3.14 The postoperative X-rays of the completed total knee arthroplasty

tructure will lead to early fatigue in standing, walking, and stair climbing [5].

Flexion contractures can impact more than just the arthritic leg. Gait studies of patients with flexion contractures have determined that there are abnormal forces on the contralateral knee due to functional limb length discrepancies and shorten stride. Harato et al. found that the contralateral knee experiences increased extension and adduction moments of up to 15% with a 15° flexion contracture [14]. This gait study also demonstrated that walking velocity decreases in a linear fashion with contractures between 15° and 20° [14]. Harato et al. also found that fixed flexion deformities can alter trunk alignment, altering the kinematics of the spine [15].

When arthroplasty surgeons do not address and correct flexion contractures during total knee arthroplasty, the deformity can create problems postoperatively for the patient. Gait and force plate analysis has shown that residual flexion contractures after TKA increase abnormal forces upon the contralateral limb [16], theoretically leading to greater wear of cartilage and accelerating the arthritic process [5]. If the flexion contracture is not corrected during the surgery, it may resolve postoperatively if less than 5° [17]. However, if the patient lacks greater than 15° of extension by 3 months postoperative, it is likely to persist [17, 18].

Results in Literature

Berend et al. [7] reviewed 52 knees with FFC >20° treated with a primary cruciate-retaining TKA. They used a stepwise algorithm to treating the contracture. First the authors corrected any coronal deformity via medial exposure, osteophyte removal, and posterior capsular soft tissue release. They then resected an additional 2 mm from the distal femur (routine when contracture is >20°). If that did not achieve full extension, the PCL was resected. Subsequently, they resected an additional 2–3 mm from the distal femur. If the contracture persisted after the distal femur bony resections, they performed additional soft tissue releases from the contracted side until full extension was achieved. If these releases resulted in instability, a constrained implant was used. With this stepwise algorithm, the authors achieved 80%

good or excellent results as measured by the Knee Society Score. In knees with no residual contracture at discharge (14 knees), all maintained <10° of FFC, with eight knees having full extension. In those knees with a FFC <10°, 73% improved to no contracture at final follow-up. Of the five knees with 11°–15° of FFC at discharge, three improved to full extension, one improved to <10°, and one remained between 11° and 15°. The one knee with >20° FFC at discharge improved to 11°–15°. Overall, 94% of their patients had less than 10° residual contracture at an average of 37 months. No revisions were performed for residual contracture. A cruciate-retaining device was used in 60% of patients, posterior stabilized in 27%, and a constrained device in 10%, and two knees received a rotating hinge.

In a similar paper, Bellemans et al. [19] reviewed a four-step algorithm for the treatment of FFCs: (1) mediolateral ligament balancing with resection of all osteophytes and over-resection of the distal femur by 2 mm, (2) progressive posterior capsular release and gastrocnemius release, (3) additional resection of the distal femur up to a maximum of 4 mm, and (4) hamstring tenotomy. They graded FFC as mild (5°–15°), moderate (15°–30°), and severe (>30°). Overall, they found 98.6% of the cases with FFC <30° could be corrected with Steps 1 and 2. Even in the 35 severe flexion contractures, additional resection of the distal femur and hamstring tenotomy were only performed in 29% and 23% of cases, respectively. In the severe FFC group, the author found that 11.4% of patients (four knees) were left with a residual FFC of <5° and 5.7% (two cases) were left with a residual FC of 10°–15°. It's important to note that two of these patients sustained a peroneal nerve palsy, one of which was permanent. By using this algorithm, the authors noted they did not rely solely upon distal femur resection, as this may lead to an elevated joint line and altered knee kinematics.

It is also important to avoid recurrence of FFCs. Su [5] suggested some useful techniques for post-operative care: the use of bolsters under the ankle to suspend the knee and put an extension moment on the joint, short-term (<48 h) plaster splint, nighttime knee immobilizers, avoidance of bolsters under the knee, isometric quadriceps strengthening

immediately postsurgery, and continuous passive motion machines that incorporate a static stretch splint into their frame. Additionally, shoe lifts can be placed in the contralateral leg, which will force the operative leg into extension while walking; and, similarly, stationary bikes with elevated seats can also force legs into extension.

Key Points

- Evaluate the extent of the flexion contracture before surgery, and request the proper prostheses if additional constraint may be required.
- Use a stepwise approach to treating flexion contractures, and reevaluate the flexion and extension gaps after each step. Address possible sources of contracture, such as impingement from osteophytes, posterior capsular contracture, hamstring shortening, and ligament contractures.
- Don't rely solely on distal femur resection, as over-resection can elevate the joint line and alter knee kinematics.
- Adjust postoperative protocols for patients at risk for redeveloping fixed flexion contractures. Consider bolsters under the ankle, short-term splinting, nighttime knee immobilizers, and even contralateral shoe lifts to increase the extension moment on the operative knee.
- Protect the peroneal nerve when considering tenotomy of hamstring tendons.

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Patellofemoral Arthritis

Giles R. Scuderi, James F. Fraser, Jess H. Lonner,
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Introduction

Giles R. Scuderi

Isolated patellofemoral arthritis (Fig. 4.1) is not a rare condition and is observed in 17.1–34% of female patients and 18.5–19% of male patients over the age of 50 years [1]. This condition also exists at a lower frequency in young and middle-aged patients. For the symptomatic patient, initial treatment begins with a nonoperative approach, including activity modification, weight loss, anti-

inflammatory medication, physical therapy, bracing, and viscosupplementation [2].

Surgical treatment for isolated patellofemoral arthritis is considered after an extended period of ineffective nonoperative treatment. Several procedures have been employed for isolated patellofemoral arthritis, including facetectomy, patellectomy, tibial tubercle elevation, and cartilage enhancement procedures such as microfracture or osteochondral grafting [2]. Usually indicated for young patients, these procedures may not be as predictable and reliable as joint arthroplasty. While total knee arthroplasty (TKA) addresses all arthritic conditions in the knee, some surgeons may consider this an overly aggressive procedure when the arthritic condition is isolated to the patellofemoral joint with a normal-appearing femoral tibial joint. In this case, especially in young active patients, patellofemoral arthroplasty may be indicated as a bone-preserving procedure. Another subset of patients is the older patient with isolated patellofemoral arthritis. In this case scenario, patellofemoral arthroplasty may be a simpler procedure with a more rapid recovery with fewer complications.

The first isolated patella replacement was performed by McKeever, who implanted a screw-on Vitallium patella shell in 1955 [3]. Early reports with this prosthesis revealed satisfactory results with poorer results in those patients with osteoarthritis in other compartments of the knee joint. The concept of a metallic implant articulating with the

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Fig. 4.1 Radiographs of symptomatic isolated patellofemoral arthritis. (a) Anteroposterior (AP) view, (b) lateral view, (c) Merchant view



articular cartilage of the trochlea was not appealing because of concerns about damage to the articular cartilage (Fig. 4.2) or failure to address the osteoarthritic changes in the trochlea.

Lubinus [4] and Blazina et al. [5] introduced the concept of patellofemoral replacement in 1979. The initial results were disappointing due to problems related to patient selection, surgical technique, extensor mechanism complications, and durability. Despite the inferior clinical results, prosthetic designs have improved, and the contemporary designs are more favorable [6–8].

While current advocates of patellofemoral arthroplasty feel that this procedure is a definitive procedure, others realize that arthritis is more likely to develop in other compartments of the knee joint and prefer TKA for the treatment of patellofemoral arthritis. Laskin and van Steijin

compared the clinical outcomes of TKA with isolated patellofemoral arthroplasty and reported that TKA had a more predictable and durable outcome in the presence of isolated patellofemoral arthritis, especially in the older patient population [9]. In a comparison study of patellofemoral arthroplasty and TKA, while a similar range of motion was reported in both groups, higher functional scores and lower revision rates were seen with the TKA group [10].

The following case presentations will describe the authors' preferred method for dealing with isolated patellofemoral arthritis. It will become apparent that both patellofemoral arthroplasty and TKA are effective procedures for treating patellofemoral arthritis, but there are specific technical considerations that need to be addressed.

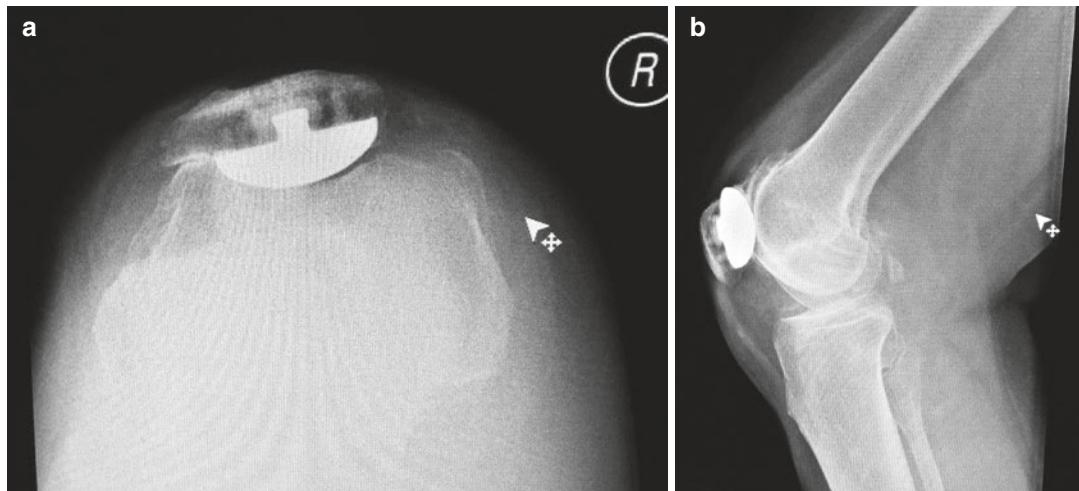


Fig. 4.2 Radiographs of failed metal patella replacement with erosion of the femoral sulcus. **(a)** Merchant view, **(b)** lateral view

Option 1: Patellofemoral Arthroplasty

James F. Fraser and Jess Lonner

Case Presentation

History

The patient is a 38-year-old woman who presents with a 3-year history of progressive, isolated retropatellar and peripatellar knee pain in both knees, left worse than right. Her symptoms are exacerbated with descending or ascending stairs, squatting, and kneeling. She also notices pain with prolonged sitting with her knees flexed. There is less pain when walking on level terrain or sitting with her knees extended. She denies any medial or lateral joint line pain and has no history of prior patellar dislocations. While initially helpful, physical therapy, weight reduction, bracing, injections, and medications are no longer effective at relieving her anterior knee pain.

Physical Examination

It is important to assess patellar tracking and lower extremity alignment on physical exam. The presence of a J sign (lateral patellar subluxation visualized as the flexed knee extends past 20° of

flexion) can indicate malalignment or muscular imbalance. Q angles more than 15° in men or 20° in women may necessitate anteromedialization of the tibial tubercle in addition to patellofemoral arthroplasty (PFA).

Localizing pain to the anterior knee is also important prior to proceeding with patellofemoral arthroplasty. Patellofemoral crepitus and pain with patellar compression are suggestive of patellofemoral arthritis. Physical exam should include investigation of other regional pain generators including the quadriceps tendon, patellar ligament, iliotibial band, medial and lateral tibiofemoral joint lines, pes anserine bursa, lumbar spine, and the hip. Additionally, the planovalgus foot can exacerbate patellar maltracking that may be improved with the use of medial arch supports. Assessment of quadriceps strength is important. Considerable weakness of the quadriceps muscles can delay recovery and negatively impact the results of PFA, in which case thorough preoperative terminal arc physical therapy exercises should be encouraged, even when it exacerbates the PF pain.

Radiographs and Advanced Imaging

Preoperative radiographs (Fig. 4.3) demonstrate isolated patellofemoral arthritis. There is mild-to-moderate patellar tilt and subluxation. Weight



Fig. 4.3 (a) Anteroposterior (AP), (b) right lateral, (c) left lateral, and (d) sunrise views of the bilateral knees demonstrate lateral patellar tracking, patellofemoral joint space narrowing, and preserved tibiofemoral joint spaces

bearing films are superior to non-weight bearing radiographs, which may underestimate the extent of tibiofemoral arthritis. Small marginal osteophytes and early squaring of the condyles do not preclude PFA so long as (1) the patient has no

symptoms on physical exam in these areas and (2) minimal chondral degeneration is observed at the time of surgery. The lateral view is helpful to identify patella alta or baja and occasionally can show patellofemoral joint space narrowing. The

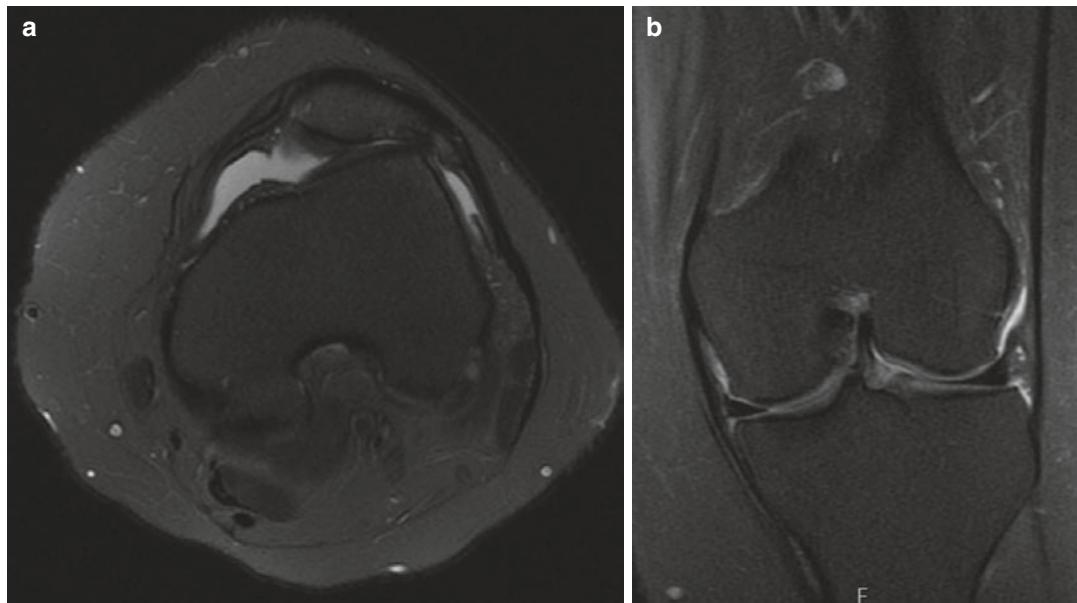


Fig. 4.4 (a) Axial and (b) coronal T2 magnetic resonance imaging (MRI) of the left knee demonstrating lateral patellar tracking, patellofemoral arthritis, and well-preserved tibiofemoral cartilage

sunrise view is taken to further assess the patellofemoral joint space, trochlear dysplasia, and patellar tilt or subluxation. This patient has narrowed lateral patellofemoral joint spaces and opposing osteophytes emanating from the lateral patellar facet and lateral femoral condyle.

Magnetic resonance imaging is routinely ordered not only to assess the extent of patellofemoral cartilage wear when radiographs and clinical exam are incongruous, but, more importantly, to identify the presence of tibiofemoral chondral disease which may require additional surgery, such as combined femoral condylar biologic resurfacing, unicompartmental arthroplasty, or total knee arthroplasty [11–13]. Selected MRI images from this case demonstrate subchondral patellar enhancement, patellofemoral articular degeneration, and well-preserved tibiofemoral cartilage (Fig. 4.4). Computed tomography is not typically necessary.

Surgical Approach

The patient is positioned supine on the operating table. The incision extends from 2 cm proximal to the superomedial edge of the patella to just medial and proximal to the tibial tubercle

(Fig. 4.5). A medial parapatellar arthrotomy is made, and careful attention is paid to protect the tibiofemoral articular cartilage, medial meniscus, and intermeniscal ligament. A small amount of fat pad is excised, and then the medial and lateral tibiofemoral articulations are visualized to confirm that the patient is a suitable candidate for PFA (Fig. 4.6).

The majority of the trochlear preparation is performed with the knee in 30°–60° of flexion. Whiteside's line is drawn to guide placement of the trochlear cutting guide (and eventually the component) (Fig. 4.7). Rotationally aligning the onlay-style trochlear component with the anteroposterior (AP) axis of the femur improves patellar tracking, reducing the more common tendency of lateral patellar subluxation observed with inlay-style trochlear components, which tend to be internally rotated along the trochlear peaks [14–19]. An intramedullary guide for the anterior femoral cut is inserted, and an outrigger boom is used to determine the appropriate depth of resection, which should be flush with the anterior femoral cortex. The guide is then pinned in place and the anterior cut is made (Fig. 4.8). Next, the milling guide is



Fig. 4.5 The incision is marked here and extends from 1 centimeter above the superomedial edge of the patella to just proximal and medial to the tibial tubercle

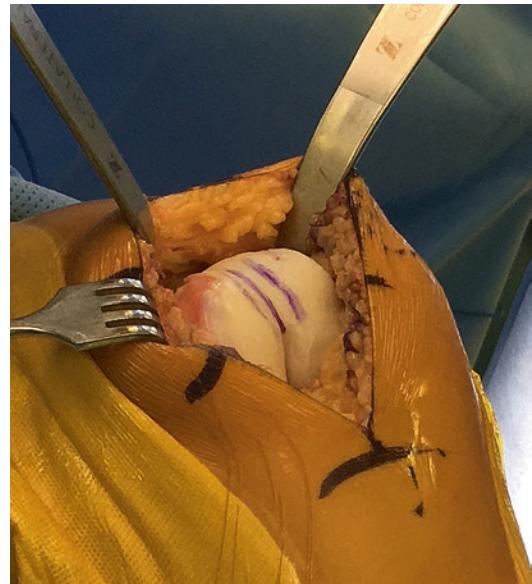


Fig. 4.7 To determine rotational alignment of the trochlear component, the Whiteside line is marked. Using this particular system (Zimmer Gender Solutions Patello-Femoral Joint [PFJ] System, Zimmer Biomet, Warsaw IN, USA), two parallel lines are drawn on either side to allow visualization of the rotational axis when the anterior cutting guide is applied

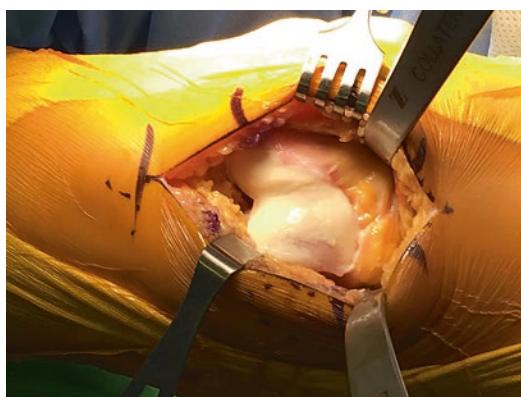


Fig. 4.6 Exposure using a mini-medial parapatellar arthrotomy demonstrates patellofemoral arthritis and allows for assessment of the adjacent compartments



Fig. 4.8 This image demonstrates the anterior trochlear cut, which is perpendicular to the rotational axis of the femur and flush with the anterior cortex of the femur

used to both determine trochlear implant size (maximizing coverage while also avoiding medial or lateral overhang) and to instrument the resection of bone in the intercondylar region (Fig. 4.9).



Fig. 4.9 The milling burr is secured into place

The correctly sized trochlear template is then inserted into the prepared bone surface. Particular attention is paid to make sure that the implant is not prominent at the implant-cartilage interface at the distal edges. The trochlear edges should be flush with the resected anterior femur proximally, medially, and laterally; distally it should be flush with or recessed 1–2 mm relative to the adjacent articular cartilage. Further, the medial and lateral edges of the implant should not extend beyond the margins of the femur to reduce the tendency of soft tissue impingement (Fig. 4.10). The trochlear template is pinned in place and the lug holes are drilled. The trial trochlear component is then impacted into place.

Patellar preparation is then carried out in similar fashion to resurfacing techniques used in total knee arthroplasty. A caliper is used to assess the depth of patellar resection to avoid over- or understuffing of the patellofemoral articulation. The objective of patella resurfacing is to restore the original patella thickness, resecting 8–10 mm from the articular surface, parallel to the anterior patellar surface. Occasionally, with severely dysplastic or eroded patellae, removal of less articular surface is necessary in order to preserve an adequate thickness of residual patellar bone



Fig. 4.10 The sizing guide for the trochlea is placed and appropriate resection is gauged based on how the sizing guide sits relative to the adjacent cartilage of the condylar surfaces

(12–15 mm). The patellar sizer/drill guide is medialized to the edge of the patella and lug holes drilled. The exposed cut surface of the lateral patella that is not covered by the patellar prosthesis should be beveled or removed to reduce the potentially painful articulation on the trochlear prosthesis in extension and midflexion [20] (Fig. 4.11). Anecdotally, this also reduces tension in the lateral retinaculum and decreases the need for lateral release.

Assessment of patellar tracking is performed with the trial components in place, paying particular attention to identify patellar tilt, subluxation, or catching of the components. Patellar tilt and mild subluxation usually can be addressed successfully by performing a lateral retinacular recession or release, unless there is considerable extensor mechanism malalignment, which needs to be addressed with either tibial tubercle realignment (if the Q angle is excessive) or a proximal realignment. In the absence of a high Q

angle, patellar maltracking with the trials in place is concerning for the possibility of component malposition (particularly internal rotation) and is more common with inlay than onlay trochlear components. The components can then be cemented into place, removing extruded cement while it cures (Fig. 4.12).

Postoperative Result

At the last follow-up after patellofemoral arthroplasty, the patient has significantly improved, with diminished pain and markedly improved

ability to ascend and descend stairs and hills, squat, rise from a chair, and ski. Postoperative radiographs show improved patellar tracking within the trochlear surface compared to preoperative radiographs and no evidence of tibiofemoral arthritis (Fig. 4.13).

Clinical Results

While the prevalence of isolated patellofemoral arthritis has been reported in 9–24% of patients [2, 21–23], patellofemoral arthroplasty is currently performed in less than 1% of knee arthroplasty patients worldwide [24–26]. The slow adoption of this surgery may be a result of the relatively poor outcomes of what Lonner previously described as “first-generation implants” [16] which may more aptly be categorized as inlay-style implants (irrespective of their “generation”) [15, 27], with survivorships as low as 58–84% at 2–10-year follow-up (Table 4.1) [14, 28–30]. These high early failure rates of inlay trochlear designs, or the need for secondary surgeries to improve patellar tracking, have been attributed to maltracking, patellar instability, polyethylene wear, and poor patient selection [14, 27, 30–32]. While initially attributed to flaws inherent to the individual trochlear designs, the high failure rates, with inlay designs or directly related to the fact that they tend to be



Fig. 4.11 The patella is prepared in standard fashion as it would be in the case of a total knee arthroplasty. Here, a rongeur is used to excise the uncovered portion of the lateral patellar facet to eliminate a source of bone impingement and facilitate patellar tracking

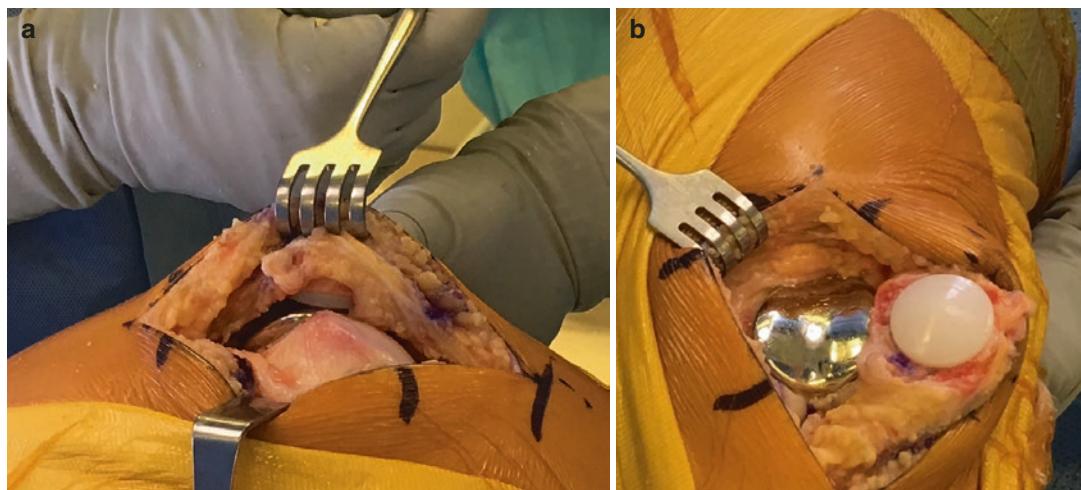


Fig. 4.12 (a, b) The final components are cemented into place, and satisfactory positioning and tracking are demonstrated



Fig. 4.13 (a) Postoperative anteroposterior (AP), (b) right lateral, (c) left lateral, and (d) sunrise views demonstrate well-positioned, aligned patellofemoral arthroplasties, with improved patellar tracking

internally rotated, flush with the peaks of the anterior trochlear surfaces, which causes early and persistent lateral patellar subluxation (Table 4.1) [15, 17, 19, 27].

In an effort to avoid the issues associated with the early PFA implants, several second-generation

patellofemoral arthroplasty systems entered the market in the 1990s [27, 32]. Trochlear components evolved from an inlay style to an onlay style, which minimized the risk of patellar instability and has enhanced both early and midterm results [27]. The survivorship of second-

Table 4.1 Clinical survivorship of first-generation patellofemoral arthroplasty

Study (year)	Survivorship
Argenson (1995) [29]	58% at 16 years
Tauro (2001) [14]	65% at 8 years
Board (2004) [28]	65% at 2 years
van Jongerden (2010) [30]	84% at 10 years, 69% at 20 years

Table 4.2 Clinical survivorship second-generation patellofemoral arthroplasty

Study (year)	Survivorship
Butler (2009) [33]	91% at 5 years
Leadbetter (2009) [34]	94% at 3 years
Odumeyna (2010) [36]	100% at 5 years
Mont (2012) [37]	95% at 5 years
Pouya Akhbari (2015) [35]	96% at 5 years
Kazarian (2016) [18]	97% at 4 years

generation PFA implants has been consistently reported to be above 90% at an average of 5-year follow-up (Table 4.2) [18, 33–37]. In addition to improved survivorship among second-generation implants, recent studies have consistently reported significant improvements in both patient-reported and clinical outcome scores following PFA [33–35, 37].

The incidence of patellar maltracking, and thus the failure rate, has been markedly reduced with onlay designs. One series reported a 17% incidence of patellar maltracking with an inlay design, with 84% good or excellent results. On the other hand, the incidence of patellar maltracking with an onlay design was less than 4%, with 96% good and excellent results [16]. Others have reported an incidence of patellofemoral instability in excess of 30% using an inlay trochlear design [14] and less than 1% with an onlay design [18, 38]. When early patellar instability is eliminated by using onlay-style trochlear designs, the primary failure mechanism is progressive tibiofemoral arthritis, which tends to occur later [39, 40]. A recent meta-analysis found that first-generation (i.e., inlay) PFAs had an elevated risk of reoperation (odds ratio of 8) compared to TKA, while there was no significant difference in reoperation rates between second-generation (i.e., onlay) PFAs and TKAs [41]. This distinc-

tion highlights the impact of trochlear component design and position, relative to the AP axis of the femur, on patellar tracking and implant performance and durability. A systematic review published in 2015 included 51 clinical studies examining PFA in 9619 patients and reported 5-, 10-, 15-, and 20-year survivorships at 92%, 83%, 75%, and 67%, respectively [42]. Improvements in functional performance has been substantial after PFA, using Knee Society Scores (KSS) as an outcome measure [42]. One study retrospectively comparing outcomes in patients undergoing PFA or TKA for patellofemoral arthritis found that patients treated with PFA had higher activity levels [36]. This supports the use of PFA in appropriately selected patients, particularly when considering that, at least in one series of 53 patients, the mean patient age was 51 and 48% are 50 years or younger [34].

Data from national joint replacement registries have also highlighted the outcome disparity between inlay and onlay components and the importance of careful patient selection. The total joint register from England and Wales reported 5- and 10-year survivorships of 90.5% and 81.3%, respectively, in their 2016 annual report [25]. The Australian total joint registry includes data on 2981 PFAs, representing 0.5% of all primary knee arthroplasty operations in that country [26]. They report 5- and 10-year survivorship of 85.7% and 72.6%, respectively, in their 2016 annual report [26]. Five-year cumulative revision surgery rate was more than 20% after PFA with inlay-style prostheses and less than 10% for PFA with onlay-style prostheses, most likely due to differences in patellar instability or poorly understood or recorded anterior knee pain between the groups. The most common reasons for revision of PFA in the Australian registry were progression of disease (45.6%), aseptic loosening or osteolysis (19.1%), and ongoing pain (13.0%) [26]. While registry data is helpful for understanding overall survivorship of PFA implants, it is inherently limited due to lack of clinical outcome measures and information about patient selection criteria.

In summary, in appropriately selected patients, modern onlay-style PFA implants and techniques

can be expected to achieve survivorship of 90% or better at 5 years as well as significant improvements in postoperative pain and function [25, 33–35, 37]. The disparity between patients presenting with isolated patellofemoral arthritis (9–24% of patients suffering with knee arthritis) and the proportion of patients receiving PFA among all knee arthroplasty patients (<1%) highlights the underutilization of PFA for this patient cohort [2, 21–26]. Given the demographics of patients affected by isolated arthritis of the patellofemoral compartment, onlay PFA may be considered an effective alternative to TKA in a larger segment of the population.

Key Points

- PFA is underutilized in a larger population of patients suffering with isolated patellofemoral arthritis.
- Patient selection is key to success in PFA.
- Correct significant PF malalignment prior to, or during, PFA.
- Optimize patellar tracking at time of surgery.
- Results are improved with onlay-style trochlear implants compared to inlay-style implants, as a result of optimization of trochlear component rotation.

Option 2: Total Knee Arthroplasty

Dexter K. Bateman, Jared S. Preston, Bertrand W. Parcells, and Alfred J. Tria

Case Presentation

The patient is a 72-year-old female with a 10-year history of slowly increasing bilateral anterior knee pain. She has not had any previous knee surgery but has been treated with oral medications, physical therapy, hyaluronic acid injections, and bracing. Her pain is aggravated by stair climbing, elevation from a chair, and when she drives her car. She has less pain when ambulating on level surfaces and when she uses her braces.

Physical Examination

The patient walks slightly hesitantly but does not have an antalgic gait. She arrives wearing bilateral patellar cutout braces without hinges and does not use a cane or a walker. Each knee has a range of motion from 5° to 130° and has crepitus in all three compartments. However, the main area of tenderness is around the patellofemoral joint with both medial and lateral patellar facet tenderness. The tibiofemoral joint lines are tender but much less so than the patellofemoral areas. All ligaments of the knees are intact and there is a small effusion in each knee.

Radiographs

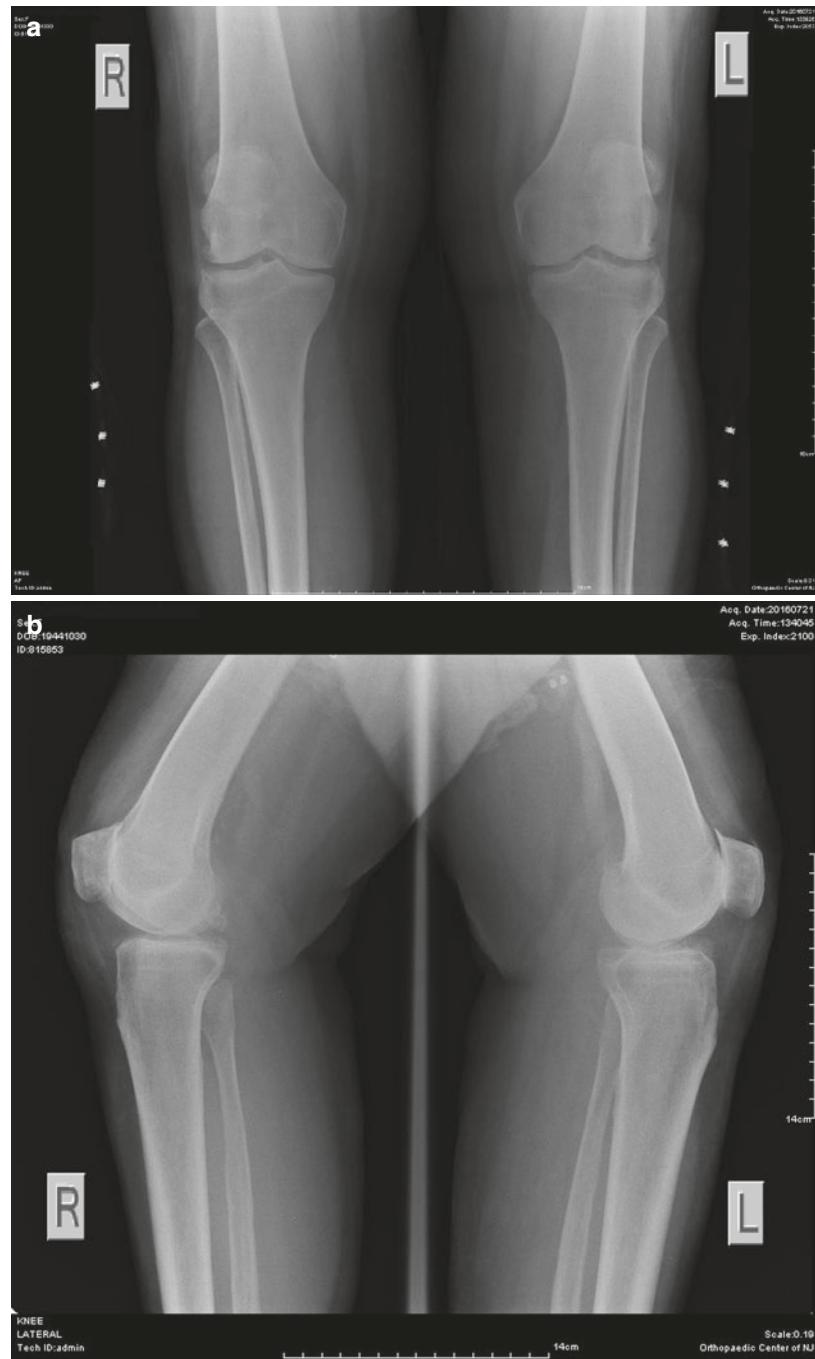
Each knee is aligned in 5° of anatomic valgus on the standing anteroposterior X-rays (Fig. 4.14a). There is no joint space remaining in the patellofemoral joint (Fig. 4.14b). The tibiofemoral joint space is preserved both medially and laterally. The patellofemoral joint has large osteophytes with deformation of the joint surfaces. The tibiofemoral joint surfaces are irregular but the joint space is preserved.

Surgical Approach

Following the administration of preoperative antibiotics, the patient was taken to the operating room and placed in supine position on the operating room table. After establishing adequate anesthesia, both lower extremities were prepared and draped in the customary sterile fashion with an arterial tourniquet in place. The surgeries were performed sequentially in an identical fashion.

A midline incision was made and minimal medial and lateral flaps elevated. A median parapatellar arthrotomy was performed. The patella was subluxed laterally. The intercondylar notch was cleared. The patellofemoral joint had advanced degenerative changes (Fig. 4.15a) with moderate changes in the tibiofemoral joints (Fig. 4.15b). The femoral anteroposterior (AP) axis was drawn. The intramedullary hole was made and evacuated, and the first guide pin was placed parallel to the AP axis and perpendicular to the epicondylar axis for proper rotation and subsequent patellar tracking. Anterior and then distal femur cuts were performed, and the femur

Fig. 4.14 Preoperative X-rays (a, b) showing complete loss of joint space in the patellofemoral joints with some space remaining in the tibiofemoral joints



was sized. A finishing block was placed and all femoral cuts were then completed.

The extramedullary tibial guide was set. Varus, valgus, flexion, extension, and depth were checked. The flexion gap technique was used,

and the cut was taken across. The flexion and extension gaps were checked with a spacer block and an extramedullary rod. The surfaces were completed to match the femoral and tibial components.

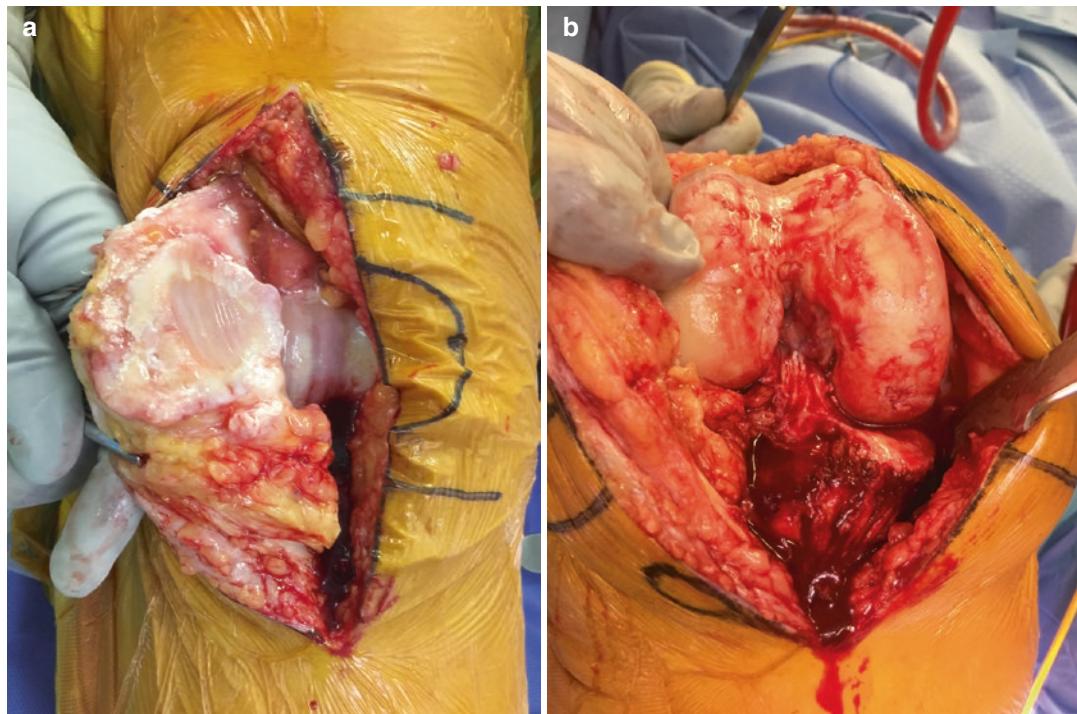


Fig. 4.15 (a) Operative picture of the patellar surface showing advanced changes with osteophyte proliferation and surface eburnation. (b) Operative picture of the tibio-

femoral joint showing eburnation with less severe degenerative changes than in the patellofemoral joint

The patella thickness was measured at 22 mm (Fig. 4.16). A reaming instrument was applied to remove enough bone to match the thickness of the all polyethylene implant with an onlay prosthesis (Fig. 4.17). Alternately, the surface can be resected using an oscillating saw (Fig. 4.18). Similar reaming instruments exist for an inlay prosthesis design (Fig. 4.19). The patellar surface was finished for the three pegs and the implant was inserted (Fig. 4.20). The final thickness was measured and planned to match the original measured thickness (Fig. 4.21).

The trial components were inserted, and the alignment, balance, range of motion, and patellar tracking were all confirmed.

After tourniquet release, the capsule was closed in the standard fashion. A final check of the patellar tracking and balance of the knee was performed and the remainder of the closure completed.

The second knee was completed in a similar fashion and both knees were dressed.

Postoperative Result

X-rays were taken in the post anesthesia care unit (Fig. 4.22). The patient underwent full weight bearing ambulation on the day of surgery and range of motion on the first postoperative day. She had an uneventful postoperative course and regained full range of motion by 6 weeks after surgery, and at 6 months after surgery, she no longer had any patellofemoral symptoms or tenderness on physical examination of the knees.

Clinical Results

Isolated patellofemoral arthritis (PFOA) is not uncommon, with 11% of men and 24% of women over 55 years old seeking treatment [43]. Patients typically complain of anterior knee pain and difficulty with stairs and arising from a chair. Walking on level ground, however, is usually relatively pain free. The severity of arthropathy may be overlooked by primary care physicians who do not routinely order sunrise or Merchant view radiographs [44]. Conservative modalities



Fig. 4.16 The caliper instrument for measuring the patellar thickness

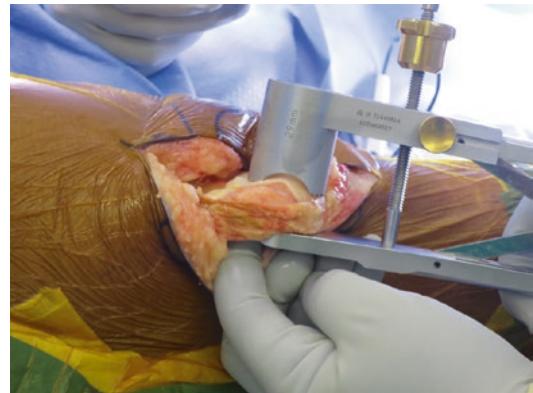


Fig. 4.19 The milling type of instrument for an inlay patellar implant



Fig. 4.17 The milling type of instrument for an onlay patellar implant



Fig. 4.20 Example of patellar implants with differing number of pegs for fixation and cementless insertion

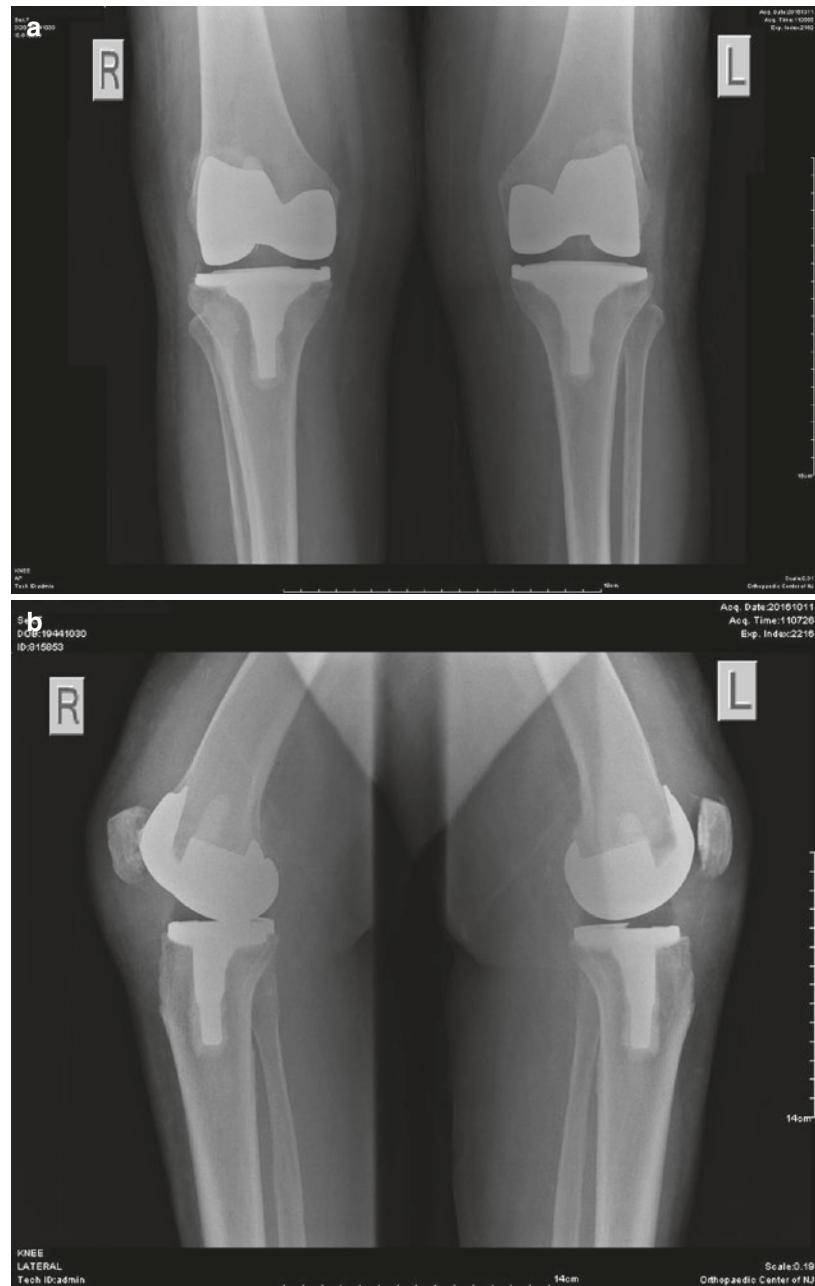


Fig. 4.18 Patellar clamp instrument for resection of the surface with an oscillating saw



Fig. 4.21 Intraoperative picture of the final thickness of the trial implant

Fig. 4.22 Postoperative X-rays (a, b) of both knees showing good alignment with resurfaced patellae



such as stretching, exercises, activity modification, bracing, anti-inflammatory medications, and injections should be tried. Nonoperative treatments, however, have not been shown to slow the progression of arthritis [10].

Operative treatment is indicated for patients who fail nonoperative methods with significant continued disability. Surgical treatment of iso-

lated PFOA, with minimal to nonexistent femorotibial disease, remains controversial. A variety of procedures including arthroscopic debridement, soft tissue releases, bony realignments (anterior advancement or anteromedialization of the tibial tubercle), patellar osteotomy or patellectomy, and microfracture are often employed as first-line treatments, especially in younger

patients [43]. Patellofemoral cartilage restoration procedures have variable results, have high failure rates, and have not been investigated in older populations [10, 45]. Moreover, isolated patellar resurfacing has not been shown to be effective and is not recommended [46].

Controversy exists regarding the best treatment for end-stage, isolated PFOA when arthroplasty is indicated. Total knee arthroplasty (TKA) has been shown to be a successful treatment option for these patients, with approximately 5% of patients undergoing TKA for isolated PFOA [10, 44, 47]. Other authors have advocated for patellofemoral arthroplasty (PFA) as a less invasive procedure that preserves surrounding bone stock in the tibiofemoral articulation [45]. However, higher complication and revision rates, mainly due to progression of tibiofemoral arthritis, have been reported with PFA [8, 48, 49].

While relatively little has been written about the use of TKA in patients with isolated PFOA, generally good to excellent results have been reported. Laskin and van Steijn [9] presented the results of 53 patients with isolated PFOA who underwent TKA (mean age, 67 years). These patients were compared to a matched cohort who received TKA for tricompartmental arthritis. At mean follow-up of 7.4 years, equivalent range of motion (knee flexion, 122° vs. 117°, $P > 0.05$), better Knee Society Scores (KSS, 96 vs. 88, $P < 0.05$), stair climbing, and ability to rise from a chair independently were seen in the isolated PFOA group. Residual anterior knee pain was present in 7% of patients in both cohorts. The authors reported 98% overall survivorship and 81% good to excellent results [9].

Parvizi and colleagues [50] reported the outcomes of 31 TKAs in 24 patients with isolated PFOA (mean age, 70 years). Twenty-one lateral releases and three proximal realignment procedures were performed at the time of index arthroplasty. Significant improvements were found in Knee Society pain and function scores (53.6–88.9 and 36.3–89.5, respectively, $P < 0.0001$). Three reoperations were performed, with one manipulation to gain motion, one revision of a loose patellar component, and one extensor mechanism realignment.

Similarly, Mont et al. [11] performed TKA in 27 patients with isolated PFOA (mean age, 73 years).

No patient had prior procedures on the knee. At mean 81-month follow-up, 28 patients had an excellent result, and 1 patient had a good result. One poor result was observed in a patient who fell and sustained a patellar tendon rupture postoperatively, requiring patellar tendon reconstruction. Average KSS improved from 50 to 93 points. All 12 knees that necessitated a lateral release had excellent outcomes. Another review of 33 cemented TKAs in 35 patients with isolated PFOA (mean age, 70 years) found improvements in KSS from 62 to 96 points at 5.2-year follow-up [44].

Thompson et al. [47] performed TKA without patellar resurfacing in 31 patients with isolated PFOA (mean age, 73 years). Patellar maltracking and malalignment were corrected with patellar contouring and lateral release as necessary. At mean follow-up of 20 months, 21 knees were considered to be pain free, 12 had occasional knee pain, and no revision surgeries were required. These authors conclude that TKA without resurfacing patella is effective option, provided the patellofemoral joint is well balanced.

Proponents of PFA urge caution in performing TKA in younger patients. However, Meding et al. [48] compared the results of TKA and PFA in 27 patients (33 TKAs) with a mean age of 52 years. At 6.2 years mean follow-up, KSS improved from 49 to 88. Only two patients reported anterior knee pain, and no complications, revisions, or reoperations were encountered. The authors found these results to be similar to age-matched controls undergoing TKA for tibiofemoral disease. Additionally, outcomes of TKA for isolated PFOA in this study were found to be superior to the historical results of PFA.

Delanois et al. [49] performed a systematic review of PFA and TKA performed for isolated PFOA. The survival rate of PFA ranged from 95 to 100% at 5 years, 85 to 90% at 7 years, 75% at 10 years, and 58% at 16 years. More than 99% of the failures were attributed to progression of osteoarthritis in the tibiofemoral compartments, and these knees were revised to TKAs. Higher survival rates were observed in patients with history of patellar fracture (posttraumatic patellofemoral arthritis), trochlear dysplasia, and normal Q angle. Loosening was reported in up to 20% of cases. In general, patients treated with TKA were

older than those who underwent PFA (70.1 vs. 60.2 years, respectively). While similar range of motion was found between both arthroplasty groups, higher functional scores and lower revision rates were seen with TKA. More recently, another systematic review of PFA found survivorship of 91.7% (5 years), 83.3% (10 years), 74.9% (15 years), and 66.6% (20 years) [8]. Overall functional outcomes were reported to be 82%, and lower revision rates were found in more recent prosthesis designs.

The thickness of the resurfaced patella in either the PFA or TKA setting remains controversial. The literature has supported decreasing the thickness to decrease the patellofemoral forces as long as the remaining bone bed is at least 12 mm in thickness and to decrease lateral subluxation [51, 52]. However, other investigators have recommended increasing the thickness to return the patella to the original thickness before there was cartilaginous wear [53, 54]. The relationship of the thickness to postoperative anterior PF pain has not yet been well established.

Key Points

- TKA provides significant pain relief and excellent functional outcomes for treating patients with isolated patellofemoral disease.
- The results of patellofemoral arthroplasty in the past have not been as good as those of TKA.
- More long-term data is needed regarding outcomes of newer patellofemoral arthroplasty designs to see if they make sense in the younger population of patients.
- The ideal final thickness of the resurfaced patella has not yet been established, but the authors favor returning the thickness to the original measured thickness at the time of the surgery.

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Fred D. Cushner, Nirav H. Amin,
Antonio G. Manocchio, and Adolph V. Lombardi Jr.

Introduction

Fred D. Cushner

In many ways, total knee arthroplasty (TKA) has become easier to perform and to obtain reproducible results. We have improved instruments, better pain control methods, and now indicate patients for surgery before the onset of severe deformities. Despite this, there still remains a subgroup of arthritic patients requiring TKA surgery that remains difficult to treat, the patient with retained hardware.

We all know the phrase, “No one looks good taking out hardware,” and this is just as true for the TKA patient. The patient with retained hardware now complicates the case and careful surgical planning is required.

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As with all cases, preoperative planning is key for the patient with retained hardware. One must first evaluate the hardware that is in place and make a determination whether or not the hardware needs to be removed. Not all hardware requires removal, and certainly by retaining the hardware, potential complications can be avoided. Limited hardware removal is often enough to allow traditional instruments to still be utilized [1].

The patient history is very important in the retained hardware patient. Often this hardware was placed in the setting of a trauma, and infection must be ruled out. One must also evaluate the patient’s soft tissue envelope around the knee. This is important in not only planning the skin incision for the TKA procedure, but one must determine if the soft tissue envelope will handle the surgical trauma of the TKA procedure. If there is any question, a plastic surgery consult should be obtained for possible tissue expanders prior to the indicated TKA. It is not only the incision but significant scarring and loss of tissue mobility are two indications to preoperative soft tissue expanders.

There have been several technological advances that allow the TKA procedure to be performed without significant hardware removal. One option is the use of patient-specific instruments (PSI). Here, a preoperative computed tomography or magnetic resonance image scan is obtained, and patient-specific cutting guides

are then created that allow the procedure to be performed without the use of an intramedullary guide. The only limit here is the proximity of the hardware to the joint, which if too close can provide scatter that makes it impossible to obtain reliable guides.

If indeed PSI is not an option, certainly computer navigation is a possibility [2, 3]. The limit here is whether the hospital is equipped with computer navigation and therefore has it available as a viable option. If computer navigation is not an option, then handheld navigation is a possibility. These devices can be used to obtain proper alignment using gyroscope technology and have been shown to be quite accurate.

Certainly, one must have the proper instruments if complete hardware removal is being considered. It is often helpful to have the original operative report to see what hardware was used so that appropriate removal tools can be made available if needed. If hardware removal will result in a significant stress riser, then stemmed components need to be available as well. With careful preoperative planning and the use of modern “smart instruments,” the indicated procedure can often be done safely and accurately without the requirement of complete hardware removal.

Option 1: Retained Hardware or Partial Removal in Complexed Total Knee Arthroplasty

Nirav Amin

Case Presentation

A 69-year-old female presents with right knee pain of 3 years with a history of a prior right hip fracture. The patient sustained a right intertrochanteric hip fracture 6 years previously and was treated with an intramedullary femoral rod. Since the hip fracture fixation, the patient has had a gradual onset of the right knee pain. She has had nonoperative treatment to date with physical therapy, bracing, injections (corticosteroids and viscosupplementation), and nonsteroidal medica-

tion with minimal relief of her right knee pain; she opted for a total knee arthroplasty (TKA).

Physical Exam

The patient has passive range of motion (ROM) of the knee from 5° to 100°. There is 5° flexion contracture, no extension lag, or instability in the anteroposterior or mediolateral direction. The hip ROM is painless from 0 to 90° of flexion, 0–30° of internal and external rotation, and 0–30° of adduction and abduction. No prior skin incisions are noted around the knee and the patient is neurovascular intact. The knee is clinically in valgus in the standing position.

Radiographs and Advanced Imaging

The X-rays show an intramedullary femoral nail with a valgus knee and severe lateral space narrowing (Fig. 5.1). The preoperative radiographs revealed a previous femoral intramedullary nail with a valgus deformity and severe lateral joint space narrowing (see Fig. 5.1). In this case, the full-length standing radiographs along with the knee X-rays were also obtained for preoperative planning in order to determine the position of the femoral rod and locking screws.

Surgical Approach

This patient underwent a standard preoperative workup to ensure the pain was related to the knee. Prior corticosteroid injections were able to completely relieve the pain, confirming the primary pain generators were from the osteoarthritis of the knee. Therefore, with no prior surgical incisions, a standard medial parapatellar arthrotomy is performed for exposure. Once the knee joint is exposed, a handheld navigation system is used to prepare the distal femur since the presence of the femoral rod prevents insertion of conventional intramedullary femoral instrumentation. The proximal tibia was resected along the mechanical axis with the I-Assist navigation system (Zimmer Biomet, Warsaw, IN, USA) followed by resection of the distal (Fig. 5.2). The handheld navigation system is secured to the distal femur over a small spike that is not impeded by the presence of the femoral nail. The distal femur is resected in the coronal and sagittal plane along the mechanical



Fig. 5.1 Preoperative X-ray of the right knee with retained hardware on the femoral side of the joint. (a) Skier view, (b) lateral view, (c) sunrise view

axis. Final preparation of the distal femur, including the rotational position of the femoral component, is performed with conventional instrumentation (Fig. 5.3). Following bone resection, the flexion and extension gaps were balanced with spacer blocks. In this case, a release of the lateral collateral ligament was necessary to balance the knee. The final components were cemented in place and the knee was closed in a routine fashion.

Postoperative Result

The patient was weight bearing as tolerated immediately postoperatively and had no special precautions related to the surgical procedure. The postoperative radiographs show the components in satisfactory position and the femoral rod still

in place (Fig. 5.4). The patient has improved her range of motion, Oxford knee scores, Knee Society scores, and knee functional scores over the course of her postoperative care with no postoperative complications.

Clinical Results

When assessing a TKA candidate with hardware present, whether on the femoral or tibial side, it is paramount for the surgeon to ensure that the inciting pain generators are coming from the knee. Based on the underlying concern for an infection or other pathologic processes, such as a nonunion and/or malunion, a complete blood workup for inflammatory markers, such as a C-reactive protein level and an erythrocyte sedimentation rate, is critical [4]. If the labs are elevated, it is criti-

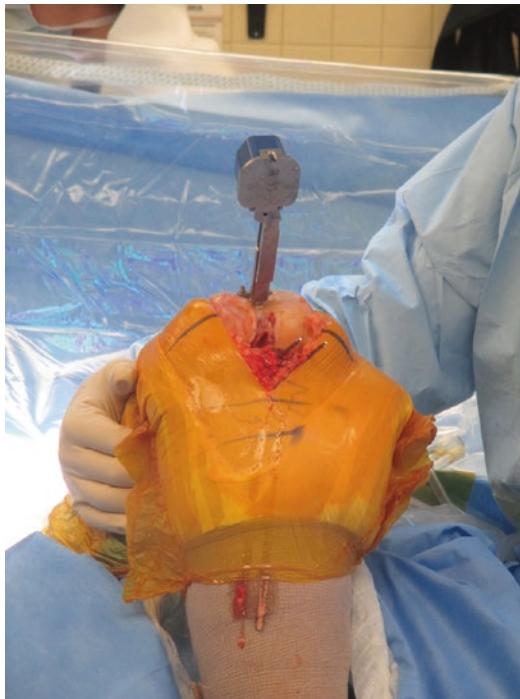


Fig. 5.2 The I-Assist is placed on the distal femur, and the two proximal tibial pins are left in place in case further bony resection is needed in the proximal tibia

cal to consider aspirating the knee prior to any planned surgical procedure. However, if the labs are within the normal range and the retained hardware continues to be a source of pain prior to the TKA, the surgeon should consider addressing the hardware prior to the TKA to obtain an optimal result. In the event the working diagnosis is unclear, an option to help differentiate the pain from the retained hardware and knee arthritis is to perform a diagnostic aspiration and placement of a therapeutic injection into the knee with a temporary analgesic [4]. Once the lower extremity is clear of an infectious etiology, preoperative planning is necessary for the removal of parts or all of the hardware, such as locking plates [6, 7]. Radiographic analysis should include necessary views of the knee, along with images of the involved bone and associated hardware. Additionally, full-length standing radiographs from the hip to the ankle are needed to assess coronal and sagittal alignment. Computed tomography may be needed to assess hardware position,

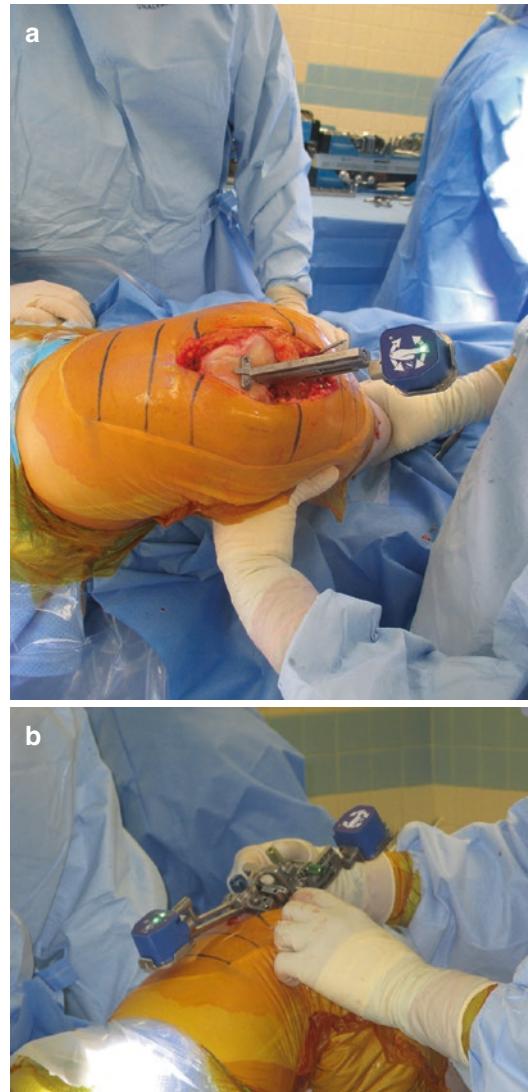


Fig. 5.3 (a) A valgus knee with retained hardware on the femoral side; (b) the distal femur cut is made with the I-Assist without an intramedullary guide

evaluation of the deformity, and/or preoperative planning for possible bone grafts, wedges, and/or stem extension past screw holes to avoid stress risers [4–7].

Additionally, it is important to analyze the approach, considering that the standard medial parapatellar arthrotomy is based on the predominately medially derived blood supply to the anterior knee [8]. However, if a standard approach is not possible, it is important



Fig. 5.4 Postoperative X-ray of the right knee with the retained hardware. (a) Anterior view, (b) lateral view, (c) tibial alignment of the total knee arthroscopy

to recognize large lateral skin flaps are at risk if incisions are far medially based [4]. If the patient has several incisions from prior surgeries, it is important to prevent wound problems, which can lead to deep prosthetic infections [9, 10]. Ideally, the most recently healed or lateral-based scar is recommended to avoid wound complications [9]. If there is a concern with the soft tissue envelope, it may be critical to involve plastic surgery [11].

Based on the paucity of literature involving partial removal or retained hardware in the setting of TKA, several case reports and/or case series have demonstrated methods to optimize outcomes. The literature includes two case reports of retained plate-screw construct with minimally invasive screw removal and plate retention in the setting of tibial hardware [4]. Three studies have documented the use of navigation with retained femoral hardware in the setting of a TKA [12–14].

The navigation assists with the distal femoral and proximal tibial cuts and allows for proper rotation. The soft tissue balancing is assessed using the trial components through a cycle of flexion to extension [5].

In a conventional TKA, traditional instrumentation includes an intramedullary guide, which is used to improve the alignment of the components [12]. Several studies have demonstrated the importance of restoration of the mechanical axis and component alignment with proper soft tissue and ligament balancing for a successful outcome and prolonged longevity of the prosthesis [13–15]. Failure to address the mechanical axis of the entire lower limb with changed anatomic landmarks based on intra- or extra-articular deformity may lead to patella maltracking, early loosening, and higher rates of polyethylene wear [5, 14–16]. More recently, computer-assisted navigation has provided an alternative option for accurate alignment in complexed situations, such as deformity and retained hardware where an intramedullary guide cannot be used [17–19]. Additionally, using navigation in the absence of intramedullary guides may lead to a decrease risk of systemic emboli and potential fat emboli [5, 15, 20–23]. Although some have suggested a TKA with removal of hardware or in a staged manner, the results have been inferior to a routine TKA [24]. In patients with retained tibial implants, surgical scars must be considered to avoid converging superficial incisions and/or larger subcutaneous skin flaps leading to wound complications and potential infections [25]. Another factor is that in older patients, the concern regarding restrictions on weight-bearing status and postoperative rehab may delay the overall recovery, leading to poorer results; therefore, if possible, a single-staged conversion may be optimal [26, 27].

With the assistance of navigation systems, the surgeon is able to address the altered surgical field with retained or removed hardware and/or deformity with improved clinical care. Several studies have reported the accuracy of the bony cuts and the restoration of the mechanical axis with a computer-assisted navigation system [28–30]. The navigation-assisted TKA provides accurate bone cuts, rotational alignment of the

components, and soft tissue balancing without the need of intramedullary guides [5, 19, 20, 23, 30–33]. Therefore, it is critical for surgeons to evaluate the location of the hardware, accurate source of the pain generators, prior surgical incisions, and restoring mechanical and rotational alignment for an optimal outcome.

Key Points

- Rule out an infection and hardware complications prior to assess the patient for a TKA.
- Partial removal of hardware is a reasonable option if the retained hardware does not interfere with bone preparation or position of the components.
- Computer navigation may be helpful to prepare the femur or tibia when conventional instrumentation cannot be used because of the retained hardware.
- Be careful of the skin incisions to ensure viability of the healing potential postoperatively.

Option 2: Removal of All Hardware

Antonio G. Manocchio and Adolph V. Lombardi Jr

Case Presentation

History

A 64-year-old male patient was initially seen and evaluated in our office 10 months following open reduction internal fixation of a left lateral tibial plateau split-depressed fracture. The fracture occurred after he fell from a ladder, approximately 4 ft. He was admitted to the hospital following the injury and fixed shortly after by an outside surgeon. Patient was seen in our office for a second opinion and evaluated for continued knee pain. He was subsequently diagnosed with osteoarthritis of the left knee with retained hardware. Incidence of osteoarthritis after previous tibial plateau fracture ranges from 22 to 44% [34, 35]. This was evident in our case. Fixation of his previous fracture was done through a lateral curvilinear approach of the lateral and proximal

tibia. Review of the previous operative report showed that the approach was taken down to the fascia over the anterior tibialis. The fascia was split in line with the incision. The muscle was then dissected off the bone. Next a sub-meniscal arthrotomy was done showing an intact meniscus and bloody hemarthrosis. The surgeon also utilized the vertical split to look inside the knee joint. A more central depression was elevated and back grafted with 3 mL of Norian betacalcium phosphate (DePuy Synthes Trauma, Zuchwil, Switzerland) as a bone void filler. The fragments were then reduced using a large periar-ticular bone clamp through a small medial-based incision to compress the plateau together. This was provisionally fixed utilizing k-wires. Next a 6-hole Synthes Proximal Locking Tibia Plate (DePuy Synthes Trauma, Zuchwil, Switzerland) was utilized to maintain fracture reduction. He was placed in a knee immobilizer postoperatively.

Postoperatively the patient had significant knee stiffness and subsequently returned to the operating room approximately 3 months after initial fixation for manipulation under anesthesia with arthroscopic lysis of adhesions and partial lateral meniscectomy. A small 2 mm depression was noted in the lateral tibial plateau. Range of motion (ROM) following manipulation was 5–110°. He was then started in physical therapy in which he struggled and lost range of motion, lacking 15° of full extension with maximum flexion of 100°. This was later complicated by a deep venous thrombosis for which he was started on rivaroxaban.

Patient was generally healthy with a previous medical history of hypertension and deep venous thrombosis following his recent fracture fixation. He weighs 205 lb and is 73 in. tall yielding a body mass index of 27 kg/m². Social history included previous history of tobacco smoking with no alcohol or drug abuse. Family history was significant for hypertension. Remaining review of systems was noncontributory.

Given the aforementioned case, there are multiple challenges and thought processes that should be considered. Given the patient's history of fracture and retained hardware with continued pain, ruling out infection is top of the prior-

ity list, especially prior to proceeding with total joint arthroplasty. Challenges also exist with the approach to total knee arthroplasty (TKA), making sure to preserve adequate perfusion of the soft tissues while getting adequate exposure to proceed with total joint replacement. Next, one needs to consider the surgical plan, and to evaluate fracture healing to make sure the bone is adequate to accept total joint implants, and to plan accordingly based on the patient's retained hardware. What hardware can remain, what should be removed, and what is a secondary option if something is encountered intraoperatively that is unexpected such as an unhealed fracture or incompetent lateral plateau?

Physical Examination

Upon our initial examination, the patient had a healed lateral proximal tibia J-type incision with mild erythema. He had significant knee pain globally through passive and active range of motion with a majority of his pain on the lateral side. His ROM was lacking 10° full extension with a maximal flexion of 75°. He had severe crepitus on exam with extreme pain and tenderness. He was tender to touch over previous incision. He was not able to continue with previous everyday activities secondary to pain which he rated 2/10 while at rest and 7/10 with walking. He required crutches for mobilization. Multiple views were taken during office examination and showed patient to have retained proximal lateral tibial locking plate with healed fracture. There was significant joint step-off appreciated on the lateral tibial plateau. The proximal tibia was widened, and the patient has significant lateral joint space narrowing consisting of bone-on-bone arthritis with mild medial compartment disease, as well as patellofemoral osteoarthritis which was significant on the lateral facet. Also noted were large joint effusion and what appeared to be calcification of the medial soft tissues likely representing the medial collateral ligament.

Based on the patient's physical exam, radiographs of knee and retained hardware, multiple issues should be addressed in order to treat the patient effectively to give him the best result possible. First the issues of infection need to be

addressed. Given the patient's erythema and continued pain and effusions, basic laboratory values need to be obtained in order to rule out infection, that of both the knee joint itself and the retained hardware. Ruling out infection of the joint itself can be obtained through simple aspiration of the knee effusion and processing in labs with cell counts and cultures. Despite a negative knee aspiration workup, this does not entirely rule out infection that is extra-articular in nature. The retained hardware itself must also be evaluated for infection given that the plan is to proceed with total knee arthroplasty. Besides the technical challenges, these screws and plate have an association with an increased incidence of infection with secondary total knee arthroplasty [36]. Ruling out infection cannot easily be achieved in the office unless a large fluid collection or draining sinus is present. Based on the patient's presentation, the decision was made to do a staged reconstruction consisting of removal of retained hardware with intraoperative fluid culture and tissue culture. Moussa et al. demonstrated that in 53% of cases with fixation devices without clinical signs of infection, bacterial contamination was proven in wound swabs [37]. Although the study by Moussa did have some major limitations in sample size, this high frequency is troubling and should give the surgeon some serious thought about doing a staged procedure. Previous internal fixation with residual orthopedic fixation devices had also been identified as a major risk factor for deep infection in knee arthroplasty by Suzuki et al. In their retrospective study of 2022 total knee arthroplasties, a significantly increased incidence of infection (25%) among patients with internal fixation material in situ was observed [36]. In contrast Klatte et al. did not find an increase in periprosthetic joint infection in their study of 115 patients followed for 5.4 years [38]. Based on the literature and the redness of the patient's previous hardware, we felt it appropriate to remove the hardware in a staged manner with plans for intraoperative cultures.

Results of removal of hardware and cultures can dictate future proceedings and whether it is safe to proceed with total joint replacement without a lingering infection. Reconstruction in

light of retained hardware needs to be approached with caution as implanting a total joint around previous infected hardware can be a disaster for the patient and surgeon. The patient subsequently had hardware removed with a universal screw removal set. Intraoperative cultures were obtained which yielded no signs of growth at 14 days out.

In many cases with retained hardware about the knee, selective removal of implants can be safely done at the time of surgery. Given our patient's physical exam and possible infection, we chose to do a staged procedure with removal of all hardware. We also took into consideration future placement of the tibial baseplate which would be hindered by the proximal locking screws. If the tibial plateau was deemed incompetent to support a standard tibial baseplate, a stemmed prosthesis would need to be utilized, and based on measurements the distal screws could hinder positioning of the stemmed prosthesis. For these reasons the hardware was removed in its entirety. When multiple incisions are needed to accomplish removal of hardware and placement of a total joint prosthesis, a staged approach should be used to allow tissue healing prior to total joint replacement. Previous operative reports can help clarify specific implants, which can make screw removal much easier. It may be beneficial to have a universal screw removal set and high speed burr available in case of unanticipated failure of hardware.

Radiographs and advanced imaging prior to removal of hardware (Figs. 5.5 and 5.6).

Surgical Approach

At the time of total joint replacement, patient had a fully healed lateral-based incision from the previous hardware removal. An adductor canal and sciatic nerve block were utilized for the procedure. Patient was placed in standard supine position with tourniquet high on the left thigh. Preoperative antibiotics were given, the left lower extremity was exsanguinated, and the tourniquet was elevated. Intraoperative arc of motion was poor with ROM from 20 to 40°. A midline incision was performed followed by medial parapatellar arthrotomy. The patient had

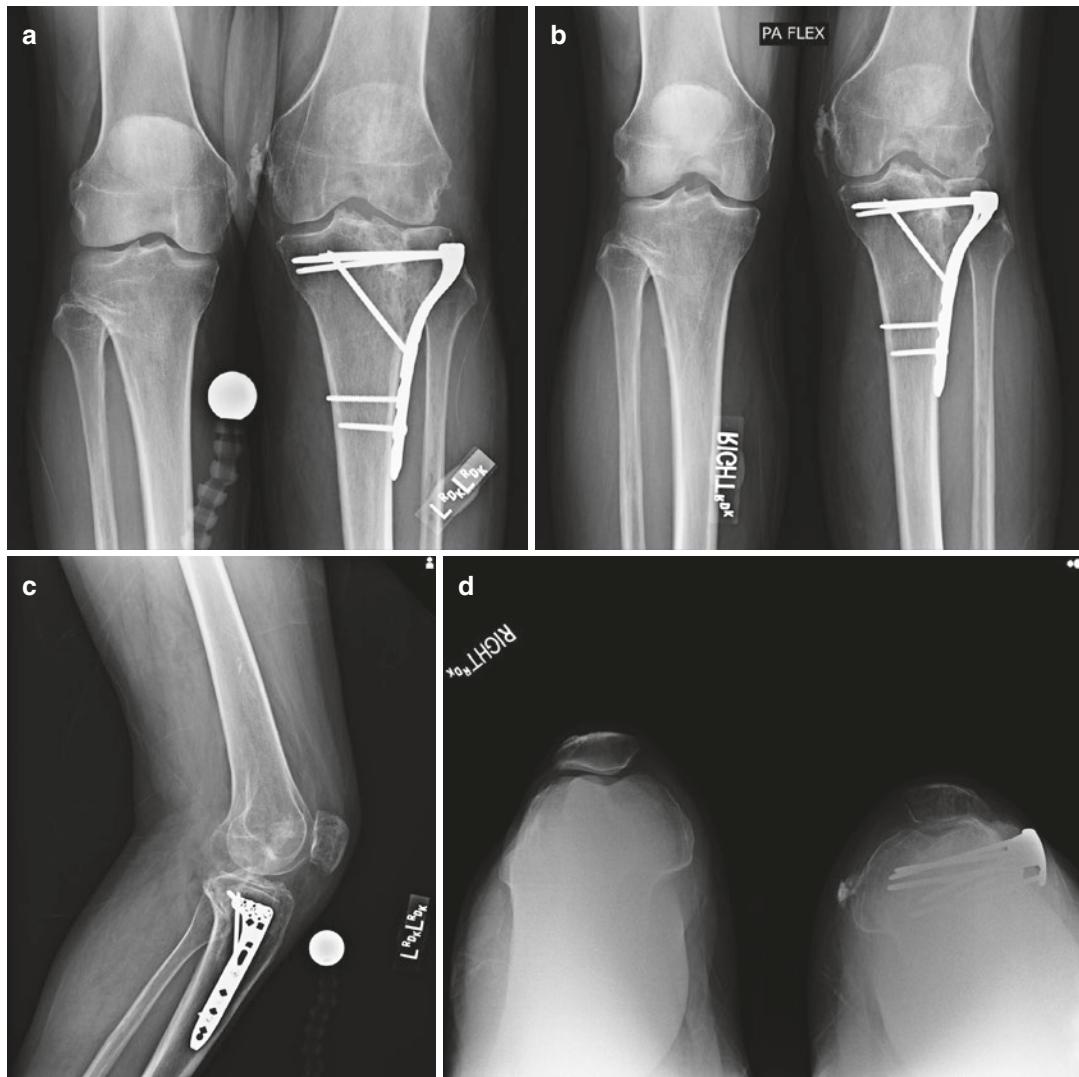


Fig. 5.5 Radiographs prior to removal of hardware: (a) standing anteroposterior view of both knees, (b) posterior to anterior view of both knees in 40° of flexion, (c) lateral view of the left knee, (d) merchant patellar view of both knees

a fair amount of scar tissues in the medial and lateral retinacular folds and a fair amount of scar tissue around the patellar tendon. The scar tissue was excised in its entirety. Once this was completed, we were able to flex the knee and performed distal femoral resection utilizing an intramedullary guide rod in 5° valgus. Next the femur was sized to 67.5 mm and cut using a 4-in-1 cutting block. We utilized Vanguard Complete total knee arthroplasty system (Zimmer Biomet, Warsaw, IN, USA). Next we moved to tibia, which was cut 90° to tibial axis

with slight posterior slope utilizing an extramedullary jig. The posterior recesses were cleaned out. The posterior cruciate ligament was scarred and carefully released. The tibia was punched for an I-beam stem and sized to a 75 mm baseplate. The tibia was found to be competent with no signs of plateau failure. We felt that surgery could be accomplished with standard primary implants. Trial implants were then placed and found to be balanced with a 13 mm polyethylene insert after pie crusting of the popliteus for lateral tightness in flexion. We next everted the



Fig. 5.6 Radiographs postoperative to removal of hardware: (a) standing anteroposterior view of both knees, (b) posterior to anterior view of both knees in 40° of flexion.

(c) lateral view of the left knee, **(d)** merchant patellar view of both knees

patella, resected using freehand technique, and sized to a 31 mm. Next all trial implants were removed, the knee was thoroughly irrigated, and implants were cemented utilizing Cobalt G cement (DJO Global, Vista, CA, USA). The knee was placed into extension allowing cement to harden. The tourniquet was released prior to final assessment of patellar tracking and wound closure. Next powdered topical vancomycin was added to the wound, and capsular closure was

carried out with interrupted Vicryl (Ethicon, Inc., Somerville, NJ, USA) and Quill (Surgical Specialties Corporation, Wyomissing, PA, USA), followed by subcutaneous Quill and Dermabond (Ethicon) skin adhesive. Patient had ROM from 0 to 135° following the procedure. He was given appropriate pain control and DVT prophylaxis which include rivaroxaban and leg pumps. He was started into physical therapy

three times per week to improve ROM until follow-up in 6 weeks.

Radiographs postoperative to total knee arthroplasty (Fig. 5.7).

Postoperative Result

The patient was seen in the office at 6 weeks. Incision was well healed. Patient did complain of increasing stiffness and had ROM from full extension to 80° of flexion. Decision was made for increased intense physical therapy, and patient would return in 2 weeks for further evaluation. He was also given a JAS splint (Joint Active Systems, IL, USA) to help with extension. He subsequently followed up and continued to make

no progress with physical therapy. Decision was made to return to surgery for manipulation under anesthesia. Intraoperatively we were able to gain 25° flexion with a final ROM of 0–105°. He since has maintained ROM of 0–95°.

Clinical Results

The goals of arthroplasty for post-traumatic arthritis with retained hardware are similar to that for a non-injured native arthritic knee. Our goal was to restore the mechanical axis and create a stable pain-free joint. It has been well documented that following arthroplasty of a previously fractured tibial plateau, complications are as high as 26% [39]. Of those complications stiff-

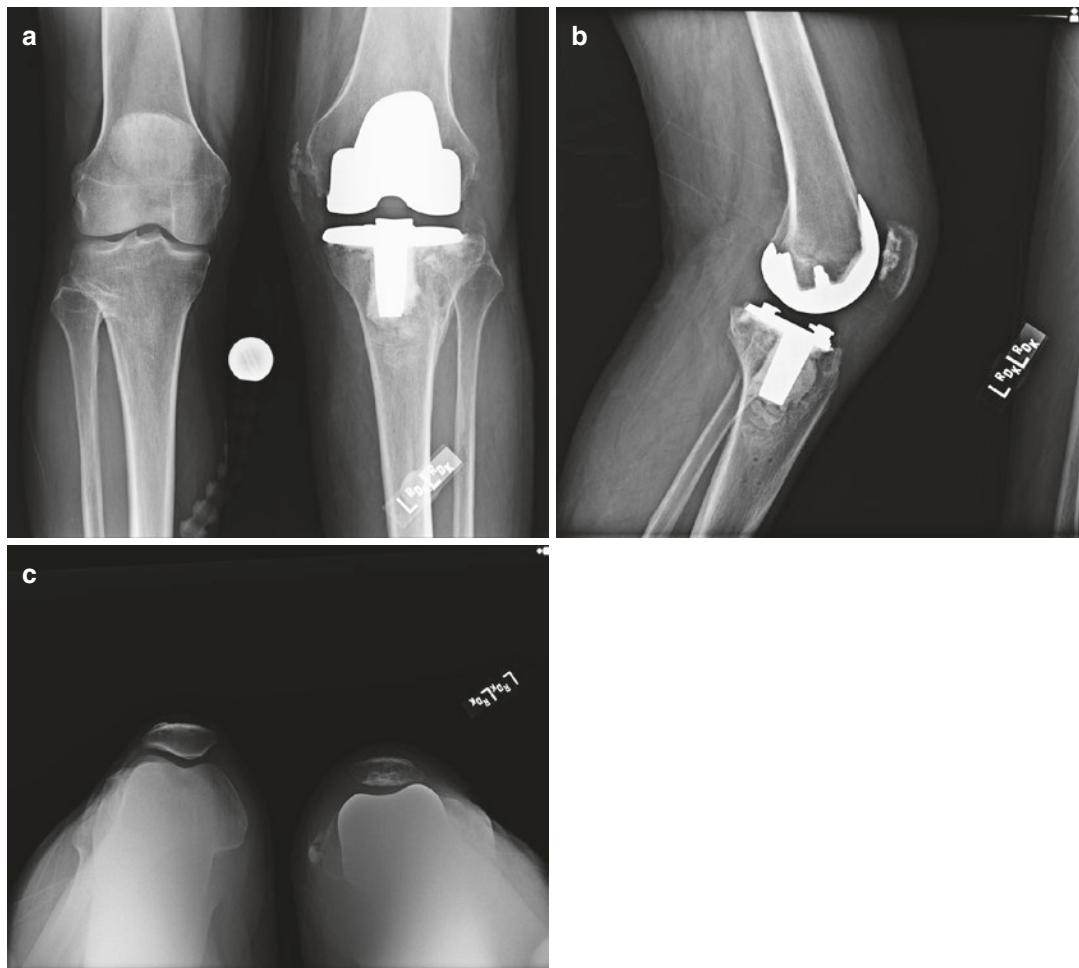


Fig. 5.7 Radiographs postoperative to total knee arthroplasty: (a) standing anteroposterior view of both knees, (b) lateral view of the left knee, (c) merchant patellar view of both knees

ness, wound dehiscence, deep infection, and patellar tendon rupture were among the highest. Lonner et al. have reported a complication rate as high as 57% following total knee arthroplasty for post-traumatic knees [40].

Improvement following total joint arthroplasty for post-traumatic arthritis does not appear to be as good versus for the osteoarthritic patient. Weiss et al. reported excellent to good results in 77% of their patients with previous tibial plateau fracture, while fair and poor results each accounted for 11% [39]. In contrast Lizaur-Utrilla et al., in their prospective matched control study of 29 patients with post-traumatic arthritis of the tibial plateau undergoing TKA versus 58 routine TKA, noted that outcome scores between groups were not significantly different at 6.7-year follow-up [41].

The post-traumatic osteoarthritic knee with retained hardware can be difficult to deal with, but total knee arthroplasty is a viable option to improve the patient's pain and overall function. Depending on each individual patient's situation, a competent surgeon should not take the procedure or reconstruction lightly. Although the procedure may be technically demanding, appropriate planning can minimize issues that may arise in the operating room. The surgeon should also discuss with patients the increased complication and reoperation rates, as well as ensuring patients are realistic about postoperative outcomes.

Key Points

- Evaluation of fracture healing. Pain could be from failure of fracture healing.
- Be sure to rule out infection; this can be devastating if missed and arthroplasty is done.
- Create a surgical plan and backup plan with appropriate implants available.
- Staged procedures for suspected infections or difficult wound management.
- Appropriate exposure as post-traumatic knees usually have increased scar tissue.
- Disclose increased risk of postoperative complications and increased risk of reoperation. Discuss realistic postoperative outcomes prior to surgery.

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The Super Obese Knee

Alfred J. Tria, Paraskevi (Vivian) Papas,
Fred D. Cushner, Jason Wong,
and Jeffrey A. Geller

Introduction

Alfred J. Tria

Obesity has become a major problem in the treatment of knee arthritis [1]. These patients have multiple comorbidities that contribute to the perioperative increase in complications, along with difficulty with the surgical exposure compared to the normal size knee joint [2]. The preoperative evaluation must be thorough to reveal any and all associated medical comorbidities so that the patient is clinically optimized prior to surgery. While preoperative weight loss is certainly desirable, extreme measures immediately before the

surgery may compromise the patient's ability to heal and avoid infection with a lowered serum albumin and a negative caloric state [3, 4]. The surgical procedure demands adequate extensile exposure, and the choice of the implant may need to be modified to protect the prosthetic device from subsequent loosening [5].

The case presentations in this section review the approach to the super obese and emphasize the pitfalls to avoid during the operation.

Option 1: Surgical Technique with Specific Instrumentation

Vivian Papas and Fred J. Cushner

Case Presentation

History

Our patient is a 37-year-old male who presented with bilateral knee pain, worsening over a span of 2 years. He was experiencing difficulty ambulating and stated the right knee was more painful than the left. The patient complained of stiffness, locking, and numbness and had failed non-operative treatment. The pain was interfering with his daily work routine as a pipeline worker with pain described as a ten out of ten. The patient had a history of tibial osteotomies secondary to tibia vara as a child. He was a "big-boned" individual with a body mass index (BMI) of 47.25 (5 ft, 8 in., and 320 lb).

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Physical Examination

The patient has an antalgic gait on both sides. His range of motion (ROM) is 0–120° and clinically has nearly 40° of varus deformity. The patient has mild instability with varus stressing of the knee. His osteotomy incisions are well healed and do not appear that they will compromise the planned total knee arthroplasty (TKA) incision.

Radiographs and Advanced Imaging

Standard X-rays show medial degenerative joint disease with significant varus deformity (Figs. 6.1 and 6.2). The standing X-ray obtained for the patient-specific instrumentation (PSI) guides showed a severe deformity with varus deformity and tibial deformities secondary to previous osteotomies. The magnetic resonance image (MRI) obtained at the time of PSI preparation was helpful for creating the guides, but is not used for clinical knee evaluation.

Surgical Approach

This case is complex for numerous reasons. Since this is a chapter titled “The Super Obese Knee,” the weight is an obvious reason of concern for this patient. Other risk factors include the patient’s age. He has failed non-operative treatment and is only 37 years of age. Of course the medical history of this patient is also important. He had tibia vara as a child and his history of previous osteotomies needs to be taken into consideration. His occupation also needs to be considered. He does not work at a desk job and needs his mobility to remain employed. It is becoming more common at many institutions, to have a maximum BMI above a threshold value where the total knee arthroplasty (TKA) will not be performed. While limiting patient access is not ideal, the fear of complications has led to this practice.

The patient was given the option of a total knee arthroplasty based on his significant symptoms and failure of non-operative treatment. The patient stated he wanted to proceed with surgery.



Fig. 6.1 Anteroposterior and lateral radiographs of the right knee showing severe genu varus with complete loss of the medial compartment of the right knee and residual tibia deformity



Fig. 6.2 Anteroposterior and lateral radiographs of the left knee showing severe genu varus with complete loss of the medial compartment of the left knee and residual tibia deformity

The surgical risks were discussed at length, and he was counseled on the potential complications of his right total knee arthroplasty and the possible influence of his high BMI. Due to his large BMI and the fact that he has residual deformity from his previous osteotomies, it was elected to use patient-specific instruments to perform this procedure. A preoperative magnetic resonance image (MRI) and long-standing X-rays are obtained and used to fashion these patient-specific instruments. A preoperative plan was then created and alignment checked presurgery to correct for tibial deformities (Figs. 6.3 and 6.4). While the use of PSI has shown good efficacy for preoperative deformities, it may also help to improve accuracy in a young patient with greater prosthesis longevity needs.

Surgical Technique

Surgical technique started with preoperative planning for this patient. Due to the severity of varus deformity, various constraint options

should be available. Given the patient's age, it is best to limit the degree of prosthetic constraint to allow for greater longevity; however, if a more constrained option is selected, the implant system for the surgery should allow for this choice.

With PSI guides, a standard incision is utilized (Fig. 6.5). While often the senior author of this paper utilizes a mid-vastus arthrotomy, this would not be considered in this case. There is no role for the minimally invasive surgical incision. The incision must be large enough to achieve adequate visualization. For large extremities, the medial arthrotomy is favored, not only because of its exposure, but its ability to be extended. A quadriceps snip may also be included at the proximal extent of the arthrotomy with this approach.

For standard TKAs, the senior author favors a tibial first surgical flow. For nonobese knees, this allows for greater visualization if a smaller incision is attempted. For the PSI knees, a femur first approach is utilized. The femoral PSI, due to the numerous femoral contours, has a secure fit.

Fig. 6.3 Working plan for patient-specific instrumentation (Visionaire, Smith & Nephew, Memphis, TN, USA)

VISIONAIRE®	
Patient Matched Instrumentation	
 A technology from smith&nephew	
TKA CUTTING BLOCK SURGICAL ALIGNMENT PLAN	
PATIENT	
ANATOMY	RIGHT
SURGEON	DR. CUSHNER - LENOX HILL
IMPLANT	LEGION PRIMARY
SURGERY DATE	01/15/13
X-RAY MEASUREMENTS	
PRE-OP FULL LEG DEFORMITY	35.6 VARUS°
MECHANICAL AXIS FEMUR VALGUS ANGLE	7.0°
TIBIA DEFORMITY	1.9°
FEMUR PART NO.	
VARUS/VALGUS ALIGNMENT	5 DEGREES
MECHANICAL VARUS PREFERENCE	.0°
EXTERNAL ROTATION	A/P AXIS
FLEXION	4°
DISTAL FEMORAL RESECTION	RESECT TO TROCHLEAR SULCUS
SIZE	7
DISTAL MEDIAL RESECTION	4.5 mm
DISTAL LATERAL RESECTION	11.5 mm
DISTAL SULCUS RESECTION	.0 mm
POSTERIOR MEDIAL RESECTION	13.5 mm
POSTERIOR LATERAL RESECTION	11.5 mm
TIBIA PART NO.	
VARUS/VALGUS ALIGNMENT	MECHANICAL AXIS OFF PATIENT X-RAY
EXTERNAL ROTATION	ALIGN W/ MEDIAL 1/3 TIB TUBERCLE
POSTERIOR SLOPE	5 DEGREE
PLANNED INSERT THICKNESS	STANDARD RESECTION (9 MM INSERT THICKNESS)
SIZE	7
PROXIMAL MEDIAL RESECTION	.0 mm
PROXIMAL LATERAL RESECTION	11.0 mm
RESECTION TO EMINENCE	13.5 mm
NOTES: DID NOT RESECT TO TROCHLEAR SULCUS SINCE THIS WOULD RESULT IN A DISTAL RESECTION GREATER THAN 11.5MM. DUE TO A LARGE AMOUNT OF MEDIAL WEAR, RESECTED +2MM FROM PROXIMAL TIBIA. MAY WANT TO TAKE ADDITIONAL RESECTION TO FULLY RESECT TO THE MEDIAL PLATEAU. AT CURRENT RESECTION, THERE IS A GAP UNDER THE MEDIAL SIDE OF TIBIA IMPLANT THAT MAY REQUIRE A WEDGE. PLEASE NOTE THAT THE MEDIAL PADDLE OF THE TIBIA BLOCK DOES NOT FULLY CONTACT BONE. DO NOT FORCE BLOCK DOWN WHEN FITTING.	

This guide is easily positioned and position confirmed (Fig. 6.6). The tibia is a bit harder to position correctly. Therefore, once the femoral cuts are made, visualization is improved and correct PSI tibia position can be achieved (Fig. 6.7).

While using the PSI guides, one should never assume that all cuts will be correct. At each

step, the accuracy of the cuts can be visually confirmed (Figs. 6.8 and 6.9). For example, by observing the anterior femoral cut, the appearance of a piano or old boot sign confirms proper external rotation. Through the utilization of spacer blocks, accuracy of all the cuts can be confirmed or adjusted as needed (Figs. 6.10 and

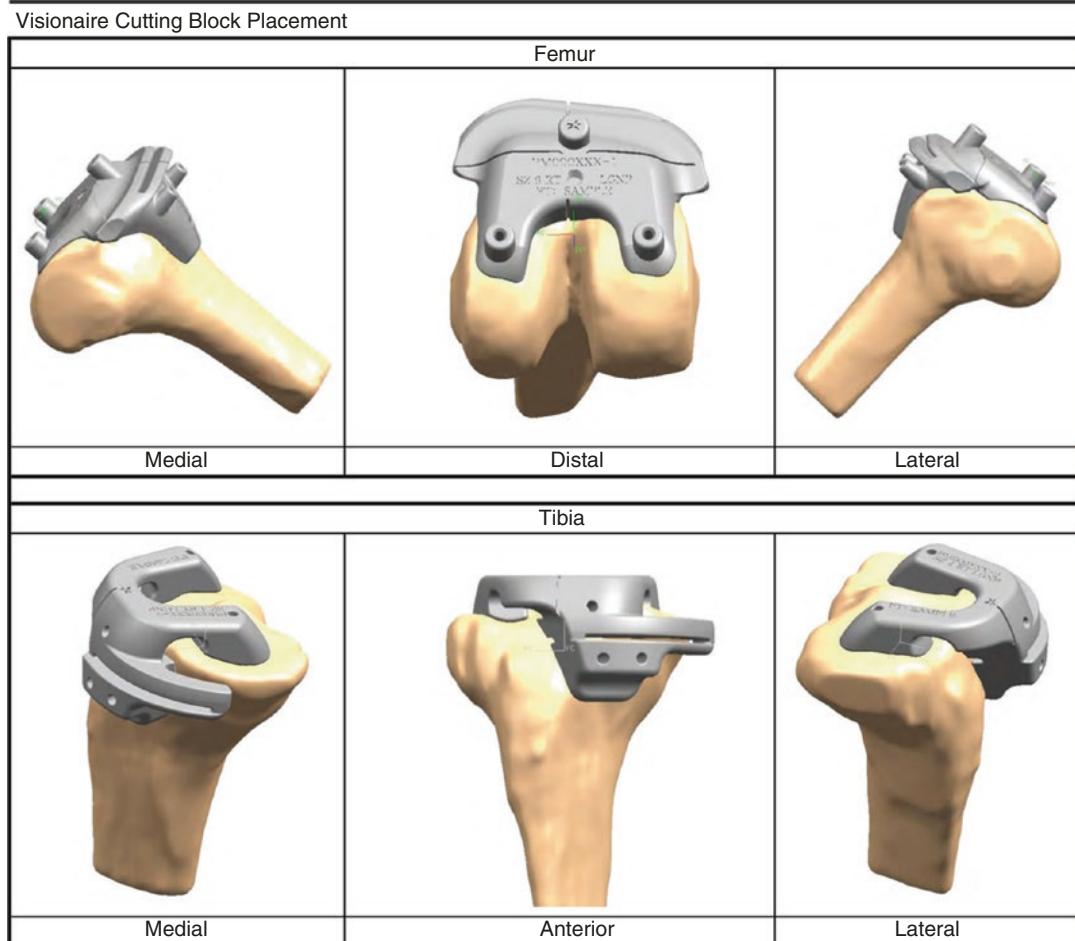


Fig. 6.4 Working plan showing patient-specific instrumentation guides in place (Copyright Visionaire, Smith & Nephew, Memphis TN, USA, used with permission)

6.11). The balancing should be closely monitored because the weight of the limb may make distraction difficult and lead to an insert that is much too small.

Proper cementation is critical and is even more important for the obese patient. The boney surfaces need to be irrigated and well prepared. There should be a complete cement mantle around the entire tibia, and cement should be placed on the posterior femoral runner to assure firm fixation in all areas of the knee.

In large extremities, it is best to be conservative with the depth of the tibial cut. After surgery the soft tissue envelop about the knee often stretches and can lead to instability that requires

reoperation and polyethylene insert exchange to a thicker size.

Postoperative Results

Postoperatively the patient did well. X-rays showed proper alignment of the components (Fig. 6.12), and clinically, the limb was well aligned. Zero to 120° of ROM was achieved and no complications noted. The patient was able to return to his job as a pipeline worker.

Clinical Results

In order for surgeons to best discuss options with their patients, they must understand the potential of increasing complexity throughout the care and



Fig. 6.5 Right limb at time of the indicated total knee arthroplasty with varus deformity and obese extremity



Fig. 6.7 Patient-specific instrumentation in place



Fig. 6.6 Femoral patient-specific instrumentation in place. A comparison can be seen to preoperative diagram



Fig. 6.8 4-in-1 guide in place matching preoperative plan

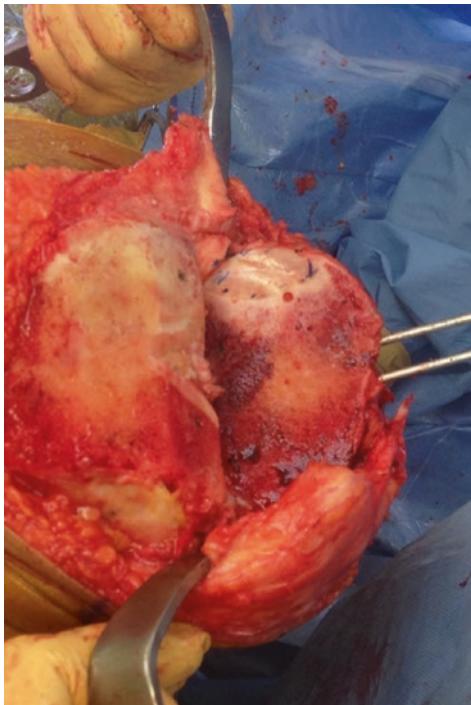


Fig. 6.9 Tibial cut completed with pins in place for resection if needed. Medial defect as noted on initial plan

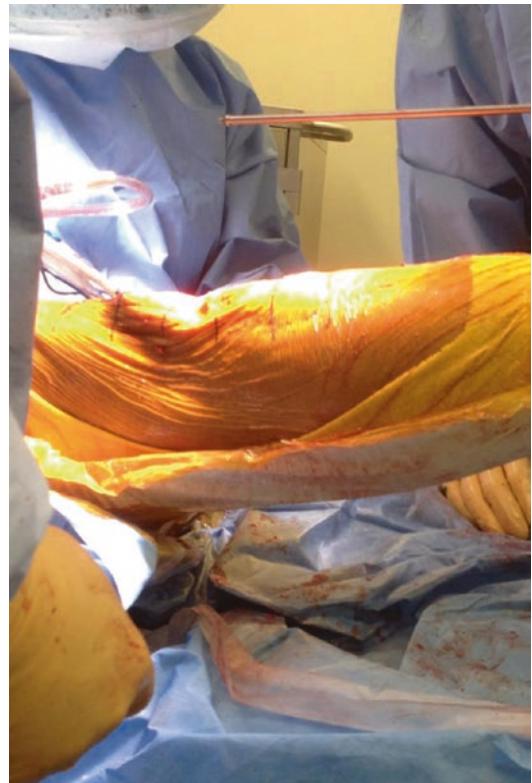


Fig. 6.11 Confirmation of alignment in extension

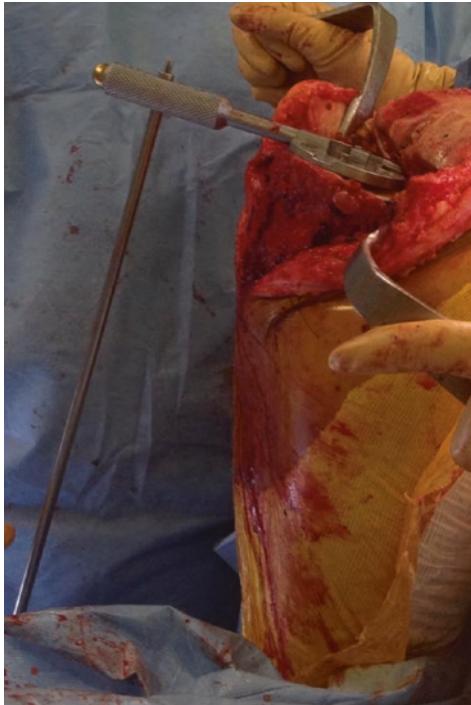


Fig. 6.10 Confirmation of tibial cut and alignment check

cases of patients with higher BMIs [6]. With obesity being so strongly linked to degenerative joint disease, it is understandable that as the obese population within the developed world continues to grow, so does the number of total knee arthroplasty procedures being performed annually [7]. Researchers have noted that obesity rates are increasing most rapidly among middle-aged Americans, which may account for the decreasing average age of the total knee arthroplasty patient [8].

In 2012 researchers Kerkhoffs et al. at the University of Amsterdam published an article describing the results of a large systematic literature review including 20 previously completed studies, concluding that obesity did indeed have a negative influence on total knee arthroplasty outcomes. Several other studies have reported similar results, indicating higher BMIs of over 40 were predictors of postoperative complications and inferior knee society scores in the morbidly



Fig. 6.12 Postoperative X-rays showing good component position and alignment

obese [9, 10]. Kerkhoffs et al. searched through peer-reviewed articles from 1970 to 2009 that would help answer their question on whether the outcome of a primary total knee arthroplasty was impacted by a patient's BMI. Defining obesity as a BMI of over 30, the results of the study reported that in the obese patient population infection was significantly more common at an odds ratio of 1.90. The study showed that superficial infection and deep infection were also more prevalent in patients defined as obese with odds ratios of 2.17 and 2.38 consecutively. Revision rates were reported to be more frequent in obese patients (odds ratio of 1.30). This was in agreement with another study that reported the morbidly obese group had a significantly higher revision rate [11]. However, upon further analysis researchers reported that when considering the reason behind the revision (infection vs. aseptic loosening), revision rates were not significantly different

between the obese and nonobese patients. The complication rate of DVT or pulmonary embolism was also reported to not be significantly different between the two populations. The systematic literature review done also looked at infection rates broken up into short- and long-term categories, for further clarification. When looking at short-term outcomes, data displayed an infection rate two times greater among the obese patients than the nonobese. Revision rates in patients for over 5 years post-op were found to be twice as high in the obese patients long term (odds ratio 1.79) within a 95% confidence interval. This fairly recent systematic review concluded that when looking at both a long-term and short-term interval of patients post-op, those with BMIs over 30 had higher revision rates and higher infection rates [12].

As obesity rates within TKA patients continue to increase, more physicians and researchers have

been interested in subcategorizing the obese population into categories such as morbidly obese or in the case of Schwarzkopf et al. “super obese.” Patients are classified as “super obese” if their body mass index exceeds 45. The researchers performed a retrospective chart review in which they studied the charts of patients who had a total joint arthroplasty procedure performed between 1996 and 2004 at one major city hospital. Patients with a BMI of 45 and higher were identified and compared with a group of patients that underwent surgery during the same time period with BMI’s within a normal range of 20–25. Complications observed throughout the inpatient period included deep vein thrombosis (DVT), pulmonary embolism, revision, intraoperative complications, pneumonia, ICU transfer, and urinary tract infections. Postoperative complications observed included pulmonary embolisms, myocardial infarctions, surgical site infections, revisions, dislocation, DVT, and fractures. When analyzing inpatient complications between the different BMI groups, the researchers reported the patients categorized as super obese had a higher proportion of complications in comparison to patients with a BMI of 20–25 (*p*-value 0.0144). Each 5-U increase over a BMI of 45 was associated with a statistically significant rise in a postoperative or inpatient complication risk and an increased length of stay [13]. Demographics were controlled and confirmed that the patient demographics were not significant in influencing complications, confirming the high BMI made an impact. These results resemble those of another study that reported that for each unit increase in the BMI, adverse events increased by 8%, even after accounting for other demographic differences such as age and gender [14].

Researchers Friedman et al., using data from the RECORD clinical trial program of rivaroxaban for prevention of venous thromboembolism after TKA or total hip arthroplasty, analyzed factors to determine whether morbidly obese patients had an increased risk of a venous thromboembolism, bleeding, infections, and other adverse events within the postoperative period. Friedman et al. would agree with the results of researchers Namda et al. who reported no significant differences between DVT complications in obese and

nonobese groups but rather an increased infection rate in obese patients [2]. A total of 12,355 patients were included in the review, and a BMI of over 40 was viewed as the threshold to be considered morbidly obese. Patients were further categorized into subgroups based on their BMI (BMI less than 25, between 25 and 29, between 30 and 39, and over 40). While no statistical significance was found between the morbidly obese groups and the other subgroups for symptomatic or asymptomatic DVT and no differences in the rates of bleeding between the BMI groups, there were differences between adverse events. Other studies agreed on no significant differences between DVT both symptomatic and asymptomatic in obese and nonobese groups. In comparison to groups of lower BMIs, patients with a BMI of over 40 experienced a higher amount of serious adverse events (including wound-related complications, erythema, respiratory, neurologic, GI, cardiac, edema, etc.). The serious adverse events experienced most commonly within the patients with BMIs over 40 were device-related infections, femur fractures, hypoxia, infective arthritis, increased alanine aminotransferase, nausea, and wound dehiscence. Along with an increase in adverse events, infection rates were reported as significantly higher in the patient population with a BMI over 40 in comparison to the lower BMI subgroups. Wound inflammation and infection, respiratory tract and lung infections as well as infections excluding the surgical site were also higher (*P* values, respectively, *P* = 0.0021, *P* = 0.0391, *P* = 0.0015).

Surgeons however may still choose to operate on obese patients, and ample literature supports them doing so, as long as the patient understands the potential of increased risk. Studies report ample improvement in knee scores of morbidly obese patients and high patient satisfaction even within the morbidly obese population [15, 16]. Some studies report implant survival as not being negatively impacted by higher BMI, while others acknowledge the possibility of earlier implant failure but great improvement in postoperative pain of obese populations [17, 18].

With all studies come limitations. When reviewing literature on the correlation between obese

patients and perioperative complexities, we notice many studies report trends toward greater risk in the obese patient, but few report statistically significant complications. Previous literature may report conflicting results, and this can be due to the different limitations among studies. There is a notable lack of power that comes from smaller-scale population sizes and an imbalance between the sizes of various BMI categories. Although the sample sizes studied by researchers may be large, a longer follow-up time may be more reliable in comparing the surgical outcomes among the different BMI groups. Several of the researchers noted it is difficult to find orthopedic surgeons and anesthesiologists willing to operate on morbidly obese patients, causing an exclusion of large numbers of these patients among literature studying obesity and surgical outcomes. One study that reported increased risk in the super obese also discussed the limitations including its retrospective nature and data including both hip and knee patients, varying surgeons, surgical technique, and postoperative care [13].

Ultimately, a thorough discussion between the patient and their surgeon is critical to setting realistic patient expectations and providing the best options for each patient on a case-by-case basis. Obese patients should not automatically be excluded from the potential benefits of a total knee arthroplasty, as previous literature has shown patient reported outcomes were similar in patients of both lower and higher BMI groups [19]. While there is potential that obese patients benefit from the procedure, recommending weight loss and warning patients of the signs and symptoms of wound problems can lead to better surgical outcomes. While no BMI cutoff is currently proven to draw a line between low- and high-risk patients, patients should be encouraged to work on improving their BMI prior to surgery.

Key Points

- Ensure patient has failed non-operative treatment and weight loss.
- Inform patient of the potential of increased risk with higher BMI, set expectations for surgical outcomes.

- Obese patients have increased anterior knee pain after TKA and should be mentioned to the patient prior to performing the procedure.
- In large extremities, it is best to be conservative with the tibia cut since often the soft tissue envelope can stretch out requiring a larger polyethylene tray.
- Proper balancing of the knee is critical. The weight of the limb may give a false sense of stability, and if the femur is lifted, more instability may actually be present.
- The medial collateral ligament is at more risk with the obese patient and must be protected at all times during the procedure
- The medial collateral ligament is at more risk with the obese patient and must be protected at all times during the procedure
- Monitor patient wounds closely postoperatively, as literature has shown increased infection rates among obese patients.
- The medial collateral ligament is at more risk with the obese patient and must be protected at all times during the procedure.
- Watch for external rotation deformities of the limb which can lead to pressure ulcers if left to occur.
- Obese patients have increased anterior knee pain after TKA and should be mentioned to the patient prior to performing the procedure.
- Bariatric surgery with significant weight loss following the TKA procedure can lead to increased knee laxity.

Option 2: Surgical Technique with Conventional Instrumentation

Jason Wong and Jeffrey A. Geller

Case Presentation

History

Our patient is a 47-year-old female who presented to us initially with 1.5 years of left knee pain. The pain became significantly worse over the last 2 months whereby she could barely walk more than a few steps without needing to stop and rest. She had been to the emergency room

multiple times in the previous 2 months for the left knee pain. She was 5 ft 1 in. tall and weighed 270 lb with a BMI of 51.0. At the conclusion of the first visit, we injected her knee with corticosteroids and recommended weight loss and physical therapy with a 3-month follow-up.

Before we indicate our obese patients for surgery, we try to exhaust all non-operative treatments in treating knee osteoarthritis. It has been shown that weight reduction in this specific population is particularly useful in reducing knee pain [20]. Isolated weight loss occurring via bariatric surgery resulted in statistically significant improvement in patients' knee arthritis symptoms at both 6 and 12 months [21]. A study that looked at total knee arthroplasty outcomes before, within 2 years, and after bariatric surgery showed that TKA performed 2 years after bariatric surgery has significantly shorter anesthesia, operative, and tourniquet times but no difference in complication, transfusion rates, and duration of hospital stay [22]. This demonstrated that whenever these patients decide to proceed with total knee arthroplasty in the future, weight loss is still beneficial to them in the long run. When the patient ultimately has surgery, this preoperative weight loss led to shorter surgical times and less anesthesia [23]. Intra-articular injection to the knee may also be utilized as a non-operative treatment. It was demonstrated in one study that hyaluronic acid injection may be preferred over corticosteroid injection due to the potential alteration of glucose metabolism with corticosteroid use [24].

Our patient returned in 3 months and reported that the left knee pain did not get better over the course of physical therapy and she wanted to proceed with surgery.

She was then appropriately counseled as to the increased complication rates associated with TKR, specifically the rate of wound healing problems, periprosthetic infections, venous thromboembolism, as well as increased need for manipulation under anesthesia postoperatively.

Additionally, advice about preoperative planning includes surgical templating. Due to the increased body habitus of the patient, there may certainly be an increased risk of oversizing of the

femoral component if exposure to the anterior cortex and visualization is difficult. A blueprint of the size of the component is often helpful pre-operatively; however, as in hip arthroplasty, the distance between the X-ray beam and the bony structure must be accounted for and may be variable, thus resulting in overestimation of the template size [25].

Physical Examination

We usually begin our physical exam by inspection. As demonstrated in Fig. 6.13, our patient had a significant amount of adipose tissue on the medial aspect of the knee. Her left knee was essentially locked with a range of motion from 40 to 45° with diffuse tenderness about a 2+ effusion. No instability of the knee was noted. She had acceptable, painless range of motion of bilateral hips, which must always be examined in any patient complaining of knee pain. She also walked with a severely antalgic gait on the affected side.



Fig. 6.13 Photograph of patient's knee. Significant amount of adipose tissue can be seen on the medial aspect of the thigh

Radiographs and Advanced Imaging

As demonstrated on the AP view of the left knee (Fig. 6.14), it was obvious that there was a significant amount of adipose tissue on the medial aspect of the knee. The left knee was in severe varus alignment and most cartilage was worn out in the medial compartment of the knee. On the lateral view of the left knee (Fig. 6.15), there was significant osteoarthritis present in the patellofemoral compartment.

Surgical Technique

Given the difficulties associated with airway and potential pulmonary complications in this patient population, regional anesthesia is typically preferred over general anesthesia, though still more difficult than in the nonobese population [26]. However, it should be noted that peripheral nerve blocking is also more difficult in this specific population and surgeons should be vigilant of the effectiveness of the nerve block and potential need for back up pain relief modalities. Ultrasound assisted peripheral nerve block, though now standard of care, maybe particularly important and recommended for this cohort of patients due to that reason [27]. Surgeons should be increasingly aware that given the increased rates of infections and altered pharmacokinetics,



Fig. 6.14 Anteroposterior (AP) radiograph of the left knee demonstrating severe osteoarthritis in varus alignment



Fig. 6.15 Lateral radiograph of the left knee

ics, antibiotic timing and dosage are particularly important in the super obese patient [28].

The application of tourniquet is often difficult in the obese population. We have found the following three steps helpful to improve our operative technique: positioning of the thigh tourniquet snugly and as proximal as possible to afford enough surgical exposure, generous demarcation of the surgical field using an adhesive U drape around the thigh to provide enough surgical draping and exposure to drape, and, finally, marking out an adequate incision with marking pen as visualization is an extremely important part of surgical success in this challenging population. There should be no illusion that a small, minimally invasive approach is appropriate for patients with a severely enlarged body mass index. Another tip in preventing a venous/ineffective tourniquet is to have an assistant pulling on the adipose tissue distally while the tourniquet is being applied as demonstrated in Fig. 6.16. Once the tourniquet is secured, the assistant can release the adipose tissue [29]. Wider, low-pressure tapered tourniquet cuffs are often utilized as high-pressure tourniquets should be

avoided due to the increased chance of neurologic or vascular injury. Similarly, tourniquet pressure should be raised to 300 mmHg to ensure adequate effectiveness, if one elects to use them. In the scenario when a tourniquet is too difficult to be applied, the majority of the surgery, especially the cementing phase, should be performed



Fig. 6.16 Demonstration of the application of a tourniquet on an obese knee

with the knee in flexion as bleeding is significantly reduced in this position. We have found that leg positioners are essential to make positioning of the leg easier. Our practice is to place a hip positioner that is commonly used for total hip arthroplasty, lateral and just proximal to the final position of the tourniquet of the operative leg to prevent excessive external rotation of the leg/hip during surgery (Fig. 6.17).

For the surgical approach, an extensile approach such as midline incision with a median parapatellar arthrotomy is recommended in case (Fig. 6.18). We try to create a “pocket” by extending the subfascial dissection on the lateral side to facilitate eversion of the patella which is often difficult as many of these patient present with patella baja position. The patella can be everted or subluxated depending on surgeon’s preference [30].

It is also advised to be careful in placing medial and lateral retractors during the surgery for exposure (Fig. 6.19). There have been reports that there may be a higher chance of medial collateral ligament avulsion during total knee



Fig. 6.17 (a) Placement of hip positioner at the level of the greater trochanter to prevent external rotation of the hip and (b) a different angle looking at the placement of the hip positioner



Fig. 6.18 Incision for a super obese knee



Fig. 6.19 Retractors placement for a super obese knee

arthroplasty in obese patients [31]. This is likely secondary to the fact that there is an increased amount of fat that needs to be retracted around the tibia and hence an increased tension in the collateral ligaments during exposure.

Assessment of limb alignment with standard jigs is more difficult as the normal bony landmarks may be obscured. There is also an identified risk of cutting the tibia in varus, caused by fat pushing extramedullary jig medially (Fig. 6.20) [15, 31]. As a result, intramedullary guides may be used to cut the tibia as an alternative technique. Some investigators have shown that the use of an intramedullary guide made surgical intervention easier and was associated a shorter tourniquet time in morbidly obese patients [32].

In terms of implant selection, standard cemented femoral and tibial components are acceptable but due to the high rates of aseptic loosening of the tibial components, additional fixation of short cemented stem can also be considered [33]. Some authors have advocated for computer-assisted technology over conventional technique for TKA in the obese patient population, as it may improve mechanical alignment with no significant increase in operative time given the fact that it usually takes longer to perform TKA in obese patients [34].

Layered closure is highly recommended and we believe is essential for obese knees, as there is an increased risk of wound complications (Fig. 6.21). Also, some authors have suggested (and we agree) using negative pressure wound therapy for total knee arthroplasty in patients with a high risk of infection in order to promote wound healing (Fig. 6.22) [35–37]. We recommend early and close postoperative monitoring for wound healing problems and assessment of range of motion. This population of patients is so fragile that lengthy, unchecked post-op gaps in follow-up can have potentially disastrous consequences. We encourage patients to send us frequent digital images of their surgical wound postoperatively, and if any question arises, there is a low threshold to bring them in for a wound check in the office.

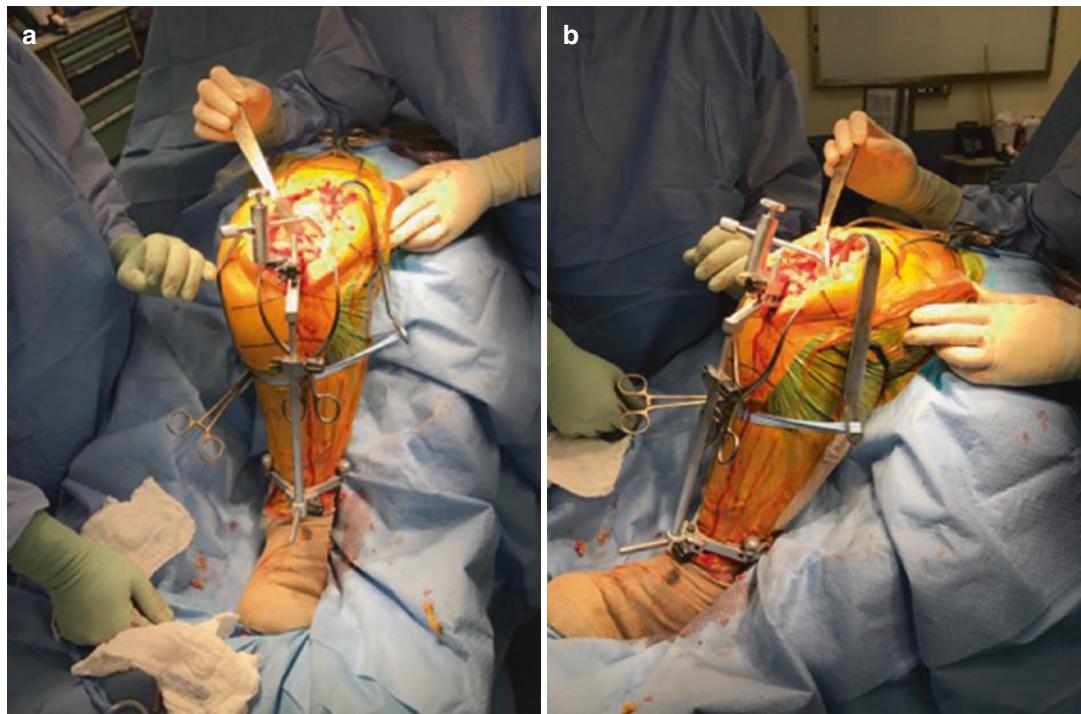


Fig. 6.20 (a) Demonstrating the importance of neutral placement of the extramedullary tibia cutting jig and (b) examining the placement of the tibia cutting jig from the lateral aspect of the knee



Fig. 6.21 Closing the surgical wound in layers

Postoperative Result

As demonstrated in Fig. 6.23, postoperative radiographs showed acceptable, neutral alignment of the left knee.

Clinical Results

The prevalence of obesity ($\text{BMI} > 30 \text{ kg/m}^2$) and morbid obesity ($\text{BMI} > 40 \text{ kg/m}^2$) in the adult population in the United States is approximately 36% and 6%, respectively [38]. In addition, the prevalence of super obesity ($\text{BMI} > 50 \text{ kg/m}^2$) has increased 20% between 2000 and 2010 [39, 40]. It has been shown that obesity is an independent risk factor for development of knee osteoarthritis [41]; many of our patients who will undergo TKA surgery in the next 10 years will be obese. The prevalence of OA is 16.3% in patients with normal weight, 21.7% in overweight patients, and 31.6 % in obese patients [42].

It should be noted that complications were more frequent and functional outcomes were significantly lower in the group of “super obese” patients after TKA [43]. Obesity is a

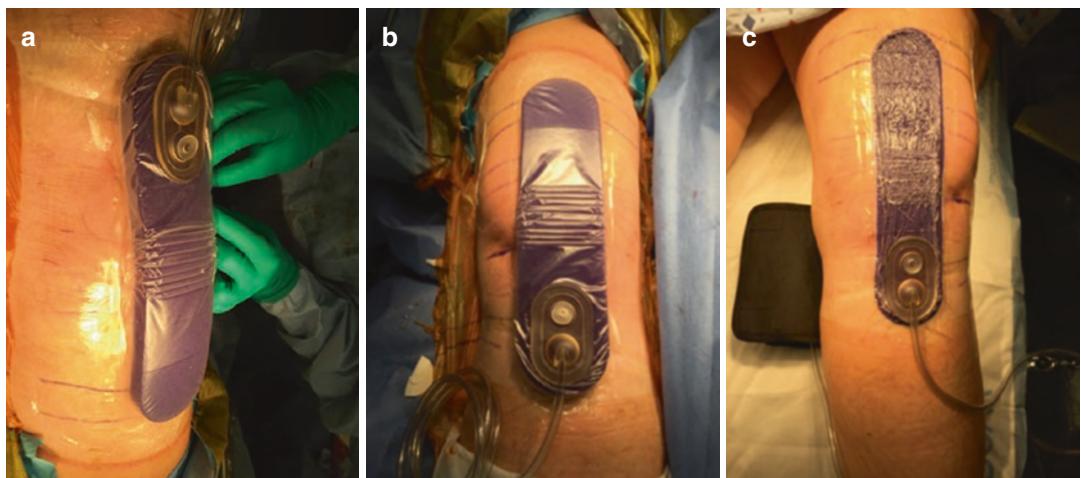


Fig. 6.22 (a) Application of an incisional negative pressure dressing, (b) application of an incisional negative pressure dressing, and (c) appearance of the incisional negative pressure dressing when applied successfully



Fig. 6.23 (a) Postoperative anteroposterior (AP) radiograph demonstrates acceptable alignment and (b) postoperative lateral radiograph demonstrates acceptable alignment

major risk factor for increasing surgical time and the risk of complications following a total knee or hip arthroplasty [44, 45]. Complications include wound healing issues, superficial and deep infections, higher revision rates, and overall complication rates [12, 22]. Some authors have even suggested complication rates even

higher in the obese group compared to a revision TKA group [46]. These authors found that the odds ratio of developing a complication within 30 days after an operation is significantly higher in patients with a BMI of over 45 kg/m^2 . It was also shown that the risk of infections is increased with obesity [47]. But despite the increased complication rates associated with obese patients, implant survival in fact has no significant difference. In a study by Naziri et al., the authors were able to show that implant survivorship had no significant difference between the super obese group and nonobese group [43]. On the other hand, despite the relatively higher complication rates, the substantial improvement in knee society scores and high rate of patient satisfaction suggest that TKA can still be performed in this group of obese patients [22]. Nonetheless, patients should be counseled on potential increased rates of complications including high rates of arthrofibrosis, requiring MUA post-procedure [48].

Key Points

- Preoperative weight loss possibly including bariatric surgery is encouraged.
- Wide exposure and visualization with intraoperative tourniquet use and optimal leg positioning is helpful for postoperative success.

- Layered wound closure with VAC-assisted dressing may help minimize wound healing problems.
- Close postoperative follow-up for early detection and aggressive treatment of wound problems.
- Monitor early range of motion to avoid arthrofibrosis.
- Successful outcomes may be achieved, but slower return of function and higher risk of complications are to be expected.

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Total Knee Arthroplasty Following a Sepsis History

7

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Introduction

Fred D. Cushner

The importance of a complete history and physical examination is stressed at the time of medical school. And if that history includes a previous history of joint sepsis, the performance of a “routine” TKA is now more complicated. The obvious question remains, has the infection been eradicated? While on the surface, it may appear easy to rule out an active infection, but certainly the other issue is a bit more difficult. Is there residual or dormant infection that could become clinically significant once soft tissue releases and bone cuts are performed?

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Therefore, prior to the arthroplasty, an infection work-up needs to be performed. This starts with routine blood tests with a CBC with differential, ESR, and a noncardiac CRP. An aspiration can also be performed at the time that TKA is indicated for this is not only valuable information but eliminates the need for a return trip to your office for the patient if indeed these blood markers are elevated. An MRI can also be obtained, looking for a nidus of osteomyelitis, but while often described, there is little in the literature that demonstrates a benefit.

Just as important as the history, the physical exam must also be meticulously performed looking for factors that could lead to a more complex TKA. For example, if the infection required an open debridement, then the incision must be evaluated, and a surgical plan on how to either avoid or incorporate the previous incision must be performed. The quality of the tissue must also be evaluated for often there is scarring and a decrease in the mobility of the subcutaneous tissue. If there is any question about the integrity of the soft tissue envelope, then a plastic surgery consult should be obtained and soft tissue expansion considered. It is much better to obtain a preoperative plastic surgery consult rather than search for an emergent consult should wound healing problems arise in the post-operative period. The range of motion should also be noted and the surgeon prepared to follow the surgical techniques as outline in the stiff knee chapter of this text in indeed limited ROM is noted.

Once active infection is ruled out and a decision is made to perform a TKA, the surgeon must determine whether to do a one-stage or two-stage TKA. The two-stage procedure allows for the TKA to be done in stages. The standard incision is made, bone cuts are performed, and a static or mobile spacer is placed. Numerous cultures are obtained at the time of the first stage, and if negative, a second procedure can be scheduled to place the final prosthesis. If cultures are positive, the spacer remains in place, a course of IV antibiotics is administered, and the second stage is done at a later date. It is very important that numerous cultures are obtained at the time of the first stage, and samples should be obtained at the time of entering the joint as well as from both the femoral canal and tibial canal. Numerous cultures are necessary and will help the infectious disease consultant rule out a contaminant if indeed one of the cultures is positive. Results of the two-stage approach are similar to those of a revision knee, and certainly the patient's overall result is a bit compromised if this method is selected.

The one-stage approach is performed in a similar fashion except the final prosthesis is placed at the time of the first procedure. Cultures are obtained in a similar fashion and indeed if positive, a course of IV antibiotics completed.

Certainly, a higher infection rate has been noted in patients with a history of sepsis. Patients must be made aware of this increased risk and know preoperatively that a period of IV antibiotics may be required if intraoperative cultures are positive.

Option 1: Previous Knee Sepsis—One Stage

Nicholas B. Frisch Brian Darrith, and Craig J. Della Valle

Case Presentation

History

A 59-year-old man presented for evaluation of right knee pain. The patient had experienced several years of intermittent but progressive pain,

which was associated with stiffness, swelling, and weakness. He was previously diagnosed with severe degenerative changes in the right knee and initially treated with anti-inflammatory medication and analgesics. He also received multiple injections of both steroids and viscosupplementation, with the last injection occurring 2 years ago and providing minimal relief of his symptoms. His past surgical history was significant for open right knee surgery in 1972 following a football injury. In December of 2013, he developed insidious onset right knee pain and was given an intra-articular injection of betamethasone after aspiration showed crystals consistent with pseudogout. His symptoms worsened over the next 10 days despite conservative management, and a second aspiration was sent for cell count and gram stain, which revealed 49,000 white blood cells/ μ L and gram-positive cocci. He was immediately admitted and underwent an arthroscopic irrigation and debridement. Operative cultures at that time grew *Streptococcus viridans*, and he was given an 8-week course of IV ceftriaxone. Pertinent past medical history includes a myocardial infarction in 2010 treated with stent placement and cardioversion for chronic atrial fibrillation for which he continues to take dabigatran.

On physical examination the patient was 6'1" tall weighing 240 lb. He ambulated with a slightly antalgic gait. There were well-healed arthroscopy portals medially and laterally, as well as a well-healed medial incision from his previous open surgery. The extremity was neurovascularly intact. Knee range of motion demonstrated full extension and 110° of flexion with painful crepitus throughout. The knee was stable to varus and valgus stress at 0° and 30°. Plain X-rays demonstrated severe degenerative joint disease (Fig. 7.1). The knee was aspirated, and the synovial fluid showed 88 white blood cells/ μ L with a differential of 15.9% polymorphonuclear cells and no growth from the cultures.

The patient was extensively counseled at this point that while total knee arthroplasty was indicated, the risks of surgery were higher than normal, especially the risk of deep periprosthetic joint infection, given not only the history of

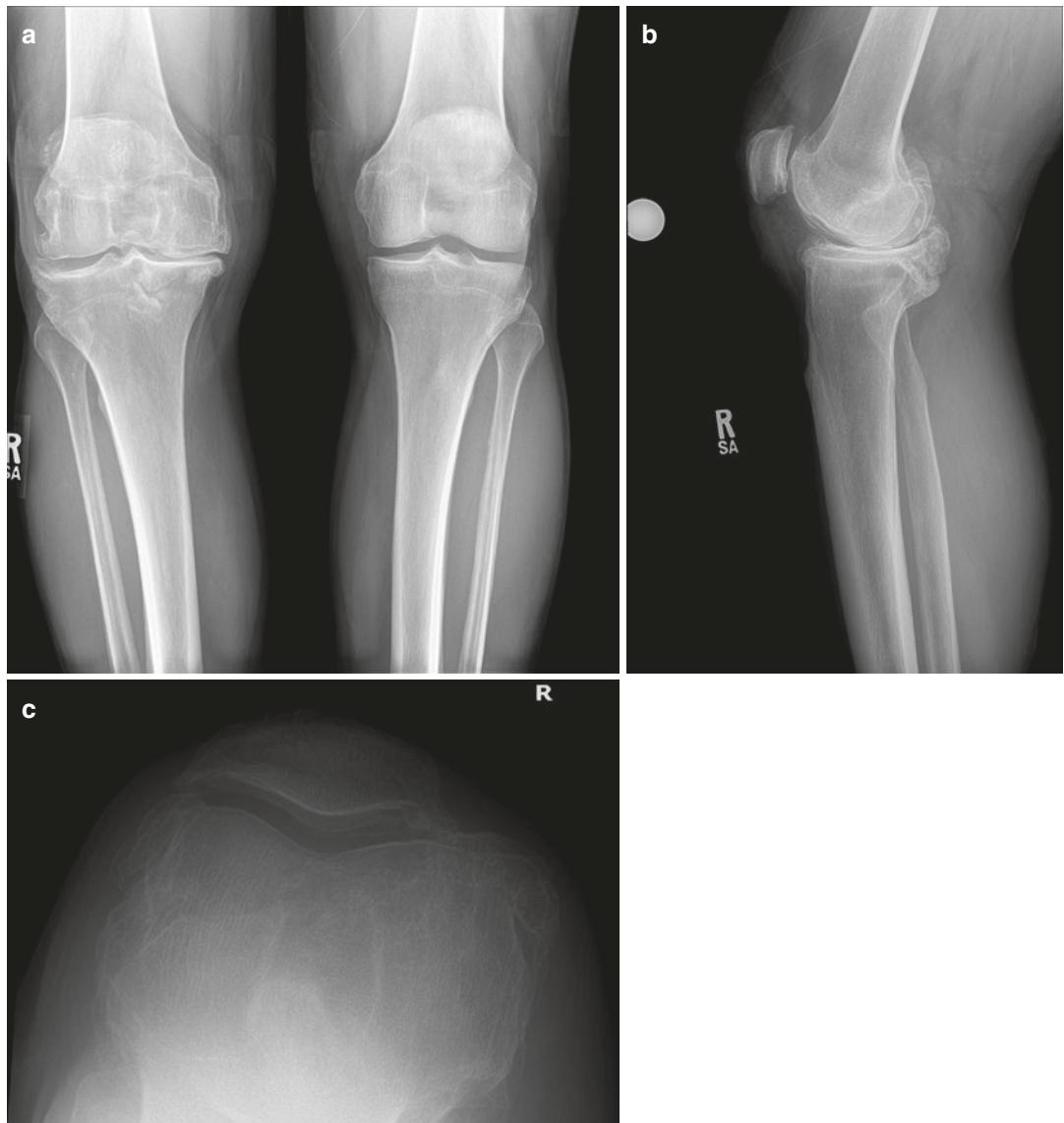


Fig. 7.1 Preoperative radiographs. (a) Anteroposterior (AP), (b) lateral, and (c) sunrise obtained at the time of initial evaluation demonstrating severe degenerative joint disease of the right knee

native joint sepsis but also his long-standing anti-coagulation and cardiac history. He was further counseled that if there was any evidence of persistent infection identified at the time of surgery, an antibiotic spacer would be placed and the knee reconstructed in a staged fashion (Fig. 7.2).

Preoperative Planning

Preoperative planning in cases of prior native joint sepsis is crucial to ensure there is no

evidence of persistent joint infection. Evaluation should include an aspiration of the joint with the fluid sent for a synovial fluid white blood cell count, differential, and cultures. In this case with a history of native joint sepsis, the clinic suspicion for osteomyelitis or a sequestrum was low; however, if the plain X-rays or history in any way suggests the possibility of osteomyelitis or a sequestrum, further evaluation in the form of a computed tomography (CT) scan, magnetic



Fig. 7.2 (a) Anteroposterior (AP) and (b) lateral radiographs of a different patient after a native knee infection that did not resolve appropriately by the time of surgery.

(c) AP and (d) lateral radiographs of the same patient after being treated with an articulating spacer



Fig. 7.3 (a) Anteroposterior (AP) and (b) lateral radiographs of a different patient after a native knee infection. The distal femoral deformity and bone remodeling in this patient demonstrates features concerning for sequestrum and in this case would warrant additional advanced imaging

resonance imaging (MRI), or an open biopsy should be considered (Fig. 7.3).

Aside from ensuring there is no evidence of infection at the time of surgery, it is important to optimize the patient's medical status preoperatively. Given this patient's cardiac history, he was seen by internal medicine and cardiology preoperatively. Patients who are on chronic anticoagu-

lants require special planning to determine the plan for anticoagulation postoperatively balancing in this case the risk of bleeding, wound healing complications, and infection with the risks associated with his arrhythmia. Furthermore, we routinely check preoperative albumin as a baseline indicator of nutrition status. If the patient's albumin is below 3.5, we would delay the case, have the patient work with our nutritionist, and improve his nutrition status prior to undergoing the procedure.

Surgical Approach

The most common approach for total knee arthroplasty (TKA) is a medial parapatellar approach. It is a simple and familiar approach to most knee surgeons and particularly advantageous in this case as it is readily extensible if needed. In general we always try to utilize prior incisions, and we incorporated this patient's previous scar, extending slightly proximal and distal to enhance our exposure (Fig. 7.4). If multiple prior incisions are present, the most lateral one is selected (so long as it would provide reasonable exposure) as the blood supply to the anterior knee is derived medially. If a new incision must be made, it is important to leave an adequate skin bridge between parallel incisions of approximately 6–8 cm. One

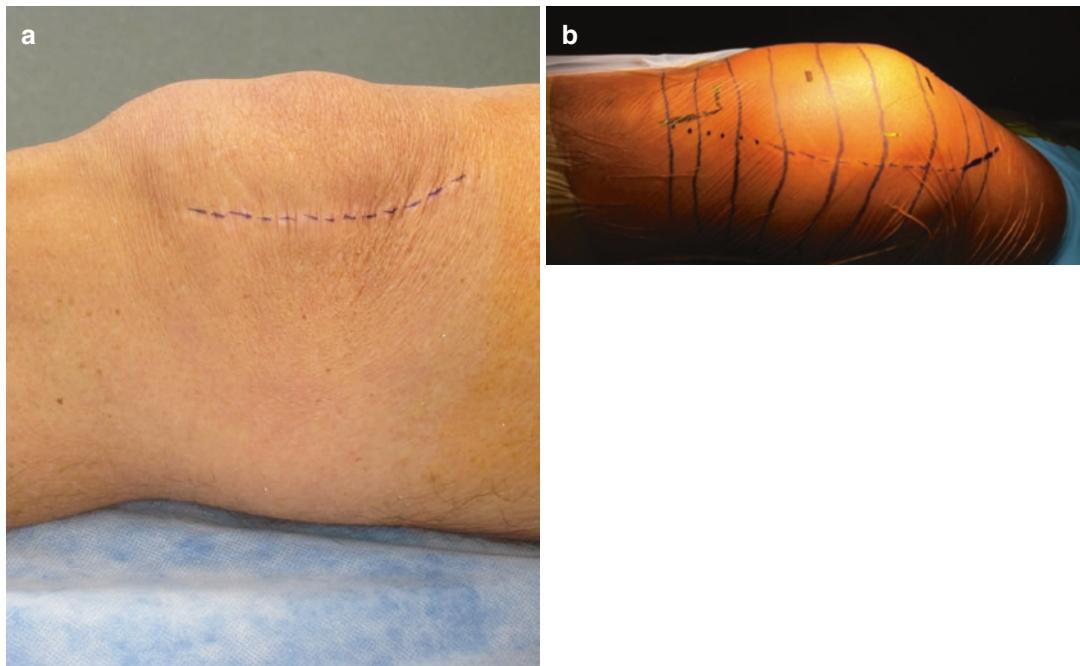


Fig. 7.4 (a) Preoperative photograph demonstrating previous scar on medial side of the right knee. (b) Planned surgical incision incorporates previous scar and extends

proximally and distally to enhance exposure. Note the location of the existing scar in relation to the patella markings and tibial tubercle



Fig. 7.5 Medial parapatellar approach

should be particularly careful if the prior incisions were performed recently.

It is critical to make full-thickness skin flaps down to the deep fascial plane as more superficial flaps can lead to skin necrosis secondary to disruption of the cutaneous blood supply (Fig. 7.5). At this point an arthrocentesis was performed and the aspirate was sent for culture

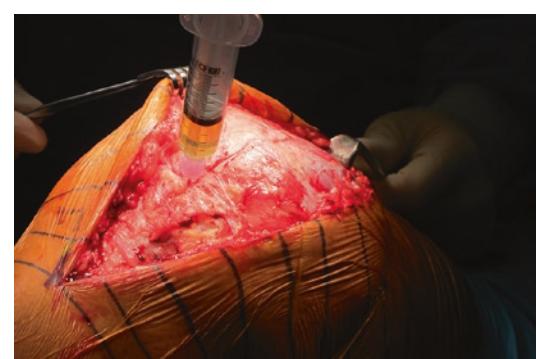


Fig. 7.6 Synovial fluid aspiration performed after initial exposure, but prior to arthrotomy

(Fig. 7.6). A medial parapatellar arthrotomy was made from the apex of the quadriceps tendon, along the junction of the vastus medialis and curving around the patella to the medial side of the tibial tubercle. The medial tissue is carefully elevated off the proximal tibia in a triangular fashion that is carried to the posteromedial corner (Fig. 7.7). Osteophytes are removed from the

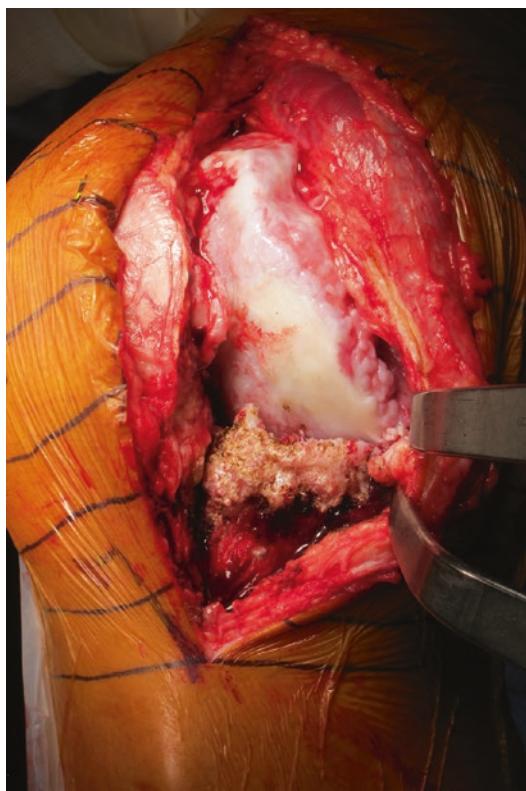


Fig. 7.7 Intraoperative image demonstrating femoral cartilage degeneration

medial aspect of the tibia and distal femur. At this point the infrapatellar fat pad is excised, and the patella is carefully subluxed laterally to fully expose the joint.

A thorough examination of the tissue for any signs of active infection is performed followed by a meticulous anterior synovectomy (Fig. 7.8) to both debride the joint and improve exposure by reestablishing the medial and lateral gutters similar to the performance of a revision total knee arthroplasty. Samples of the synovium were sent for tissue culture and for intraoperative histopathological examination and were all negative. The remainder of the case follows routine preparation and implantation of the primary components.

In this case, we used a cruciate-retaining primary total knee implant. We proceed in a step-wise fashion preparing the patella first (Fig. 7.9) to enhance exposure by facilitating subluxation of the extensor mechanism laterally. The distal femoral cut is made next taking care to adjust for appropriate valgus cut angle, in this case 5° (Fig. 7.10). Next we move to the tibia, resecting the minimal amount of proximal tibia necessary using an extramedullary cutting guide. The femur is then prepared ensuring appropri-

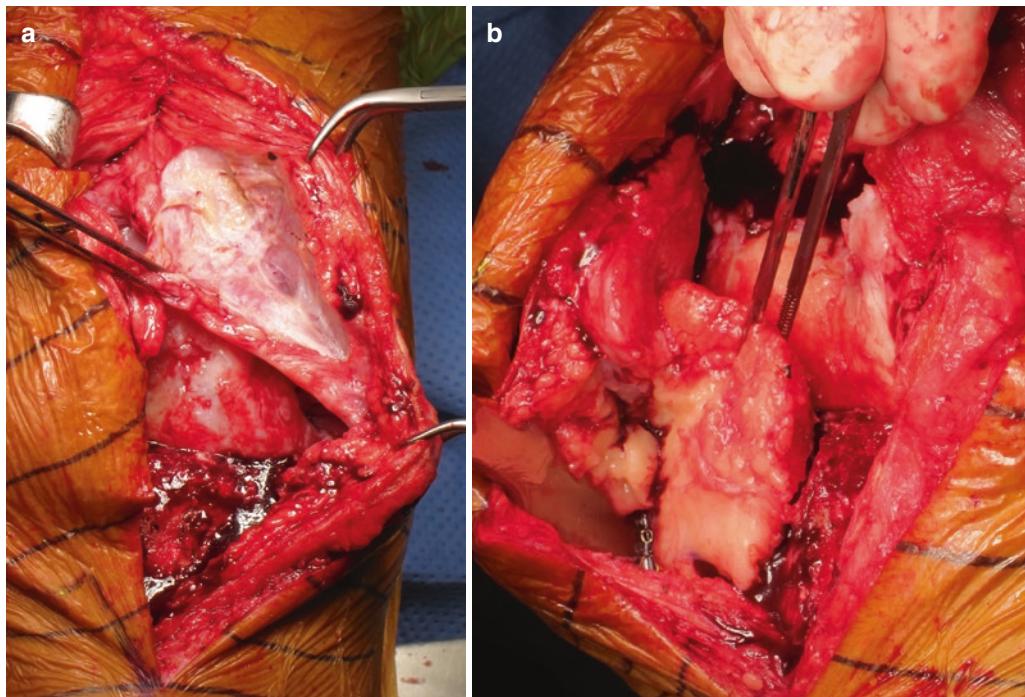


Fig. 7.8 (a, b) Debridement of scar tissue and extensive synovectomy

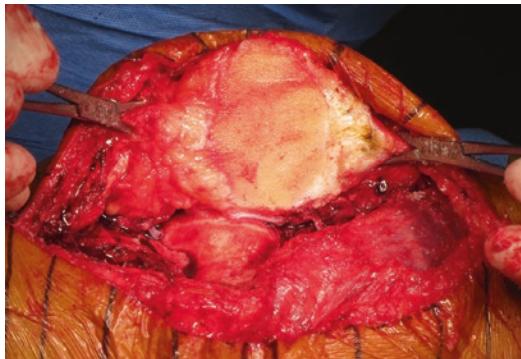


Fig. 7.9 Patellar preparation

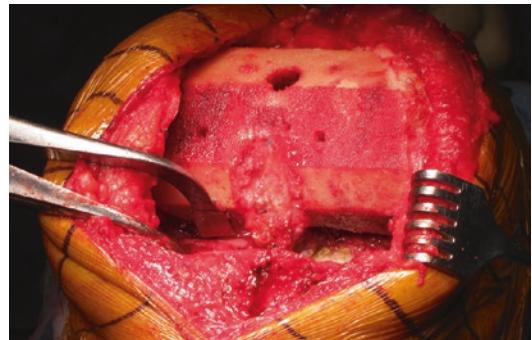


Fig. 7.11 Femur prepared for implant

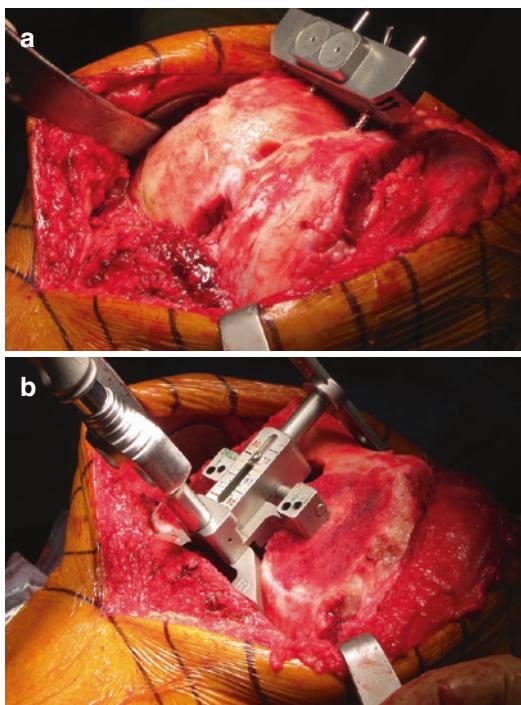


Fig. 7.10 (a) Distal femoral cut followed by (b) setting appropriate external rotation and sizing the femoral component

ate external rotation of the cutting jig and determining the appropriate size using in this case a posterior referencing jig (Fig. 7.11). The knee is extended and a thorough posterior synovectomy is performed.

Although we always thoroughly irrigate the knee with sterile saline using pulsatile lavage prior to cementation, in this case additional lavage was performed to ensure a thorough irri-

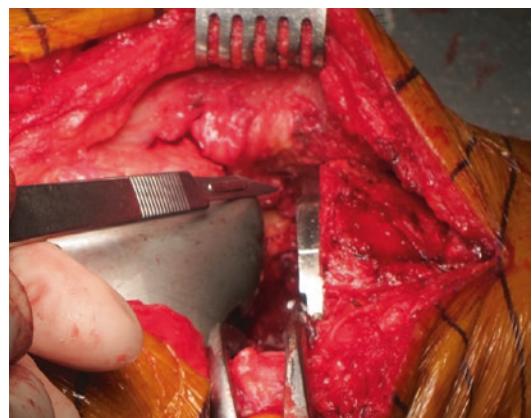


Fig. 7.12 With the components in place and a laminar spreader tensioning the joint, appropriate soft tissue balancing must be performed. In this case a medial release was required to obtain optimal soft tissue balance

gation prior to component implantation. The trial components are placed, and the knee is taken through a full range of motion to assess and ensure adequate stability and appropriate patellar tracking. Any additional soft tissue balancing can be performed at this point (Fig. 7.12). Once satisfied with the components, stability and range of motion, the trials are removed, and the knee is again copiously irrigated with sterile saline prior to implantation of the components with antibiotic-loaded cement.

As the cement is hardening, the knee is filled with a dilute Betadine solution (0.35% povidone-iodine) for 3 min which we use routinely in an effort to decrease the risk of periprosthetic joint infection [1]. The Betadine solution is then

removed and the knee is again irrigated with sterile saline prior to closure. A layered closure using absorbable, non-braided suture is performed without the routine use of a drain. An Aquacel dressing is placed over the incision.

Postoperative Results

Postoperatively the patient followed our standard protocol; however, perioperative antibiotics were continued until the operative cultures were known to be negative at 72 h postoperatively. Given the patient's complicated cardiac history, he was restarted on the dabigatran per the recommendations of internal medicine and cardiology. There were no immediate complications; the patient was cleared by physical therapy and discharged home on postoperative day number 3, as all cultures were negative.

At 6 weeks the patient reported only mild, occasional pain and had regained full functional

abilities—being able to walk as far as desired and going up- and downstairs without any support. His radiographs showed acceptable position of the implants (Fig. 7.13). The patient's range of motion at 6 weeks has surpassed his preoperative range of motion, now being from full extension to 120° of flexion with no instability.

Clinical Results

The overall incidence of deep infection after primary TKA in patients with a history of native knee septic arthritis has been reported to be as high as 9.7% [2, 3]. The use of a single-stage total knee arthroplasty has been previously studied in patients with history of prior sepsis to the native knee. Lee et al. performed 20 consecutive primary TKAs for patients with previous sepsis or osteomyelitis about the knee and at an average follow-up of 5 years reported no patients required chronic antibiotic suppression and only

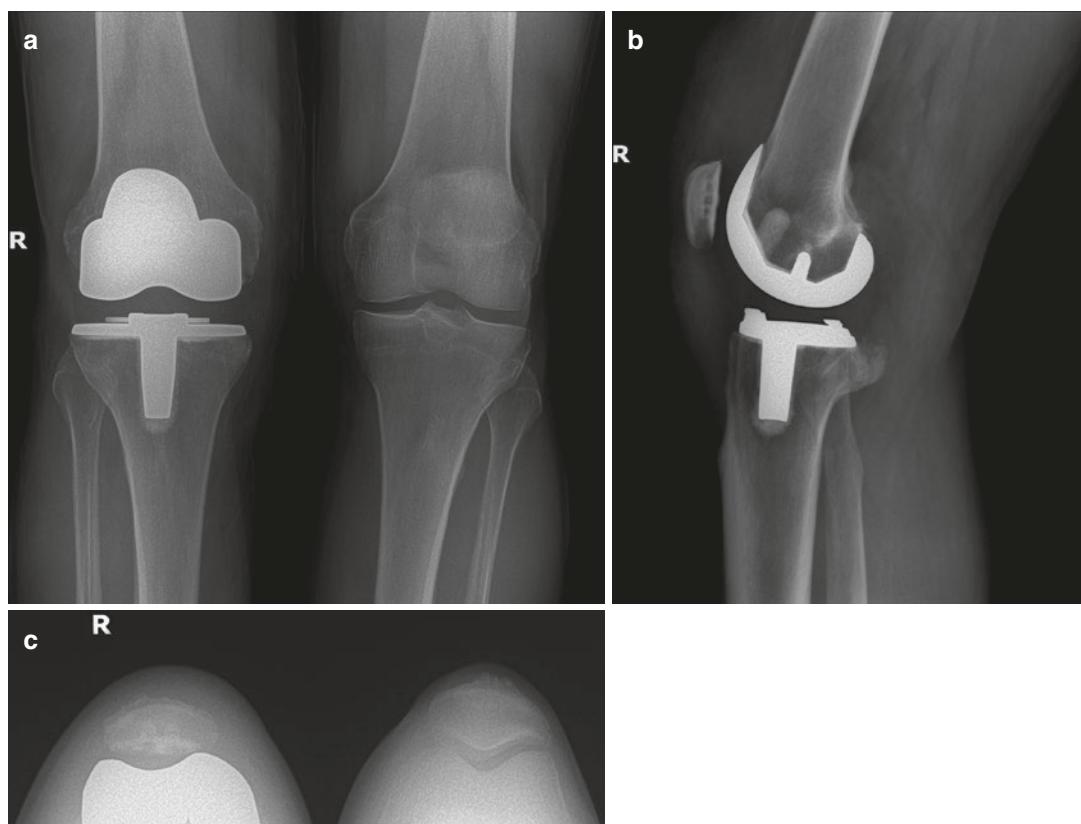


Fig. 7.13 Six-week follow-up. (a) Anteroposterior (AP), (b) lateral, and (c) sunrise radiographs

one recurrent deep periprosthetic infection [4]. Seo et al. reviewed 62 patients with prior sepsis history who underwent primary TKA with mean follow-up of 6.1 years. Postoperative infections occurred in six patients (9.7%) with the same organism being identified in five of the six infected knees. They also noted that the number of prior surgeries could be a risk factor for failure of primary TKA after native knee sepsis [3]. Baur et al. reviewed 53 cases of previous septic arthritis of native knee and hip joints treated with either one-stage or two-stage arthroplasty. They found no significant difference in functional outcome or successful eradication of infection between the two procedures. Of the one-stage procedures performed for quiescent septic arthritis, 95% were successful at 2-year follow-up, including 7 with positive intraoperative samples [5]. In our experience if there is no evidence of persistent infection at the time of primary total knee arthroplasty, we would elect to proceed with a single-stage procedure.

As in any primary or revision joint arthroplasty, preoperative assessment of the patient's overall health, identification of risk factors for perioperative complications, and medical optimization are paramount to maximizing the outcome. Obesity, diabetes, and malnutrition are well-known risk factors for PJI and should be managed in a multidisciplinary fashion with the medicine team and nutrition services [6–10]. We will routinely discuss delaying elective surgery in the event that the patient has a hemoglobin A1c > 8% and albumin <3.5 g/dL.

A preoperative and intraoperative assessment for the presence of infection is critical to the overall success of the procedure. Similar to testing for sepsis before revision TKA, we recommend a serum erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) followed by a perioperative aspiration with synovial fluid white blood cell (WBC) count and differential with culture if the ESR and CRP are abnormal or if the clinical suspicion is high; in general in these cases our threshold for aspiration preoperatively is very low [11, 12]. Adjunctive testing in the form of an intraoperative frozen section analysis and tissue culture can be performed as well.

The routine use of antibiotic-impregnated cement for primary TKA remains controversial [13, 14]; however, in the setting of prior knee sepsis, it is our preference to use antibiotic-loaded cement.

Key Points

- Preoperative assessment of overall health and nutrition status is critical.
- Preoperative assessment of infection eradication including a synovial fluid aspiration with the fluid obtained sent for a synovial fluid white blood cell count, differential, and culture.
 - If there is any question regarding residual osteomyelitis and a sequestrum, three-dimensional imaging and/or a biopsy can be performed prior to considering TKA.
- Intraoperative frozen sections and cultures can be used as additional testing for persistent sepsis.
- A thorough synovectomy and debridement should be performed including the removal of all cartilaginous surfaces.
- Adequate irrigation with sterile saline and the use of Betadine irrigation before wound closure are recommended.
- The use of antibiotic-impregnated cement is our preference in these cases.

Option 2: Previous Knee Sepsis Treated with Two-Stage Revision Arthroplasty

Casey R. Antholz and Keith R. Reinhardt

Case Presentation

History

The patient is a 72-year-old male limousine driver with rheumatoid arthritis who presents with a few-day history of worsening left knee pain. The patient complains of worsening acute or chronic swelling of the knee associated with chills, with no recent history of illness or injury. He denies any objective fevers. He notes a complex history with regard to the left knee, including

multiple prior surgeries, beginning with bilateral total knee replacements (TKR) in 1999. Subsequently he underwent irrigation and debridement with polyethylene exchange for bilateral knee periprosthetic joint infection (PJI) with methicillin-sensitive *Staph. aureus* in 2000. This failed to eradicate the infection, and 4 months later he underwent a bilateral two-stage exchange with interim articulating antibiotic cement spacers followed by bilateral reimplantation TKR. The patient reports he did well for about 3 years, until 2003 when his infection recurred in the left knee, however with *Streptococcus viridans*. This was treated with repeat two-stage exchange with an articulating antibiotic cement spacer followed by reimplantation TKR 2 months later. Since 2003 the patient notes intermittent knee pain and swelling but no overt signs of recurrent infection. He reports baseline mild pain of the knee, much worse over the previous few days. He is not currently on any suppressive antibiotics. His medical history was otherwise noncontributory. He also notes no current increase in pain or swelling of his right knee.

Physical Examination

Vitals—Afebrile, heart rate 87, blood pressure 160/77, pain 8/10, weight 270 lb, height 5'8". The patient appears well-nourished, in no apparent distress, and is alert and oriented to person, place, and time. Exam of the left knee shows mild warmth, large effusion, and no erythema. Prior surgical incisions over the anterior knee appear to be well-healed. Stiffness of the left knee is noted with range of motion of -10° to 95° with discomfort.

Radiographs and Advanced Imaging

Anteroposterior (AP), lateral, and merchant view of the left knee demonstrates a revision left total knee arthroplasty with heterotopic ossification of the surrounding soft tissues. Loosening of the femoral and tibial components is suggested by a number of concerning radiographic indicators, including significant lucencies at the implant/cement-bone interfaces and formation of small pedestals at the tip of both the femoral and tibial stems. In addition, there is formation of a neocor-

tex around the femoral component stem with erosion through the posterior femoral cortex. There does not appear to be a patellar component (previously resected) (Fig. 7.14).

A left knee aspiration was performed in the office under sterile conditions that yielded 5 cm^3 of purulent fluid, with synovial fluid white blood cell (WBC) count of 115,250 with 88% neutrophils and cultures positive for coagulase-negative staphylococcus. Inflammatory markers showed C-reactive protein (CRP) 10 and erythrocyte sedimentation rate (ESR) 33.

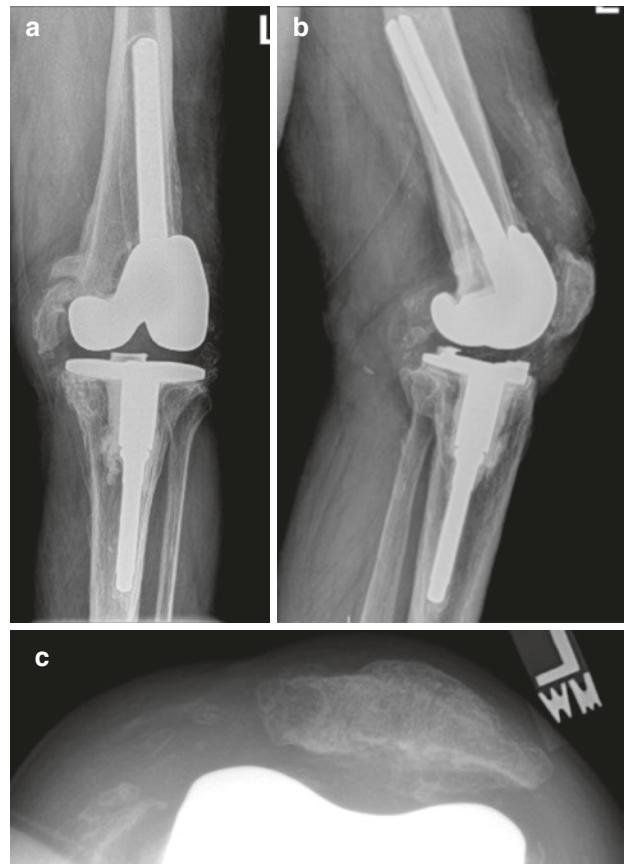
Surgical Approach

Treatment Options

In the setting of chronic recurrent periprosthetic joint infection, the options for successful salvage of the knee are limited. Nonetheless, each patient with a PJI deserves consideration of all available options, which are noted here for completeness.

- *Recurrent aspiration and antibiotic suppression*—In the case of a 72-year-old active man, this was not considered an appropriate treatment. However, rarely for patients with medical comorbidities that preclude surgery, this may be the only option.
- *Irrigation and debridement with exchange of modular components*—This is contraindicated in the setting of loosening of the components and not indicated for chronic recurrent PJI. The results of irrigation and debridement with exchange of modular components beyond 6 or 8 weeks of patient symptoms have been unsatisfactory [15].
- *One-stage exchange arthroplasty*—This has been shown to be successful when properly indicated, typically in the setting of sensitive organisms (coagulase-negative staph) with good host factors. With failure of prior two-stage procedures in this patient, single-stage exchange is unlikely to be successful [15].
- *Two-stage exchange arthroplasty*—Considered the gold standard in the United States for PJI. Studies have shown this to be a viable option with a high rate of success [15].

Fig. 7.14 Preoperative radiographs: (a) anteroposterior (AP), (b) lateral, and (c) sunrise view



- *Fusion or above the knee amputation*— Utilized as a last option or salvage procedure [15].

Due to the apparent radiographic loosening of the components and eroding of the posterior femoral cortex by the femoral stem in the setting of PJI, the patient was indicated for removal of the implants with insertion of a static antibiotic cement spacer, followed by 6 weeks of IV antibiotics, with planned reimplantation TKR once the infection was eradicated.

Two-Stage Approach

Stage 1. The patient was taken to the operating room, where removal of a left total knee replacement was performed through the previous anterior midline incision and medial parapatellar arthrotomy with placement of a static antibiotic methylmethacrylate spacer (Fig. 7.15). Two grams of

vancomycin and 2.4 g of tobramycin were added to each 40 g bag of cement in making the spacer, utilizing a 10 mm × 300 mm tibial nail for reinforcement given the significant femoral bone loss encountered during surgery. Cement was placed beneath the patella to prevent adherence of the patella to the anterior femoral cortex. The aspirate at the time of resection arthroplasty was consistent with infection, as was the final pathology. Cultures grew coagulase-negative staph pan-sensitive and *Corynebacterium*. The patient was placed in a knee immobilizer and made touch-down weight bearing during the postoperative period. He was continued on cefazolin IV antibiotics with oral rifampin for a duration of 6 weeks.

Erythrocyte sedimentation rate and CRP were trended, while the spacer was in place and on IV antibiotics. After 6 weeks, with no clinical sign of persistent infection, all antibiotics were stopped for 1 month. ESR and CRP normalized (17 and

Fig. 7.15 Stage 1 postoperative radiographs: (a) anteroposterior (AP) and (b) lateral view



0.1, respectively), and repeat aspiration of the knee after 1 month off antibiotics showed a WBC count of 609 with 37% neutrophils and negative cultures.

Stage 2. The patient was, therefore, taken back to the operating room for reimplantation TKR (3 months total with spacer in place) through the previously used anterior midline incision and medial parapatellar arthrotomy. A complex hybrid revision total knee arthroplasty was performed. There was little if any additional bone loss from the spacer. Due to deficiency of collateral ligaments from femoral bone loss, a rotating hinge was necessary. The large femoral defect was addressed with a femoral metaphyseal cone with posterior and distal augments. The femoral stem was cemented within the metaphyseal cone but was press-fit in the canal and diaphyseal engaging and bypassed the previous defect. The central tibial defect was managed with a tibial cone and the tibial hinge component was then cemented within the cone. The tibia also required augmentation (Fig. 7.16). The patella bone stock was excellent and was adequately resurfaced utilizing a cemented standard highly cross-linked polyethylene patella button. All cultures taken

during the reimplantation were negative. Due to the long-term recalcitrant recurrent nature of the infection, the patient was continued on oral doxycycline for chronic long-term suppression therapy.

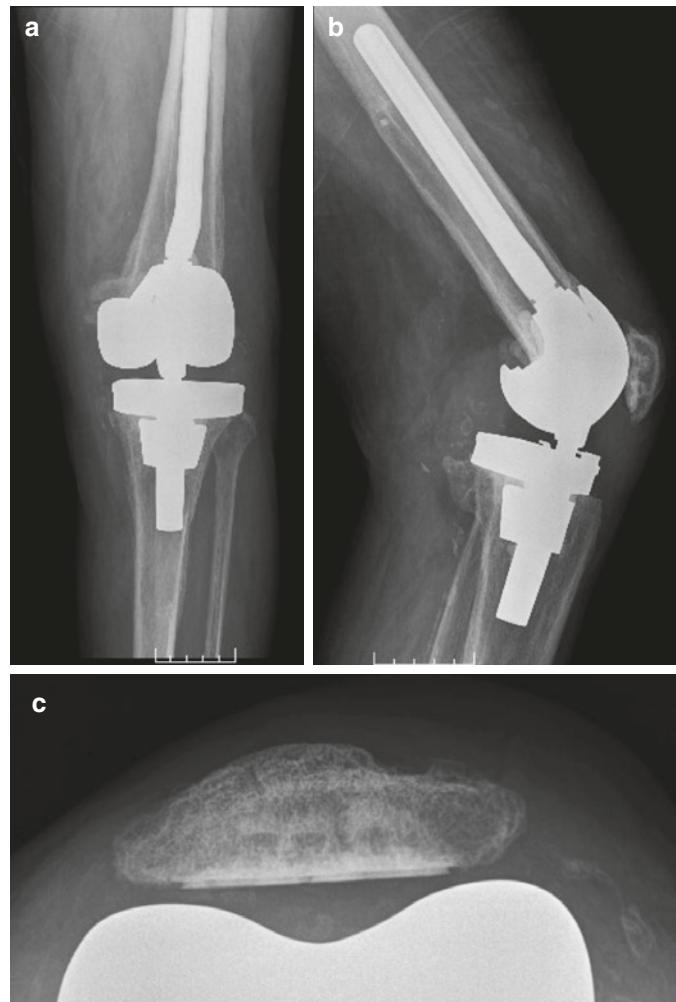
Postoperative Result

The patient had an uncomplicated postoperative course with no recurrence of infection. At 1-year follow-up, the patient had a pain-free 0°–110° of motion and no extension lag. He was able to transfer and ambulate independently without assistive devices, and he had returned to work as a limousine driver.

Clinical Results

Periprosthetic joint infection (PJI) remains one of the most devastating complications after total knee arthroplasty (TKA). As the projected demand for TKA increases exponentially over the next 10–20 years, so will the number of PJI. Different treatment strategies have been implemented based on patient-, surgical-, and organism-related factors. Two-stage exchange arthroplasty remains the gold standard in the United States with successful infection eradication

Fig. 7.16 Stage 2 postoperative radiographs: (a) anteroposterior (AP), (b) lateral, and (c) sunrise view



reports historically ranging from 80 to 100% [16, 17]. Originally described by Insall et al., ten patients underwent removal of all components and cement followed by 6 weeks of parenteral antibiotics and reimplantation. All ten patients successfully cleared the infection and nine out of ten had good to excellent results [18]. Since Insall's first reports, modifications have been made to better improve outcomes as well as patient satisfaction. More recent reports have been promising with the use of static or articulating antibiotic spacers. Lichstein et al. reviewed 107 cases with chronically infected TKAs treated with static antibiotic spacers as part of a two-stage revision TKA. Successful eradication of infection was noted in 102 of 107 (97%) patients. The authors

found consistent results while maintaining or improving post-reimplantation range of motion (ROM) [19]. Gooding et al. reviewed 117 cases with infected total knee arthroplasty treated with two-stage revision utilizing an articulating antibiotic cement spacer. Of the 117 cases, 102 (87%) had successful eradication of the infection with a minimum of 5 years of follow-up [20].

Initial evaluation of patients with PJI should always include risk stratification and medical optimization. Identifying specific risk factors preoperatively will aid in the overall outcomes and long-term success. Risk factors that greatly reduce the success of two-stage revisions have been outlined by Tande et al., most notably obesity, diabetes mellitus, rheumatoid arthritis,

immunocompromising medication, malignancy, revision surgery, male gender, smoking, antecedent bacteremia, and antecedent septic arthritis of the index joint [21]. Identifying these risks preoperatively and medically optimizing the patient through a multidisciplinary team approach will aid in the success of surgery and long-term outcomes.

Two different types of spacers are typically used during two-stage exchange arthroplasty. The indications and outcomes for each type are variable. Static or block spacers are non-articulating. These are typically handmade in the operating room and achieve leg length, alignment, and stability by filling the void left in the bone after removal of the infected prosthesis. In addition to preservation of the joint space, the spacer blocks allow for intra-articular delivery of high-dose antibiotics. This elevated level of local bactericidal antibiotics enhances eradication of any residue bacteria that may remain after initial debridement and irrigation [22, 23].

The second type of spacer used is considered articulating or a mobile spacer block. In addition to local delivery of antibiotics, articulating spacers permit joint motion and improvement in function resulting in decreased scar formation, which has shown to improve exposure during reimplantation [24–26]. Articulating spacers may be constructed in the operating room or prefabricated. Articulating spacers cannot be effectively used in the setting of significant bone loss however.

Studies do not support one type of spacer over the other, nor do they demonstrate that premade spacers are superior over handmade ones. Pivec et al. systematically reviewed 48 reports with a total of 962 spacers with at least 12 months of follow-up. Of the 962 antibiotic cement spacers, 707 were static and 255 were articulating. The mean follow-up was 56 months in the static spacers and 40 months in the articulating spacers. They found both static and articulating spacers had similar improvements in knee society scores, with a mean of 82 and 83 points, respectively. Both spacer blocks had shown improvements in ROM when compared to their preoperative ROM, but a statistical difference was noted when comparing the two. The static spacers had a mean

final ROM of 92° compared to the mean final ROM for the articulating spacers of 100°. The authors did not find a statistical difference in infection rates between the two spacer blocks [27, 28]. In addition to a high rate of eradication of infections when utilizing static antibiotic cement spacers, Lichstein et al. found a median final ROM of 100° in their retrospective study of 107 cases [19]. We recommend that static antibiotic spacers be used in the presence of significant bone loss and involvement of the surrounding soft tissues.

Typically revision total knee implants are utilized during the second stage to address collateral ligament deficiencies and/or bone loss. The mode of fixation of a stemmed prosthesis is controversial. Cementing will allow for increased delivery of antibiotics; however, diaphyseal-engaging uncemented stems will allow for easier removal in the presence of reinfection. Studies have not shown that one method is better in regard to reinfection rates [29]. We recommend a hybrid technique that includes metaphyseal cones, in part to address bone defects, but also philosophically in an attempt to obtain biologic fixation for long-term durability. We also utilized uncemented diaphyseal-engaging stems with cement applied to the undersurface of both the tibial and femoral component and cemented within the cones.

Key Points

- Two-stage revision arthroplasty is the gold standard for treatment of PJI in the United States.
- Obtaining the diagnosis is key to avoid delayed treatment.
- Preoperative WBC, ESR, CRP, and synovial fluid aspiration for cell count, gram stain, and culture will help make the diagnosis.
- Risk stratification and medical optimization preoperatively is crucial.
- Intraoperative fresh frozen sections, cultures, and fluid analysis can help confirm diagnosis at first stage or eradication of infection at the time of second stage.
- An antibiotic cement spacer (static or articulating) will aid in local delivery of antibiotics, tissue preservation, and improved knee function.

- We favor articulating cement spacers unless there is significant bone loss, in which case a static cement spacer is preferred. Anecdotally, we have not seen a difference in eventual knee ROM with either approach.
- Hybrid reconstruction techniques with a press-fit stem and components cemented within metaphyseal cones will result in a stable construct with potential for long-term biologic fixation, as well as adjunctive intra-articular delivery of antibiotics, and are our reconstruction method of choice for these patients.

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Management of Extra-articular Deformity

8

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Introduction

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Total knee arthroplasty in the presence of severe extra articular deformity is challenging. Such deformities mainly occurring secondary to femoral or tibial fracture malunion, failed osteotomy, prior physeal injury, congenital deformity, metabolic bone disease, and skeletal dysplasia. In these situations, the standard principles of TKA still apply, including restoration of the mechanical alignment

and soft tissue balance. The challenge relates to the implications of the distal femoral and proximal tibial bone resection in both the coronal and sagittal planes. The extra-articular deformity must in some way be corrected by the bone resection. There are several options for correction of the deformity; one is arthroplasty with intra-articular correction, or combined with an extra-articular corrective osteotomy, either as a staged or simultaneous procedure.

The choice of procedure is dependent upon the location and degree of deformity. The proximity of the extra-articular deformity directly

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impacts the intra-articular bone resection. The closer the deformity is to the joint, the greater will be the impact on the bone resection. Wolff suggested that the addition of an extra-articular osteotomy at the site of the deformity would aid in achieving appropriate limb alignment in severe femoral or tibial angular deformities, thus allowing routine TKA to be performed without compromise to the joint stability provided by the collateral ligaments [1]. Wang and Wang reported that intra-articular correction of deformities can be performed when the femoral coronal deformity is $<20^\circ$ and the tibial coronal deformity is $<30^\circ$. Beyond these limits, extra-articular corrective osteotomy should be performed [2]. In planning for correction of an extra-articular femoral deformity, if the planned distal coronal resection is proximal to the epicondyles and violates the attachment of the collateral ligaments, then a corrective osteotomy should be performed. For a tibial deformity, if the planned proximal tibial coronal resection places the tibial mechanical alignment outside of the tibial plateau, then an osteotomy should be performed. The appeal of a corrective osteotomy is that the femoral or tibial alignment can be restored in all planes, and a conventional TKA can be performed with routine soft tissue balance. The disadvantage is that osteotomy is a more complex procedure with the chance of nonunion, infection, and hardware that may impede instrumentation or component position.

With intra-articular correction of these deformities, restoration of a neutral mechanical axis can be accomplished by compensatory positioning of the components. Soft tissue balancing in these complex cases may be more difficult requiring extensive soft tissue releases or even constrained implants.

More recently, computer-assisted TKA has been found to be a useful alternative to conventional TKA for knee arthritis with extra-articular deformity, especially in the presence of retained hardware [3].

Correction of an extra-articular deformity during TKA is a technically demanding procedure. It is the restoration of the mechanical alignment of the limb that is critically important. The follow-

ing case reports will describe the various techniques used for managing these complex cases.

Option 1: Tibia—Correction with the Implant

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Case Presentation

History

The patient is a 63-year-old female who presents with a primary complaint of right knee pain. She reports a history of trauma to the right lower extremity sustained during a motorcycle accident at the age of 21. Treatment at the time of injury included open reduction internal fixation of an open tibia fracture and intramedullary nailing of a segmental femur fracture. She subsequently underwent removal of hardware approximately 6 years after the index operations. She reports no history of infection related to the injury or subsequent surgical procedures.

At the time of presentation, she describes right knee pain that has progressively worsened over the past 4 years. The pain is located to the anterior, medial, and lateral aspects of the knee. Despite prior conservative measures including anti-inflammatory medications, physical therapy, and cortisone injections, her pain has progressed to the point that it now affects her quality of life. She has difficulty ascending and descending stairs and has a walking tolerance of less than four blocks.

Other pertinent past medical history includes hypertension, hyperlipidemia, depression, and paroxysmal atrial fibrillation.

Physical Examination

The patient is a healthy-appearing female with a BMI of 23.9 (height 160 cm, weight 61 kg). She ambulates with an antalgic gait attributable to the right knee. Examination of the right lower extremity demonstrates well-healed scars over the lateral hip, thigh, anteromedial knee, and anterolateral tibia. There is no evidence of infection. There is a valgus deformity of her tibia

centered at the mid-diaphysis measuring approximately 9°.

Examination of the knee demonstrates a mild effusion. She is tender to palpation over both the medial and lateral joint lines. Range of motion is 5–100° of flexion. The knee is stable to both varus and valgus stress with firm endpoints at 0°, 30°, 60°, and 90° of flexion. Motor and sensory examination of the right lower extremity is intact with palpable pulses of both the dorsalis pedis and posterior tibial arteries.

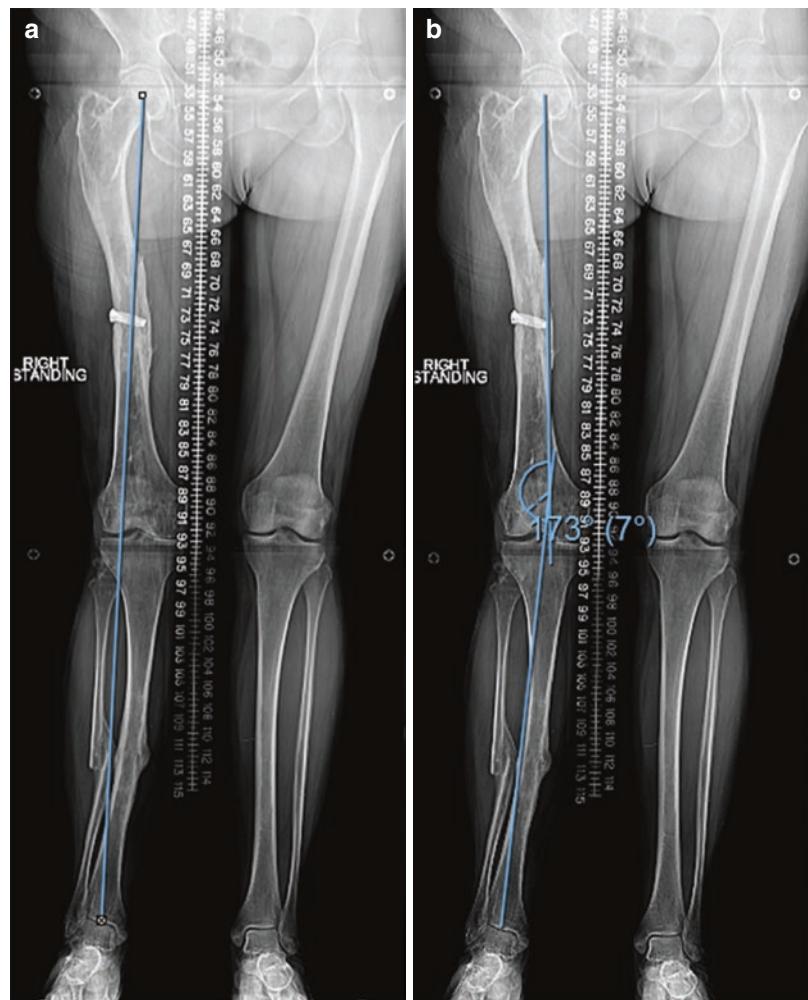
Imaging

AP, lateral, 45° PA, and patellofemoral radiographs of the knee demonstrate tricompartmental arthrosis of the knee worst within the medial compartment (Fig. 8.1). Full-length standing radiographs of the bilateral lower extremities demonstrate an overall mechanical valgus alignment of the right knee of 7° (Fig. 8.2). Post-traumatic deformity of both the femur and tibia is evident. Valgus deformity of the tibia secondary to a mid-diaphyseal fracture measures approximately 9° (Fig. 8.3).



Fig. 8.1 Anteroposterior (a), lateral (b), 45° posterior-anterior (c), and patellofemoral (d) radiographs of the knee demonstrate tricompartmental arthrosis, worst within the medial compartment

Fig. 8.2 Full-length standing radiographs (**a, b**) of the bilateral lower extremities demonstrate an overall mechanical valgus alignment of the right knee of 7°. Post-traumatic deformity of both the femur and tibia is evident



Approach

Challenges and Options

The objectives of total knee arthroplasty (TKA), namely, restoration of mechanical alignment and optimal soft tissue balancing, remain the same for cases involving extra-articular deformity. However, patients with arthritis and extra-articular deformity present a unique technical challenge. The principal question that must be answered is whether neutral mechanical alignment can be reestablished through intra-articular bone resections alone or whether an extra-articular osteotomy is necessary. This decision should be based on all available evidence including the magnitude of the deformity, the distance of the

deformity from the knee, and the direction of the deformity (coronal, sagittal, or rotational). Sagittal or rotational deformities often cannot be corrected with intra-articular bone resections alone and typically require a corrective osteotomy either before or concurrent with TKA. Clinical examination of the patient is also essential in order to evaluate supportive soft tissue structures and patient characteristics such as age, weight, function, bone quality, underlying disease, infection, and the presence of retained hardware.

Adequate planning must also include pre-operative templating in order to confirm that bone cuts perpendicular to the mechanical axis of both the femur and tibia are feasible. On the femoral side, the limitation of intra-articular



Fig. 8.3 Valgus deformity of the tibia measures approximately 9° with the center of rotation of angulation located within the diaphysis

correction of an extra-articular deformity is the collateral ligament origins. Because the femoral origins of the medial and lateral collateral ligaments are approximately 25 mm from the joint line, the limitation of femoral resection has traditionally been described as no greater than 20 mm [1]. In the setting of tibial deformity, intra-articular correction has traditionally been indicated when the anatomical axis of the tibia distal to the deformity does not violate the tibial insertions of the collateral ligaments or, similarly, the line of the anatomical axis passes within the tibial condyle (Fig. 8.4) [2]. There comes a point when the magnitude of deformity becomes sufficiently large, particularly if the deformity is adjacent to the articular surface, that intra-articular correction of the deformity will compromise the ligamentous envelope. Prior studies have recommended a limit of deformity of 10° or more in the coronal plane or 20° or more in the sagittal plane [1]. For those cases, a staged or simultaneous corrective extra-articular osteotomy is likely indicated.

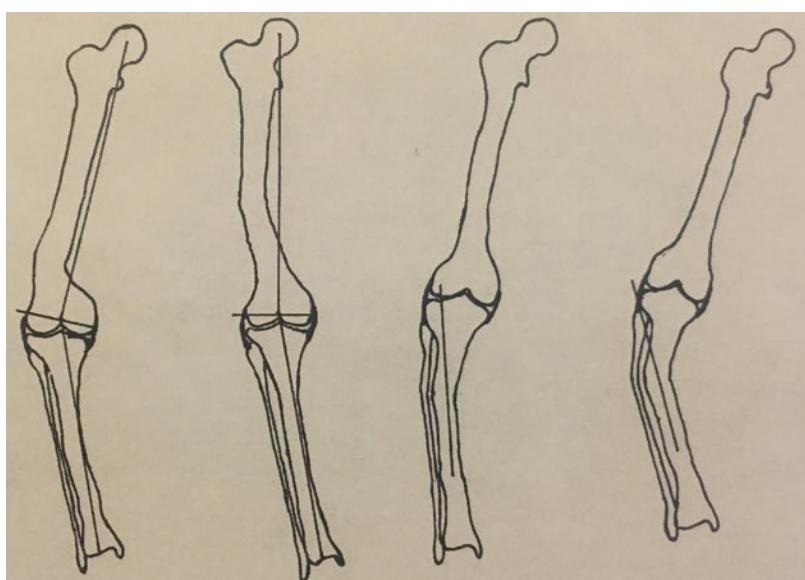


Fig. 8.4 Intra-articular correction of extra-articular deformity is limited by the origins of the collateral ligaments. Because the femoral origins of the medial and lateral collateral ligaments are approximately 25 mm from the joint line, the limitation of femoral resection has traditionally been described as no greater than 20 mm. Deformity in close proximity to the articular surface requires a larger compensatory correction, posing a

greater risk to the collateral ligaments. In the setting of tibial deformity, intra-articular correction has traditionally been indicated when the anatomical axis of the tibia distal to the deformity does not violate the tibial insertions of the collateral ligaments or, similarly, the line of the anatomical axis passes within the tibial condyle (From Wang and Wang [2], with permission)



Fig. 8.5 Preoperative digital templating estimated that a 7° varus resection would be necessary in order to cut perpendicular to the mechanical axis of the tibia



Fig. 8.6 Preoperative digital templating revealed that placement of the tibial component after a 7° varus resection would position the peg of the component within very close proximity to the lateral cortex of the proximal tibia. For this reason, the decision was made to reduce the magnitude of the varus resection to 5.5°

Preoperative Planning

With the objective of restoring neutral mechanical alignment of the knee, bony resections were determined using orthopedic digital preoperative planning software. Due to the valgus deformity of the tibia, a 7° varus resection (remove more medial than lateral bone) was calculated to be necessary in order to cut perpendicular to the mechanical axis (Fig. 8.5). However, preoperative templating revealed that a 7° varus resection would position the peg of the tibial component within very close proximity to the lateral cortex of the proximal tibia (Fig. 8.6). To reduce the risk of potential conflict between the tibial component and lateral cortex, the decision was made to make a 5.5° varus tibial resection. To account for the residual valgus of the tibia, the distal femoral resection was planned to be performed at 1.5° varus to the mechanical axis of the femur.

Due to the presence of femoral deformity and the potential difficulties associated with passing an intramedullary alignment guide, patient-specific instrumentation (PSI) was selected. Additionally, PSI was chosen with the goal of improving surgical accuracy in order to facilitate the specific resections calculated for both the tibia and femur.

Implant Choice

Stability is dependent on intact ligaments in combination with the prosthesis articular design and limb alignment. For cases in which the extra-articular deformity can be corrected with bone resections alone, stability of the knee is dependent on adequate soft tissue balancing and appropriate component sizing. For the majority of cases, flexion/extension gap balancing can be adequately achieved and a non-constrained implant design therefore sufficient. In the setting of severe deformity, a well-balanced knee may be unattainable or attainable only with significant releases that result in ligament compromise. In those cases, an extra-articular osteotomy should be considered in order to reduce the amount of intra-articular correction necessary with the goal of preserving the soft tissue envelope. This strategy may allow the surgeon to restore mechanical alignment of the limb while avoiding soft tissue releases that necessitate the use of a varus-valgus constrained, or even hinged, prostheses. For

the current case, a posterior-stabilized articular design was selected as the patient had preserved collateral ligaments and it was anticipated that flexion/extension balancing could be achieved. In cases of severe deformity or those associated with poor bone quality, one may consider using stemmed implants and/or augments in order to provide additional fixation and construct durability.

Procedure

The approach is performed through a medial parapatellar incision approximately 10 cm in length, followed by a midvastus arthrotomy. After adequate exposure of the knee is obtained, the knee is flexed and the patella subluxed.

The prefabricated femoral guide is then placed onto the distal femur. Correct position is achieved by pushing the guide into the trochlear groove and down onto the distal femoral condyles; any anterior soft tissue potentially blocking the guide should be removed. Rotation and AP position of the femoral component is then set by drilling the distal holes. The guide is then secured to the femur with headed pins placed through the distal holes. Rotation of the guide can be checked by referencing the vertical line on the distal face of the guide as compared to the sulcus line of the trochlear groove or the transepicondylar axis. The anterior face of the block is then secured to the femur by placing pins through the anterior guide holes. Prior to performing the distal femoral resection, alignment of the cut should be checked using an external alignment rod. The prefabricated guide is then removed, and prior to placing the 4-in-1 AP cutting block, the rotation guide holes are again checked to confirm appropriate rotation. The appropriately sized 4-in-1 AP cutting block is then placed and femoral cuts completed.

The tibial resection is then performed using the patient-specific tibial cutting guide after the menisci have been removed along with any soft tissue that could potentially interfere with proper placement of the cutting guide. The key contact areas for the tibial cutting guide are the medial and lateral tibial plateaus and the anteromedial tibial cortex. Pins are then placed into the proximal

holes followed by headless pins into the anterior holes. Prior to making the tibial resection, an external alignment rod is used to confirm appropriate guide alignment. After the resection has been performed, the tibial alignment guide is again used to check the accuracy of the cut.

The knee is then brought into full extension and the extension gap checked with a spacer block. For this case, given the extent of medial bone resected in order to correct the valgus deformity of the tibia, the lateral side of the knee required a soft tissue release. This was performed by sequentially pie crusting the posterolateral corner/arcuate complex and iliotibial band until the extension gap was noted to be symmetric.

Lamina spreaders are then used to tension the knee in flexion and remove the remnants of the anterior cruciate ligament, the posterior cruciate ligament, and the remnants of the medial and lateral menisci. Posterior osteophytes should be removed using a curved osteotome.

The flexion and extension spaces are then checked with a spacer block and the alignment of the resections checked with an alignment rod. If the gaps are not determined to be equal, corrections are made to ensure their equivalence. Because valgus deformities require medial intra-articular over-resection of the tibia, medial instability is most commonly encountered. In order to balance the knee, lateral releases are therefore typically required in order to balance the soft tissue envelope. Conversely, varus deformities require a lateral over-resection producing lateral instability and a compensatory medial release.

After the knee is appropriately balanced in both extension and flexion, and the alignment of both the femoral and tibial cuts confirmed to be correct, trial components are placed and the appropriately sized polyethylene insert selected. The patella is resurfaced. The components are then cemented in standard fashion.

Postoperative Result

Postoperative radiographs demonstrate successful restoration of neutral mechanical alignment of the right lower extremity (Fig. 8.7). By accounting for the valgus deformity of the tibia with both the tibial and femoral bone resections, neutral alignment



Fig. 8.7 Postoperative full-length standing radiographs demonstrate successful restoration of neutral mechanical alignment of the right lower extremity

has been reestablished. AP, lateral, and patellofemoral views of the knee demonstrate well-aligned and well-fixed components (Fig. 8.8). The femoral component is in slight varus (approximately 1.5°) to the mechanical axis to compensate for the relative 1.5° of valgus resection of the tibia (Fig. 8.9). Posterior condylar offset has been restored and the tibial slope is appropriate at approximately 3°. The patella appears to be well aligned within the trochlear groove.

At the patient's 6-week postoperative visit, she was noted to be walking without an assistive device. Her wound appeared well healed. She had no subjective feelings of instability. Examination of the knee demonstrated a range of motion of approximately 2–130° of flexion with good stability throughout range of motion.

Clinical Results

The magnitude of extra-articular deformity that can be safely corrected by a single-stage procedure without corrective osteotomy has been heavily debated in the literature [4, 5]. There are

certainly potential benefits of a single-stage intra-articular correction when considering both the patient and the cost of care. Lonner et al. reported the effective management of extra-articular deformity with simultaneous corrective osteotomy but with some complications and technical difficulty [6]. Extra-articular osteotomy can lead to malunion or nonunion, increase the risk of surgical site infection, and delay rehabilitation resulting in a more difficult recovery and potentially worse range of motion and ultimate function.

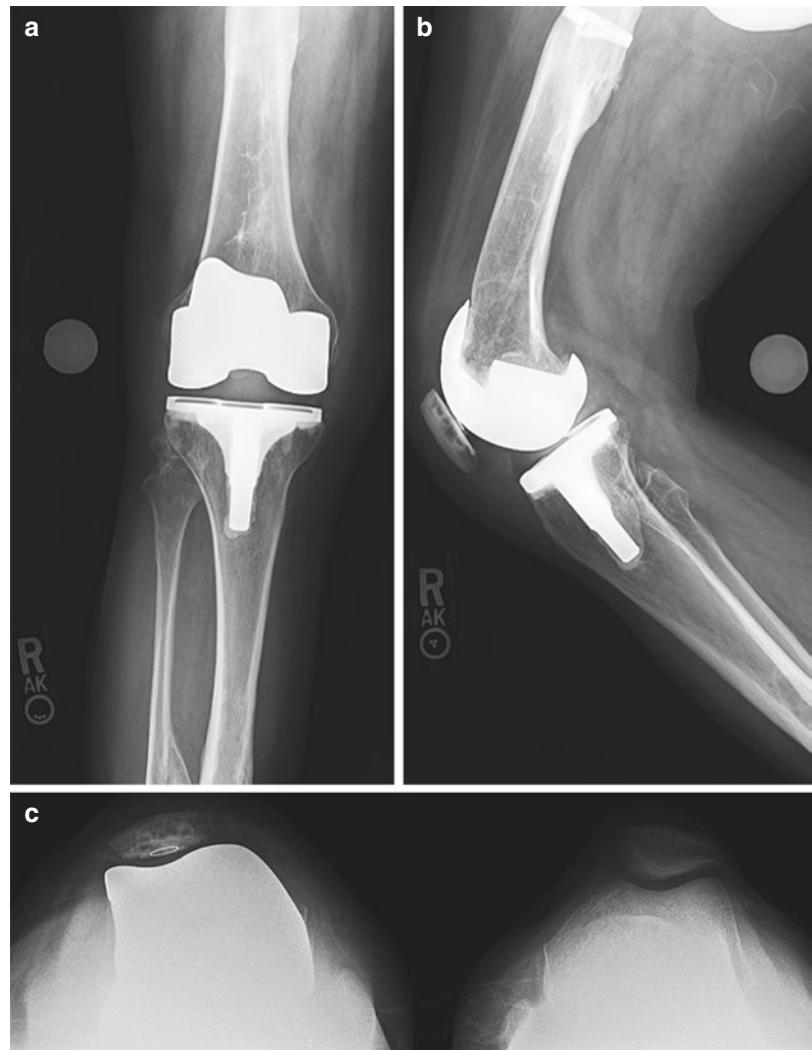
Wang et al. reported the results of 15 patients with extra-articular deformity, 8 of which had deformity of the tibia with an average deformity of 19° in the coronal plane (10–30°) [2]. All underwent TKA with a single-stage intra-articular correction. They report significant improvements in Knee Society Score (KSS) and range of motion while correcting mechanical alignment to neutral in all knees. There were no complications such as infection, ligament instability, or component loosening with an average follow-up of 38 months.

Marczak et al. evaluated 36 knees (27 with tibial deformity and 11 with femoral deformity) after TKA with intra-articular correction [7]. The average preoperative deformity was 21.4° of varus or 18.6° valgus. All patients with the exception of one displayed improvements in both KSS and range of motion at a mean follow-up of 4.8 years. The patient with a poor outcome required revision for aseptic loosening of the tibial component. Neutral mechanical alignment was restored in all but four knees and no other complications were reported.

Rajgopal et al. reported their series of 36 knees, all of which underwent intra-articular resection with soft tissue balancing in order to correct extra-articular deformity [8]. The average tibial coronal deformity among 20 knees within the cohort was 21° (12–24°); average follow-up was 85 months. They found significant improvements in KSS, range of motion, and an average correction of alignment to within 2° from neutral. No complications were reported.

With the development of new technologies such as computer-assisted navigation and patient-specific instrumentation, numerous options are available to assist the surgeon in order to accu-

Fig. 8.8 Anteroposterior (a), lateral (b), and patellofemoral (c) views of the knee demonstrate well-aligned, well-fixed, and appropriately sized components. Posterior condylar offset has been restored and the tibial slope is appropriate at approximately 3°. The patella appears to be well aligned within the trochlear groove



rately restore mechanical alignment in the setting of extra-articular deformity [9, 10]. In a multi-center retrospective study including ten patients with extra-articular deformity, PSI was used to perform single-stage TKA with intra-articular correction [11]. At a mean follow-up of 3.4 years, KSS scores were found to be significantly improved, and limb alignment was restored with a mean hip-knee-ankle angle of $179.3^\circ \pm 1.3^\circ$. The authors conclude that PSI is an effective alternative to conventional instruments for correcting mechanical alignment and, as compared to computer-assisted navigation, does not require the identification of bony landmarks which may be difficult in the setting of deformity.

Several studies have also evaluated the efficacy of computer-assisted surgery (CAS) for TKA in the setting of extra-articular deformity, most of which include relatively small series of patients and short lengths of follow-up [12]. Mullaji et al. reported the results of 40 extra-articular deformities (22 femoral and 18 tibial) that underwent TKA with CAS [13]. They found significant improvements in KSS with mean postoperative limb alignment of 179.1° . Similar to PSI, although CAS may allow for relatively precise bone cuts and implant placement, there is insufficient evidence to conclude that these technologies result in superior clinical results or longer implant survival.



Fig. 8.9 The femoral component is in slight varus (approximately 1.5°) to the mechanical axis of the femur to compensate for the relative 1.5° valgus resection of the tibia. By accounting for the valgus deformity of the tibia with both the tibial and femoral bone resections, neutral alignment was successfully reestablished

Key Points

- Treatment of extra-articular deformity of the tibia with a single-stage intra-articular correction is the preferred intervention when performing TKA as extra-articular osteotomy delays recovery and increases the risk of post-operative complications.
- Numerous factors must be considered when deciding if intra-articular correction is possible, including the magnitude of deformity, the distance of the deformity from the knee, the direction of the deformity, the integrity of surrounding soft tissue structures, and patient factors such as age, BMI, function, bone quality, and comorbidities.
- Preoperative planning is essential in order to confirm that intra-articular correction is possible. The tibial bone cut must not violate the insertion of the collateral ligaments.
- With more significant deformities, relative over-resection of the lateral tibia (in a varus

knee) or the medial tibia (in a valgus knee) can create relative laxity on the side of over-resection. Meticulous soft tissue balancing is therefore essential in order to maintain optimal stability of the knee while restoring mechanical alignment.

- Patient-specific instrumentation and computer-assisted navigation are effective alternatives that may facilitate TKA for patients with deformity that precludes the use of conventional instrumentation.

Option 2: Tibial Osteotomy and TKA

Michael J. Assayag and S. Robert Rozbruch

Case Presentation

History

This is the case of a 60-year-old retired physical therapist who was referred to us with a chief complaint of right knee pain and instability with valgus and external rotation deformity of the lower extremity, associated with a leg length discrepancy. His past medical history is positive for atrial fibrillation, hypothyroidism, and dyslipidemia for which he takes warfarin, levothyroxine, and atorvastatin. He denies tobacco, drug, and alcohol use.

When he was 5 years old, he sustained a crushing injury to the right leg for which he underwent multiple surgical procedures that resulted in a drop foot. At age 15, he underwent a triple arthrodesis of the hind foot. Of importance, he also has a history of previous tibia osteomyelitis related to the initial injury.

He is reporting severe pain in the right knee during weight-bearing activities, which has been gradually worsening in the past 5 years. He is unable to walk without assistive device. A decrease in activity level and nonsteroidal anti-inflammatory medication seem to partially alleviate the pain.

Physical Examination

On physical examination, the patient is 5'5" and weighs 175 lb. He has gross instability of

the knee with valgus and hyperextension noted. There appears to be valgus and external rotation deformity in the leg. The right leg is short and gait is grossly abnormal (Fig. 8.10). He walks with a cane on the medial border of the foot, and the foot progression angle is externally rotated. The soft tissue envelope on the medial border of the distal tibia is scarred and the skin is discolored. His sensation to light touch is preserved, and pedal and posterior tibial pulses are palpable.

The right ankle motion ranges from neutral position to 30° of plantarflexion and is painless. Subtalar motion is absent. There is a drop foot. The right knee motion ranges from 25° of hyperextension to one 120° of flexion, with a grade 3 valgus instability. The thigh foot axis is 45° external on the right compared to 15° external on the left.

Radiographs and Advanced Imaging

A 51 in. bipedal standing anteroposterior (AP) hip to ankle radiograph (Fig. 8.11) and dedicated knee and ankle radiographs were obtained (Figs. 8.12, 8.13, and 8.14). Radiographs displayed a 7.7 cm leg length discrepancy, a 28° valgus deformity of the knee with severe osteoarthritis and medial subluxation, midshaft tibia valgus deformity and right ankle valgus deformity, and severe osteoarthritis.

Surgical Approach

Preoperative Problem List

- There are three levels of deformity—knee, tibia, and ankle.
- 28° valgus of the right knee with osteoarthritis, grade 3 valgus instability.

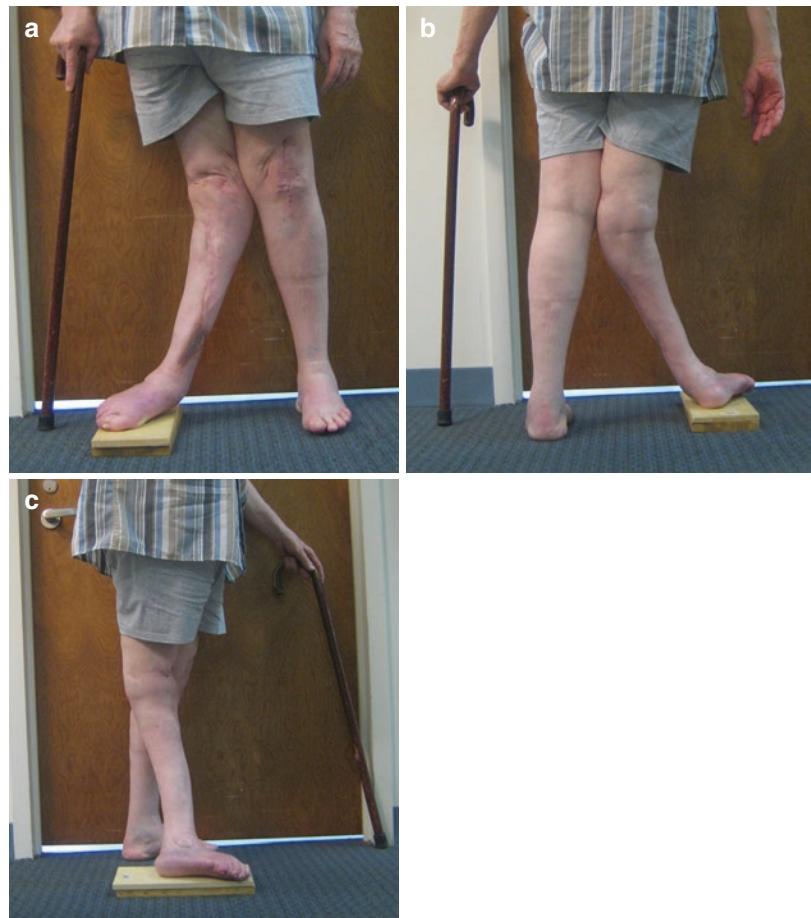


Fig. 8.10 Front (a), back (b), and side (c) views of the multilevel deformity—knee, tibia, and ankle



Fig. 8.11 51 in. anteroposterior (AP) hip to ankle radiograph shows a 7.7 cm leg length discrepancy and a multi-apical valgus deformity of the right lower extremity

- 20° valgus deformity of the tibia, 30° external rotation.
- Severe ankle osteoarthritis with 13° intra-articular valgus deformity.
- 28° valgus of the right knee with osteoarthritis, grade 3 valgus instability.
- Intra-articular correction would require excessive bone resection of the medial tibial plateau and all its remaining stabilizing structures and would dramatically decrease bone stock.
- Leg length discrepancy of 7.7 cm.
- History of osteomyelitis.

The surgical plan is to correct the leg and ankle deformity first and then correct the knee deformity with a total knee replacement. It is not possible to correct the entire lower extremity deformity through a total knee replacement without excessive bone resection.

It is imperative to recognize the extra-articular nature of the deformity and to carefully plan a staged correction. The first step in treatment is to reestablish a normal mechanical axis distal to the knee. Considering the quality of the soft tissue envelope and the magnitude of this multiaxial deformity, a gradual tibia deformity correction

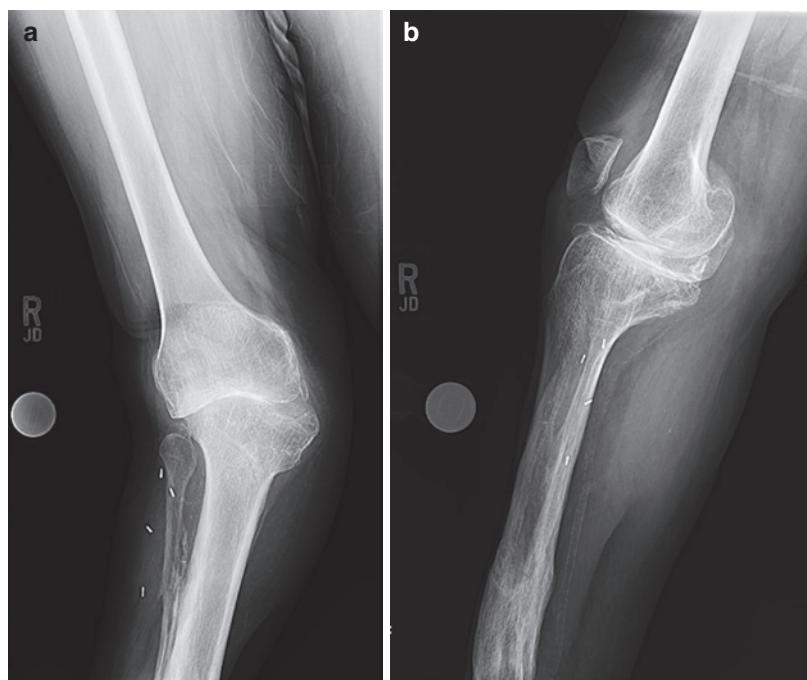


Fig. 8.12 Anteroposterior (AP) (a) and lateral (b) views of the knee show severe osteoarthritis of the knee with valgus deformity and medial subluxation, lateral femoral condyle hypoplasia, and lateral tibia plateau erosion

Fig. 8.13 Anteroposterior (AP) (a) and lateral (b) views of the tibia showing an extra-articular mid-diaphyseal valgus deformity

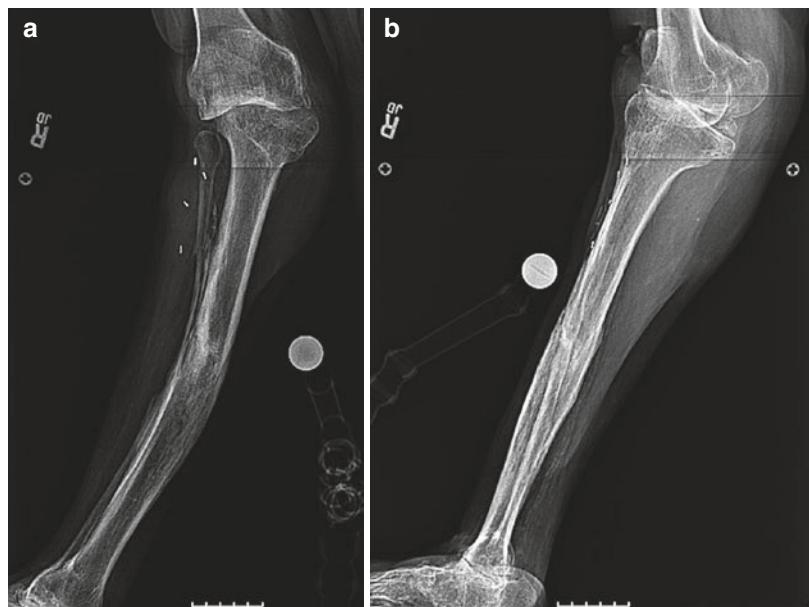
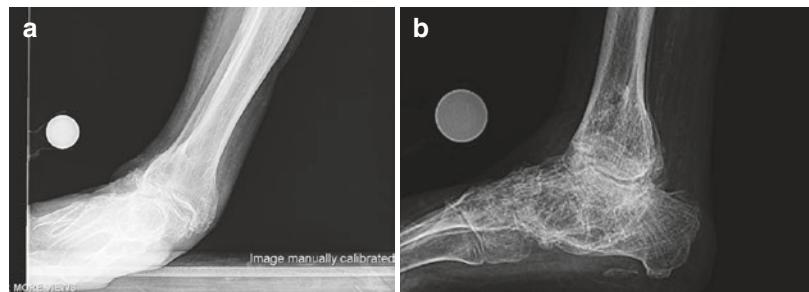


Fig. 8.14 Anteroposterior (AP) (a) and lateral (b) ankle views show severe osteoarthritis with valgus tilt of the talus. Previous well-healed triple arthrodesis



with circular hexapod external fixation is our method of choice. It is followed by an ankle arthrodesis using a modification of the same external fixator.

Tibia Diaphysis Deformity Correction with Circular Hexapod External Fixator

The patient is brought to the operating room and positioned supine on a Jackson table following regional anesthesia. A bump is placed underneath the right buttock for the patella to face forward during the procedure. Iodine disinfection is performed and an extremity sheet is used for draping. A tourniquet applied at the base of the thigh is inflated at 250 mmHg after exsanguination with an Esmarch band.

A fibular osteotomy is performed through a 3 cm lateral incision over the mid fibula.

Dissection is carried down to the fascia, which is incised carefully avoiding the peroneal nerve's superficial branch. The interval between the lateral and deep posterior compartment is used to reach the fibula. The periosteum from the anterior and posterior surfaces of the fibula is elevated, and under retractor protection, the fibula is cut with multiple drill holes and osteotome technique. A 1.8 sharp Ilizarov wire or equivalent drill bit is used to do a row of bi-cortical holes through the bone. Careful irrigation and cleaning of the drill bit flutes is necessary to prevent thermal necrosis. An osteotome is then used to complete the osteotomy along the line of holes. Translation at the osteotomy site confirms its completion. From the same incision, a fasciotomy of the lateral compartment is performed. Percutaneous fasciotomy of the anterior

compartment is performed using a 10 mm incision directly over it at mid-tibia level.

The wounds are irrigated and closed and the tourniquet is deflated. The circular hexapod external fixator (CHEF) made of two ring blocks with each four points of fixation to the tibia is then applied orthogonal to the desired proximal and distal mechanical axes. The fixation of the proximal ring block was placed peripherally in the bone to avoid contamination of the intramedullary canal. This was done to prevent contamination of the future total knee replacement [14].

The frame mounting parameters are obtained [15], and the osteotomy site is identified under fluoroscopic guidance. A 10 mm longitudinal skin incision is made at that level, just lateral to the tibial crest. The periosteum is elevated medially and laterally with a thin periosteal elevator. We proceed to a percutaneous, low-velocity, multiple drill hole osteotomy using a 4.8 mm sharp drill bit and an osteotome. The tibia was noted to be sclerotic but without any sign of infection. The fragments are then stabilized with the 6 telescopic external fixator struts [16, 17].

With the help of the CHEF software, a correction program is generated with a safe rate of dis-

traction of 1 mm/day that starts on postoperative day 7. Deep venous thromboprophylaxis and pin site care with saline and peroxide solution is initiated POD2. The patient is allowed partial weight bearing for the length of correction.

Once the deformity is fully corrected and the mechanical axis of the tibia is restored (Fig. 8.15), we proceed to the second step in treatment. The objective is to realign the ankle and hindfoot with the mechanical axis of the leg and provide a painless plantigrade foot. The patient is brought back to the operating room to perform an ankle arthrodesis using a modification of the existing external fixator (Fig. 8.16).

In this case, the ankle fixator was removed 6 months after the initial surgery with radiological confirmation of the tibiotalar arthrodesis site. Tibia bone healing was delayed. The tibia fixator was removed after 12 months, and the leg was fitted for a custom molded high AFO and casted. There was no evidence of deep pin infection during the external fixation period.

Once the extra-articular deformity is corrected, we are left with a complex valgus unstable knee with osteoarthritis that can be treated by total knee replacement using the

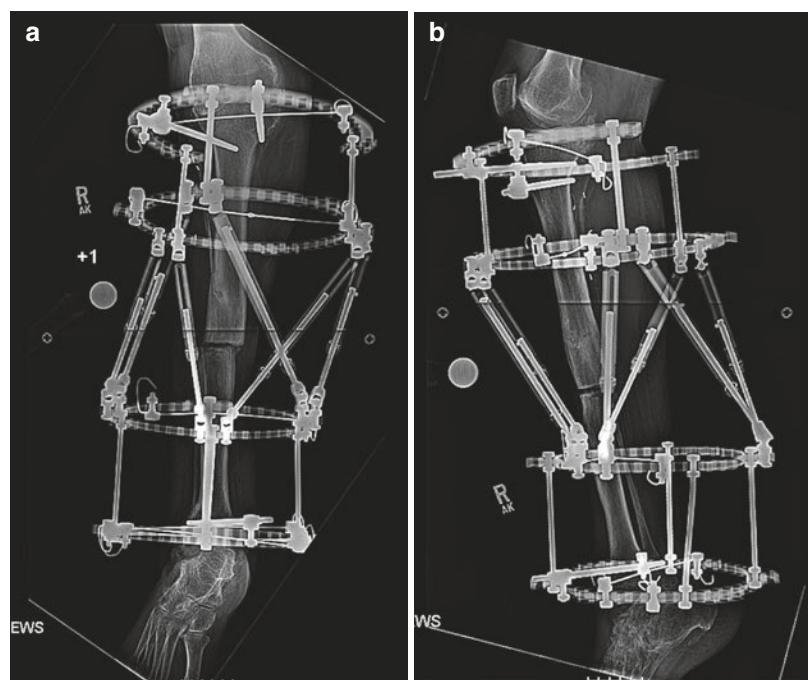


Fig. 8.15 Anteroposterior (AP) (a) and lateral (b) views of the tibia at the end of the gradual correction, 5 weeks after surgery

Fig. 8.16 Anteroposterior (AP) (a) and lateral (b) views of the external fixator modification to complete an ankle arthrodesis

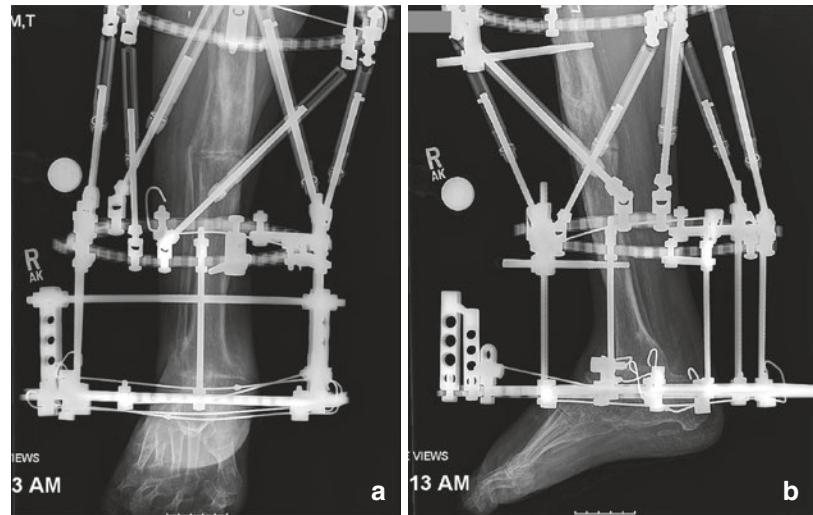
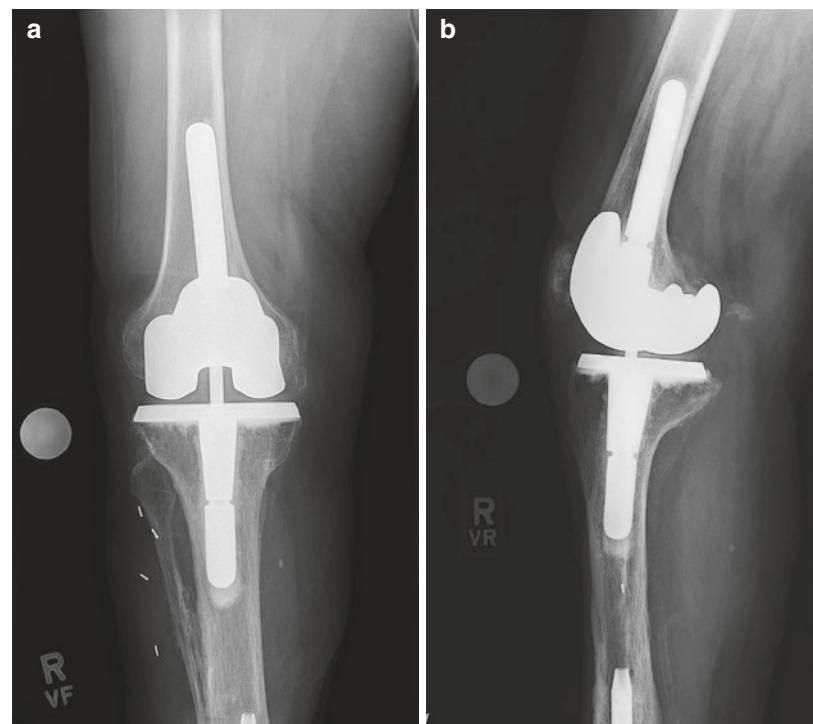


Fig. 8.17 Anteroposterior (AP) (a) and lateral (b) views of the well-positioned semi-constrained total knee arthroplasty



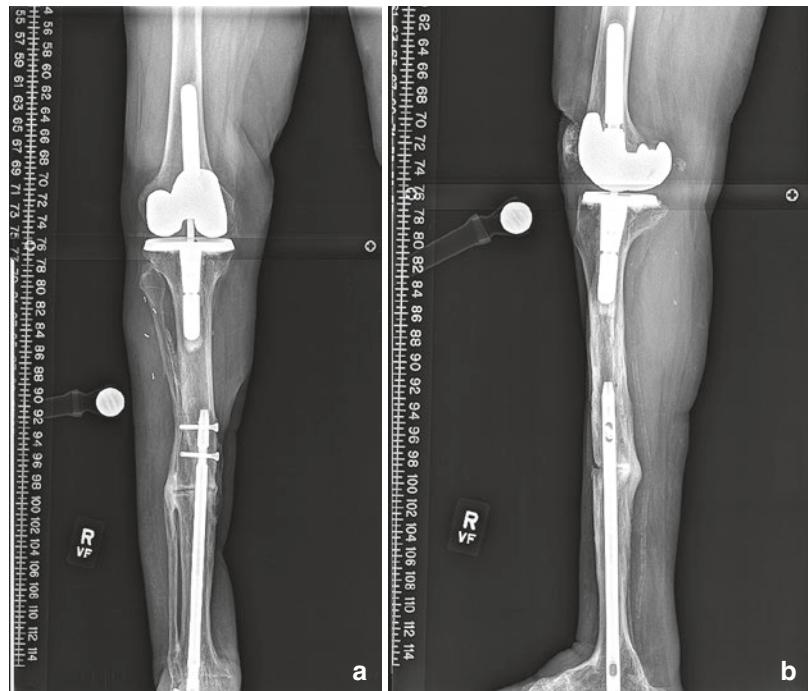
necessary amount of constraint to achieve stability. A semi-constrained implant with stems was sufficient to achieve stability of the limb (Fig. 8.17).

There was concern of insufficient bone healing at the osteotomy site; prophylactic tibio-talo-calcaneal nailing was performed (Fig. 8.18).

Postoperative Result

The patient was allowed 50% weight bearing, and physical therapy was performed to regain full range of motion. Six weeks later, the patient noticed a wound breakdown over the distal aspect of the locking plate, which was exposed over 10 mm^2 without communication with the

Fig. 8.18 Anteroposterior (AP) (a) and lateral (b) views of the tibiae demonstrate good alignment, sufficient bone healing, and no sign of instability



prosthesis. He was brought back to the operating room for plate removal and insertion of reamed antibiotic cement-coated tibio-talo-calcaneal nail, and a negative pressure therapy dressing was applied for the wound breakdown. An infectious disease consultation was obtained, and a course of 6 weeks of IV antibiotics with vancomycin and rifampin was given. The wound gradually healed and the patient progressed in activity as tolerated. Upon the latest follow-up, 6 years after the end of the surgical treatment, the patient was complaint free and had increased his level of function, including walking without assistive device and bowling. His overall mechanical alignment was clinically neutral (Fig. 8.19), the foot plantigrade, and he compensated for a 20 mm leg length discrepancy with a rocker bottom platform elevation of the right shoe. The knee motion ranged from full extension to 115° of flexion, painlessly (Fig. 8.20).

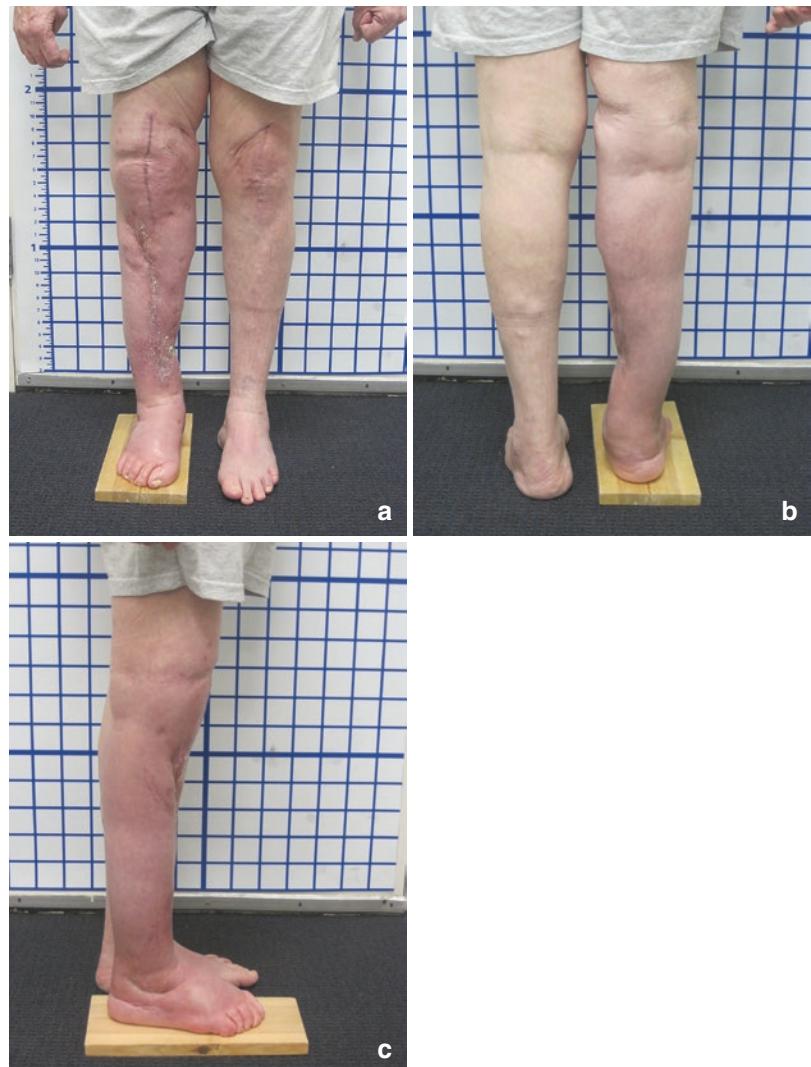
Clinical Results

There are very few reports of tibial osteotomy in association with a TKA. Mullaji et al. treated 173 “profound varus deformity knees” and included a tibial osteotomy in only 9 cases. The nine knees were treated with the osteotomy and intramedul-



Fig. 8.19 51 in. hip to ankle radiograph shows neutral mechanical alignment (arrow) and well-positioned and semi-constrained total knee replacement

Fig. 8.20 Clinical pictures: front (a), back (b), and side (c) views of the right lower extremity at the end of treatment



lary stem protection with no reported complications [18]. Ishida et al. reported a case of thermal necrosis in association with a TKA and a tibial osteotomy but felt that the combination of the osteotomy and TKA for extra-articular deformity was an effective treatment [19].

Key Points

- Correct the extra-articular deformity to normalize the tibial resection during subsequent total knee replacement.

- If a fixator is used, use circular hexapod external fixation to correct the extra-articular knee deformity. In this case, a large tibia deformity with poor soft tissue envelope was best corrected gradually.
- Preserve bone biology by performing a percutaneous low-velocity osteotomy with multiple drill holes and an osteotome.
- Address knee osteoarthritis with an implant with the minimal amount of constraint necessary to obtain stability.

Option 3: Correction of Femoral Extra-articular Deformity with Implant

Anton Khlopas, Grayson P. Connors,
Chukwuweike U. Gwam, Jaydev B. Mistry,
Ronald E. Delanois, and Michael A. Mont

Case Presentation

History

A 65-year-old man presented with post-traumatic osteoarthritis of the left knee secondary to a motor vehicle accident at the age of 24 years, during which he sustained a distal femoral fracture.

Physical Examination

On physical exam, he had a marked varus deformity of the left knee, an antalgic gait, and a 15° flexion contracture of the left knee.

Radiographs

On radiographic evaluation, the majority of the deformity was present on the femoral side. There was a total of 22° of varus angulation at the knee joint (Fig. 8.21).

Surgical Approach

Preoperative Evaluation

Extra-articular deformities of the lower extremity arise due to various causes, including malunited



Fig. 8.21 Preoperative lateral, anteroposterior (AP), and AP long-leg standing films

fractures, congenital or metabolic bone diseases, tumors, Paget's disease, and prior high tibial or distal femoral osteotomies [1, 20]. The principles that we will discuss in this chapter are going to deal with extra-articular deformities due to all of the above causes, except for proximal tibial and distal femoral osteotomies, which will be addressed in a different chapter. It is important to understand the causes of extra-articular deformities, as these may affect the treatment choice. Additionally, preoperative planning is needed to prevent component malpositioning, patella-femoral maltracking, or ligamentous imbalance [21, 22]. In addition, in this chapter we will be focusing on intra-articular corrections of deformities on the femur; however, there are similar ways to handle deformities on the tibial side as well.

One key to determining the correct treatment is to obtain long-leg standing radiographs [23]. This is especially important in patients with history of femoral fracture. The type of deformity correction in these patients depends on the magnitude as well as the location of deformity on the femur (distance from the knee). Deformities that are located near the hip joint have minimal effect on knee joint alignment, while deformities located closer to the knee joint have a larger effect. For instance, a 25° deformity located midway (50%) between the femoral head and the knee joint creates a 12.5° (one half) deformity at the knee joint. A 25° deformity located one-fifth of femoral length from the knee creates 20° deformity at the knee joint (only 20% of it at the knee). An easy way to calculate the contribution of the extra-articular angulation to the overall knee alignment is to measure the length of the proximal (P) and distal (D) femoral segments, find the percent contribution of the proximal segment [$P/(P + D) \times 100$], and multiply this number by the deformity angle. Here, we will discuss corrections of the more difficult cases ($>10^\circ$).

Other deformities of the femur and tibia may be concurrently present, and therefore a full radiographic evaluation of the long-leg standing radiograph needs to be performed. For example, if overall angulation of the knee is 24° varus, the angle of the extra-articular deformity located one-fifth of the femur length away from the knee

is 20°, mechanical lateral distal femoral angle (mLDFA) is 107°, and mechanical medial proximal tibial angle (mMPTA) is 82°; there may be a contribution from both femur and tibia to this deformity. The normal mLDFA is 88°; therefore, an angle of 107° represents a Δ mLDFA of 19°, which means 19° of knee deformity is a contribution from the femur. Similarly, the normal mMPTA is 87°; therefore, an angle of 82° represents a Δ mMPTA of 5°, which means there is a 5° deformity at the tibia. The extra-articular deformity contribution to the knee angulation is 16° (80% of 20°), which means there is an additional 4° varus deformity at the femur not accounted for by the specific extra-articular deformity.

Once one determines the true effect of the deformity at the knee, then one can use oblique bone cuts at the knee to perform the TKA appropriately. However, these oblique cuts can lead to collateral ligament balancing problems. For instance, for a severe valgus deformity, medial distal femur over-resection may be needed, which can lead to medial collateral ligament laxity during knee extension. Conversely, a severe varus deformity requires lateral distal femur over-resection, which may result in lateral collateral ligament laxity in extension. However, it is of lesser severity as lateral ligament deficiency can be compensated by tensor fascia lata and extensor mechanism structures. Therefore, it is important to template the cuts prior to the surgery and assess the implications of over-resection. If the over-resection needed to make the appropriate femoral cuts would be so large as to affect the collateral ligament origin, then an alternate strategy (extra-articular osteotomy) must be chosen to perform or stage the total knee arthroplasty.

Intraoperative Techniques

Intraoperatively, traditional intramedullary guides are not possible. Extramedullary alignment can be used by targeting the center of the femoral head (anterior superior iliac spine [ASIS] is not as accurate). An option is to place a marker on the patient's body at the center of the femoral head confirmed by an X-ray before the start of procedure. Theoretically, computer-assisted sur-

gery from preoperative computed tomography (CT) or magnetic resonance imaging (MRI) scans can be of use [13], but these require more resources, and in the case of CT scan, there is more radiation exposure.

Typically for deformities less than 20°, standard intra-articular corrections are sufficient for correction. In some cases, ligament reconstruction is needed, as well as simultaneous or two-stage osteotomy/arthroplasty. However, these are associated with higher risk of complications such as nonunion, arthrofibrosis, and infection [2, 6, 24].

Highly Constrained TKA

When the soft tissue structures can no longer support either a cruciate retaining or posterior-stabilized TKA, there are several types of constrained TKA designs that can be used. Knees with mild laxity may benefit from a high tibial post non-hinged design that augments the medial and lateral collateral ligament in providing stability. For severe deformity, a hinged rotating tibial platform is most commonly used. The femoral and tibial components are linked with connecting bars and bearings with a fixed extension stop. The final option of constraint includes a distal femoral replacement which includes a rotating hinged design. This is usually reserved for TKAs after tumor resections, but can be used in cases of severe bone loss after fractures or instability [25, 26]. The disadvantage of using a constrained prosthesis is the resulting higher load on the implant and implant bone interface. These components are able to withstand greater forces than traditional unconstrained designs, but may have increased wear, loosening, and possible eventual implant failure. Because of this, all constrained systems require the use of a medullary stem support to distribute the increased forces [27].

Constrained TKA prostheses may offer pain reduction in a select group of patients and have been associated with good outcomes after severe deformities [27, 28]. Hartford et al. [28] reported on outcomes following primary and revision TKA for severe deformity using a condylar constrained prosthesis with 82% of

patients classified as having a good outcome or better at 5-year follow-up. The mean post-operative Knee Society Score was 86 points. However, salvage knee reconstruction with rotating hinged devices may show suboptimal outcomes and should be reserved for elderly and sedentary patients according to a retrospective study by Pour et al. [29]. In 44 total knee arthroplasties in 43 patients, they observed Knee Society pain score improvements from a mean of approximately 29 to about 74 points postoperatively. Knee Society function scores showed improvement from a mean of 40–43 points postoperatively. Implant survivorships were 79.6% at 1 year and 68.2% at 5 years [29].

Postoperative Result

Extra-articular deformity was successfully corrected with intra-articular correction. No ligament reconstruction was performed (Fig. 8.22).

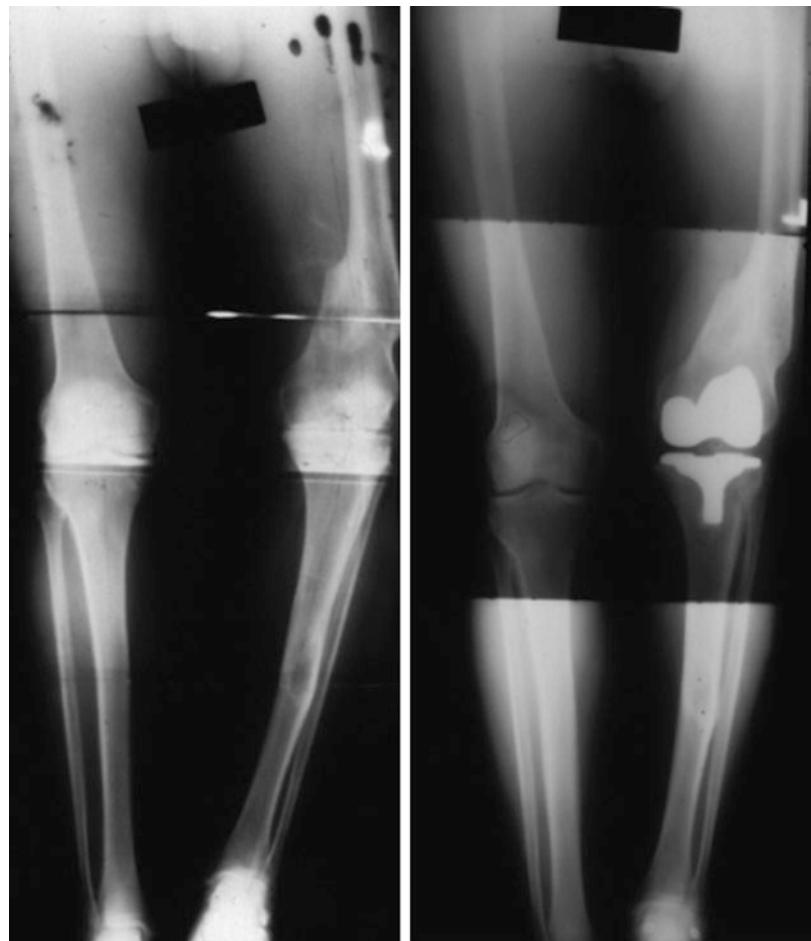
Clinical Results

At our institution, approximately 70% of 46 knees that had extra-articular deformities >10° were treated with standard arthroplasty techniques alone. The combination of intra-articular correction and ligament reconstruction was used in about 10% of cases. Osteotomy was performed about 20% of the time, including simultaneous and staged procedures.

Key Points

- Preoperative evaluation: Get long-leg standing films.
- Use extramedullary alignment guides.
- Determine mechanical axis angles.
- Measure magnitude of the deformity.
- Measure distance from the knee.
- Be aware that oblique bone cuts can lead to collateral ligament balancing problems.
- Lateral over-resection may lead to better stability in extension than medial over-resection because of compensating mechanisms.
- Stability in flexion is often not altered by varus/valgus extra-articular deformities.
- Sagittal plane alignment and rotational deformities can add to complexity.

Fig. 8.22 Postoperative anteroposterior (AP) long-leg standing films



Option 4: Femoral Osteotomy and TKA

Bertrand W. Parcells, Dexter K. Bateman,
Jared S. Preston, and Alfred J. Tria

Case Presentation

The patient is a 58-year-old female who presents with a painful, deformed left lower extremity. At the age of 8, she had polio that affected her right lower extremity leaving her with a weak quadriceps muscle and weak dorsiflexion. Subsequently, she underwent epiphysiodesis of the distal left femur in an attempt to equalize her leg lengths. She was left with a slightly shorter right lower extremity and a varus bowed distal left femur at

the end of her growth period. She used a lightweight brace for the right polio-affected knee along with a forearm crutch and put most of her weight on the left knee for many years.

Physical Examination

The patient walks with a right forearm crutch and a lightweight hinged knee brace for the right knee. She has a short leg gait on the right side but has an antalgic gait on the left side. The right leg has weak quadriceps function and dorsiflexion function. However, there is no foot drop and no pain with passive range of motion of the right hip, knee, or ankle. The left hip has normal range of motion without pain. There is a clinical varus to the distal thigh of 20–30°. The left knee has a range of motion of 5–125° with crepitus and tenderness in all three compartments. There is a 5°

fixed flexion contracture and all ligaments are intact to clinical examination. The foot and ankle examination is normal.

Radiographs and Advanced Imaging

The X-ray studies of the left lower extremity show a 35° varus deformity of the femur at the junction of the middle and distal third of the femoral shaft (Fig. 8.23). The knee X-rays show tricompartmental osteoarthritic changes with a varus inclination of 15° and multiple staples on the femoral side (Fig. 8.24).

Surgical Approach

Following the administration of preoperative antibiotics, the patient was taken to the operating room where the left lower extremity was prepared and draped in the customary fashion with an arterial tourniquet in place.

A medial incision was chosen with a 7 cm distance from the previous short lateral vertical incision. Medial and lateral flaps were elevated. A median parapatellar arthrotomy was performed, and the quadriceps tendon was split proximally. This split can be carried several centimeters beyond the tendinous portion of the quadriceps mechanism to allow full exposure of the femoral shaft without a secondary lateral approach (Fig. 8.25a). The patella was subluxed laterally. The deformity apex was identified at the meta-

diaphyseal junction and marked using electrocautery. Retractors were placed around the femur for protection. A 30 mm laterally based closing wedge osteotomy was made using an oscillating

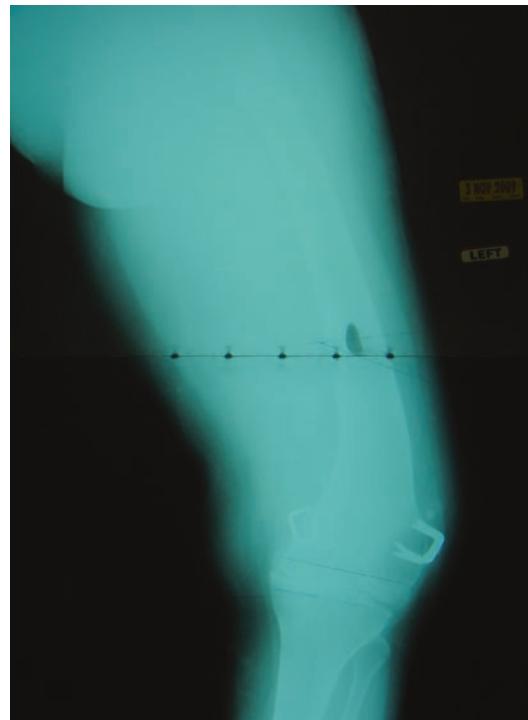


Fig. 8.23 Anteroposterior X-ray of the femur with temporary osteotomy lines marked for surgery

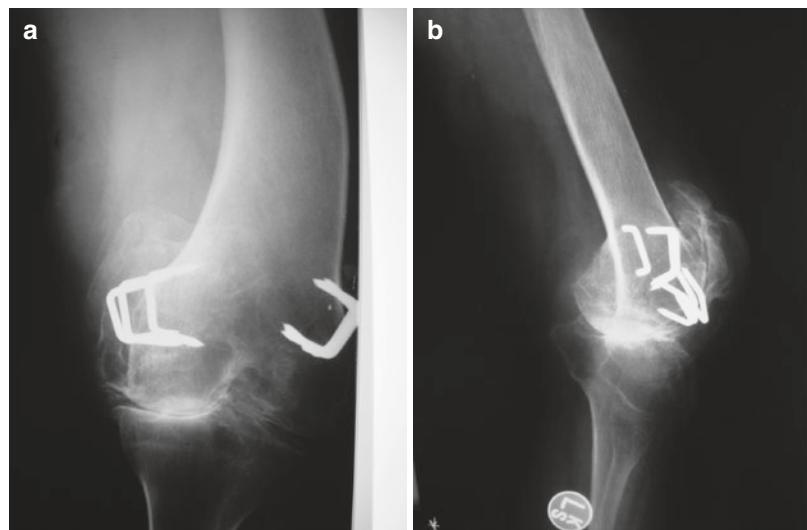


Fig. 8.24 Anteroposterior X-ray of the knee (a, b) with the epiphysiodesis staples in place

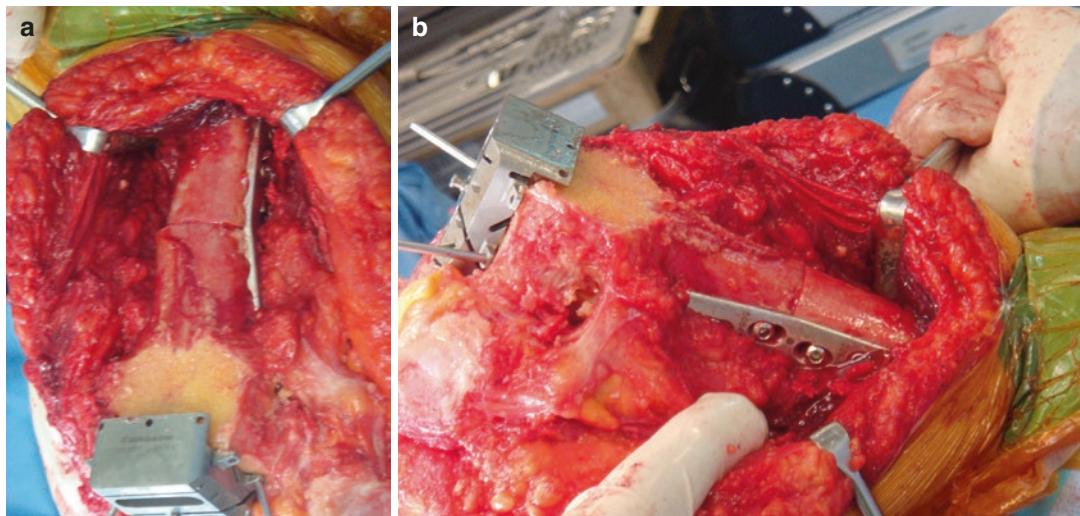


Fig. 8.25 Anterior (a) and lateral (b) intraoperative view of the distal femur with the neutralization plate in position and the finishing block on the distal surface

saw. The size of the wedge was chosen as a millimeter for each degree of correction. Bone fragments were removed and preserved for use as autograft. The osteotomy margins were approximated, and a six-hole side plate was placed with unicortical screws (Fig. 8.25). The fixation allows for placement of an intramedullary stem on the femoral component.

With secure fixation for the osteotomy, the surgery proceeded to the knee arthroplasty which can now be performed in the standard fashion for a varus knee. The femoral anteroposterior (AP) axis was drawn. The intramedullary hole was made and evacuated, and the first guide pin placed parallel to the AP axis, past the osteotomy site. Anterior and then distal femur cuts were performed. The femoral bone was sized and all of the finishing cuts were completed (see Fig. 8.25b).

The extramedullary tibial guide was set. Varus, valgus, flexion, extension, and depth were checked. The flexion gap technique was used, and the cut was taken across and checked with a spacer block and an extramedullary rod. The femoral and tibial surfaces were completed in the standard fashion. The intramedullary canals were reamed on both the femoral and tibial sides specifically to protect the femoral osteotomy with a long intramedullary stem. After resurfacing the patella, all components were cemented. The

intramedullary stems were cortical contact (1 mm less than the reamed diameter) and were, partially, but not fully cemented (Fig. 8.26). The prosthetic design (either cruciate retaining or posterior stabilized) was not critical because the arthroplasty portion of the surgery was a standard knee replacement. Added constraint was not necessary but was added for further stability in this case (Fig. 8.27).

The knee was closed in the standard fashion, and a hinged knee brace was applied with the hinges set for full range of motion. The X-rays were completed in the postanesthesia care unit (Fig. 8.28).

Postoperative Result

After the surgery, the patient was non-weight bearing on the left side for 6 weeks, but full active and passive range of motion was allowed. At 6 weeks, there was good evidence of healing on the X-rays, and partial weight bearing was started followed subsequently by full weight bearing as tolerated. Six years after the operative procedure, the patient has a well-healed osteotomy and a pain-free knee.

Clinical Results

There are very few series in the literature documenting the results of combined procedures

Fig. 8.26 Insertion of the femoral component with the intramedullary stem partially cemented



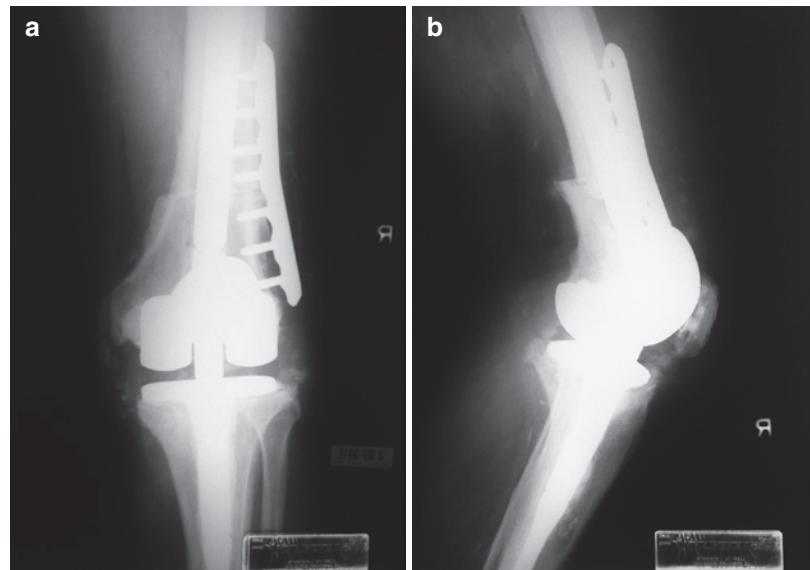
Fig. 8.27 The final cemented components in position with the neutralization plate



for diaphyseal femoral deformities in combination with total knee arthroplasty (TKA). Wolff et al.'s article is a classic summary [30]. He concludes that the closer the deformity is to the knee, the greater the effect and femoral deformities are more difficult to correct intra-articularly because the compensatory wedge leads to instability in full extension. Extra-articular femoral osteotomy avoids instability in the TKA but does involve more extensive surgery. Wang and Wang published their results in 15 patients treating extra-articular deformi-

ties with intra-articular corrections. He had no infections, ligament instability, or component loosening with 38 months of average follow-up; however, his cutoff for the femoral deformity was 20° [2]. Lonner and colleagues reported on 11 patients undergoing simultaneous corrective osteotomy and TKA, at an average of 46 months postoperatively, and found the Knee Society Score increased from 10 points to 87 points, and the alignment was restored to within 2° of normal. One of the 11 osteotomies went on to nonunion [6].

Fig. 8.28 Anteroposterior (a) and lateral (b) X-rays of the final components and the plate



When performing the femoral osteotomy, the wedge resection should be corrective in the coronal, sagittal, and axial planes. In the case described here, the primary deformity was in the coronal plane, and there was little flexion or rotational deformity. Therefore, the anteroposterior X-ray was used for the determination of the wedge resection. In more complex cases, it may be helpful to use a three-dimensional CT reconstruction of the femur for planning the osteotomy.

Key Points

- Determine the location of the femoral deformity: intra-articular, metaphyseal, and diaphyseal.
- Measure the magnitude of the deformity and the planes that are involved.
- Femoral diaphyseal deformities greater than 20° should be separately addressed from the TKA. Intra-articular corrections at the time of the TKA may lead to implant instability.
- The femoral osteotomy can be performed as a separate operation or at the same time as the TKA.
- The choices of fixation include a plate and intramedullary stem, a blade plate without an intramedullary stem, or a long-stem, press-fit, femoral component.

- If the two surgeries are performed at the same time, it is safest, and easiest, to complete the osteotomy first and stabilize it with plate fixation rather than depending completely upon an intramedullary stem from the femoral component.

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Part II

Revision Total Knee Arthroplasty

Management of the Infected Total Knee Arthroplasty

9

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Henry D. Clarke, Thorsten Gehrke, Akos Zahar,
Mustafa Citak, Majd Tarabichi, Javad Parvizi,
David N. Shau, and George N. Guild III

Introduction

Alfred J. Tria

As total knee surgery matures, many of the early difficulties have been addressed and solved. Today most revisions are related to subtle instability, unusual wear, and infection [1, 2]. Of the three remaining problems, infection continues to be difficult to solve. There are now several approaches to the infected knee, but complete eradication of infection seems to be near impossible. The treatment protocols include incision and drainage [3], immediate exchange [4], and two-stage reimplantation [5]. The case presentations in this section address these techniques and review additional treat-

ment protocols that can be included in the approach to infection.

Option 1: Irrigation and Debridement

Joshua Bingham, Mark J. Spangehl, and Henry D. Clarke

Case Presentation

History

A 68-year-old male presented to the emergency department in the late evening complaining of increased right knee erythema, warmth, and drainage from his incision for the past 4 days

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after undergoing a total knee arthroplasty (TKA) 2 weeks prior to end-stage osteoarthritis (Figs. 9.1 and 9.2).

Physical Examination

Physical examination revealed a swollen knee with purulent drainage from the incision. His passive range of motion was 10–95° with moderate pain throughout the entire arc of motion.

The serum white blood cell (WBC) count was 8300/ μ L, with a differential of 82% neutrophils. The serum C-reactive protein (CRP)

was 136.0 mg/L, and the erythrocyte sedimentation rate (ESR) was 81 mm/h. The knee was aspirated in the emergency department and sent for WBC count, differential, and aerobic and anaerobic bacterial and fungal cultures. The synovial cell count was 23,833 nucleated cells/ μ L with a differential of 70% neutrophils.

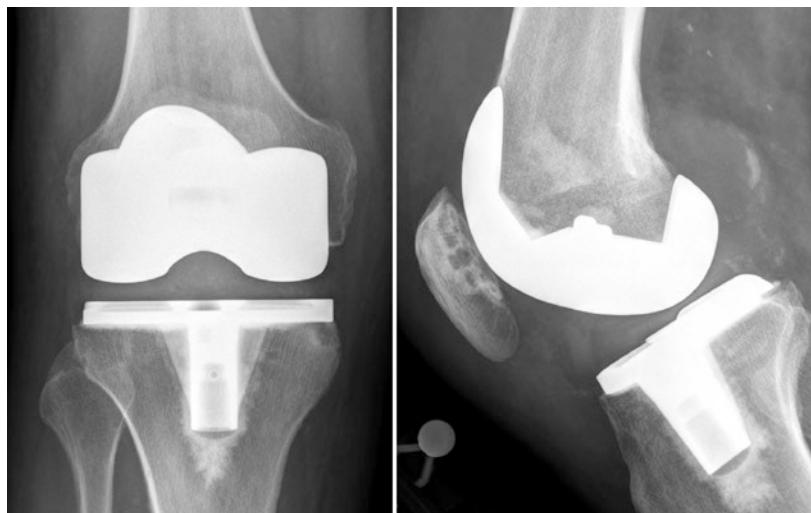
Radiographs and Advanced Imaging

X-rays of the knee were unchanged from the images that were taken immediately after the original operation.

Fig. 9.1 Preoperative anteroposterior (AP) and lateral radiographs of the patient's right knee



Fig. 9.2 Initial postoperative anteroposterior (AP) and lateral of the patient's right total knee arthroplasty



Surgical Approach

Based on history, clinical exam, and laboratory findings, the patient was diagnosed with an acute postoperative infection, and a debridement with component retention was recommended. As the patient was stable, all antibiotics were held prior to surgery. The next morning the patient was taken to the operating room for the first stage of a two-stage debridement using antibiotic-impregnated beads. Three deep tissue samples were taken for culture. All modular components were removed and disinfected with Betadine (Purdue Products, Stamford, CT, USA) followed by chlorhexidine scrub. A thorough debridement was performed, and the wound was irrigated with both dilute Betadine and dilute chlorhexidine gluconate. The disinfected modular components were reinserted. Antibiotic-loaded bone cement beads were placed, and the wound was closed using a clean set of instruments.

The patient was started on vancomycin pending culture results. The cultures were positive for *Streptococcus mitis* and methicillin-sensitive *Staphylococcus aureus* (MSSA). An infectious disease consult was obtained, and the patient was transitioned to intravenous ceftriaxone and rifampin.

On postoperative day 5, the patient returned to the operating room for the second-stage debridement and antibiotic bead removal. All the modular components and antibiotic beads were removed. Repeat irrigation and debridement were performed including the use of Betadine and chlorhexidine antiseptic irrigation. New sterile modular components were inserted, and the wound was closed.

Discussion of the Approach

Irrigation and debridement of an acute postoperative or acute delayed infection can be performed as a one- or two-stage procedure. The two-stage procedure includes placement of antibiotic-loaded beads at the initial debridement and removal of the beads at the time of the second debridement 4–6 days later. If the organism is unknown, preoperative antibiotics should be held until tissue cultures have been obtained at the time of debridement.

Equipment

The following equipment is required for the treatment of an acute periprosthetic infection:

- Implant specific polyethylene extraction tool or osteotome
- Padded lamina spreader
- Rongeurs and curettes
- Six to nine liters of irrigation
- 0.35% Betadine (i.e., 17.5 mL of 10% povidone-iodine in 500 mL of normal saline)
- 0.05% chlorhexidine gluconate (i.e., 6 mL of 4% chlorhexidine gluconate in 500 mL of normal saline)
- Sterile scrub brush
- Monofilament suture
- Drain
- A clean setup for closure

If a staged debridement with antibiotic-loaded cement beads is planned, the additional equipment required is:

- One batch of bone cement (poly[methyl methacrylate] [PMMA])
- Antibiotics (i.e., 3.6 g tobramycin, 3 g vancomycin, 2 g cefazolin)
- Large-diameter Prolene suture

Technique

The previous surgical approach should be used. If there are multiple incisions, the most lateral incision should be utilized.

A medial parapatellar arthrotomy is used to expose the joint space (Fig. 9.3). A quadriceps snip can be performed to gain additional exposure if needed.

A clean unused instrument should be used to collect a minimum of three tissue samples. The tissue samples should be sent for aerobic and anaerobic cultures. Fungal cultures may also be obtained if these pathogens are common in the geographic region; however, fungal pathogens are an unusual cause of acute infections. Bacterial cultures should be grown for 2 weeks and fungal cultures for 4 weeks to isolate slow-growing pathogens.

During the first-stage debridement, all modular components are removed. If a one-stage

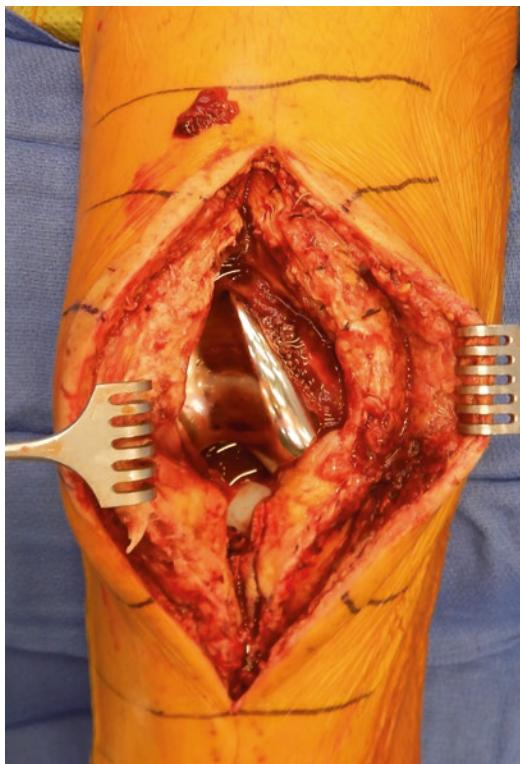


Fig. 9.3 Intraoperative photograph of the patient with an acute postoperative infection after medial parapatellar arthrotomy. Notice the thickened synovium throughout the knee

debridement is being performed, all modular components should be discarded and new sterile components inserted prior to closure. If a two-stage debridement is being performed, the modular parts are soaked and scrubbed in antibacterial Betadine and chlorhexidine solutions (Fig. 9.4). Later in the case these parts are reinserted prior to placement of the antibiotic beads.

At this point a meticulous and thorough debridement and synovectomy are performed.

All inflamed and hypertrophic synovium should be meticulously excised from the suprapatellar pouch and the medial and lateral gutters.

A padded lamina spreader should be placed to allow access to the posterior tissues in the knee, and the posterior compartment can be debrided with a rongeur and curettes (Fig. 9.5).

The deep aspect of the extensor mechanism should also be debrided including removal of the tissue and the “meniscus” around the patellar implant (Fig. 9.6).



Fig. 9.4 The modular tibial insert is removed and disinfected with a Betadine (povidone-iodine) and chlorhexidine scrub and soak



Fig. 9.5 A padded lamina spread is used to allow access to the posterior compartment in the knee and then thoroughly debrided with a rongeur and curettes

Curettes should be used to debride the bone prosthetic interfaces.

The retained components are then cleaned with a scrub brush and an antiseptic solution to mechanically remove as much biofilm as possible (Fig. 9.7). The preferred antiseptic solutions at our institution are Betadine and chlorhexidine [6, 7].

After a thorough mechanical debridement, the joint space is filled with a 0.35% Betadine solution and allowed to soak for 3–5 min, followed by a 3–5 min soak of 0.05% chlorhexidine gluconate (Figs. 9.8 and 9.9).

The joint is then irrigated with 6–9 L of irrigation solution using the pulsatile lavage.

Next, outer gloves are changed and a new set of clean instruments is used for the remainder of the case.



Fig. 9.6 The knee should be meticulously debrided. This intraoperative photograph shows a thorough debridement with a curette around the implant-bone junction. Other implant surfaces should also be debrided in a similar fashion



Fig. 9.7 The implants are mechanically scrubbed with Betadine and chlorhexidine gluconate solutions



Fig. 9.8 After a thorough mechanical debridement, the knee is filled with dilute Betadine and allowed to soak for 3–5 min



Fig. 9.9 Following the dilute Betadine soak, the knee is filled with dilute chlorhexidine gluconate and allowed to soak for an additional 3–5 min

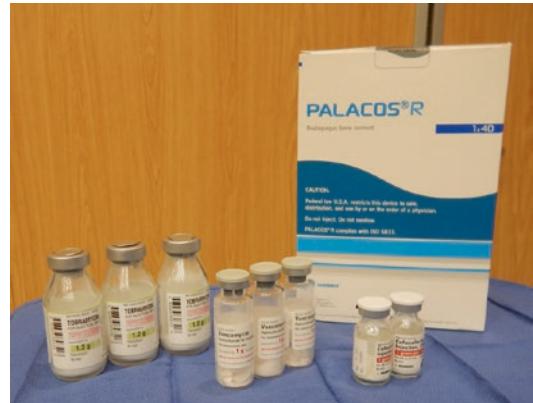


Fig. 9.10 The typical antibiotic mixture used in the antibiotic-loaded bone cement beads includes 3 g of vancomycin, 2 g of cefazolin, and 3.6 g of tobramycin per batch of Palacos bone cement (Zimmer Biomet, Warsaw, IN, USA)

The tourniquet is deflated and hemostasis is obtained.

If performing a single-stage debridement, new sterile modular components are placed, and the wound is closed over a drain using monofilament absorbable suture.

If a two-stage debridement is being performed, the disinfected modular parts that were removed are reinserted, and the antibiotic-loaded beads can be prepared.

High-dose antibiotic beads are made by mixing one packet of PMMA with 3.6 g of tobramycin, 3 g of vancomycin, and 2 g of cefazolin (Fig. 9.10).

While the cement is still in the dough phase, it can be fashioned with a bead making mold or by hand into 10–15 mm diameter beads (Fig. 9.11).

With the cement still in the dough phase, a no. 1 Prolene suture (if it is the surgeon's preference) is used to string the beads. Knots are tied at each end of the suture to prevent the beads from sliding off. Alternatively, the beads may be placed individually into the joint. With both techniques the beads should be allowed to harden before implantation. Furthermore, whether or not the beads are placed on a suture chain, the number of beads implanted should be carefully recorded to ensure that they are all removed during the second-stage debridement.

The antibiotic beads should then be placed in the medial and lateral gutters and suprapatellar pouch. Typically, the entire volume of cement can be placed, but if the closure is too tight, some of the antibiotic beads should be removed (Figs. 9.12 and 9.13).

The wound is then closed over a drain with monofilament suture.

The drain is removed on postoperative day 1. Continued antibiotic elution occurs until the time



Fig. 9.11 After combining the antibiotic powder and cement, the mixture can be fashioned into 10–15 mm diameter beads. While still in the dough phase, the beads are strung onto a heavy monofilament nonabsorbable suture



Fig. 9.12 After the antibiotic beads have hardened, knots are tied on the ends of the monofilament suture, and the antibiotic-loaded bone cement beads are ready for placement into the suprapatellar pouch and the medial and lateral gutters



Fig. 9.13 This intraoperative photograph shows placement of the beads in the suprapatellar pouch and medial and lateral gutters. At this point the knee is ready to be closed over a drain

of bead removal. We believe that the benefit of using a drain to prevent excessive hemarthrosis and swelling outweighs the disadvantage of allowing some of the eluted antibiotics to be lost in the drain.

Patients are allowed out of bed and are weight bearing as tolerated with a brace immobilizing their knee in extension.

Various venous thromboembolism prophylaxis modalities can be used between debridement stages. Our preferred prophylactic regimen includes mechanical prophylaxis with low-molecular-weight heparin starting on postoperative day 1.

The timing of the second debridement and bead removal is typically a logistical issue with a goal being 4–6 days after the initial debridement.

At the second debridement repeat tissue cultures are obtained. The debridement is performed again with meticulous debridement of soft tissue and antimicrobial irrigation. The previously used modular components are replaced with new sterile components.

The wound is then closed over a drain with monofilament suture.

Postoperative Protocol

A standard postoperative rehabilitation protocol is implemented for all patients after undergoing two-stage debridement.

An infectious disease consultation is obtained, and intravenous antibiotics are typically used for 6 weeks. Rifampin is added to the antibiotic therapy for those patients with *Staphylococcus* species.

A course of oral antibiotics is then prescribed for 3–6 months which has been shown to increase infection-free survivorship.

The criteria for stopping antibiotics include clinical exam findings consistent with resolution of infection and normalized inflammatory markers.

Patients with substantial local and/or systemic compromise (i.e., immunocompromised, active malignancy, chronic lymphedema, transplant recipients, etc.) and those patients in whom implant removal may jeopardize the limb (tumor implants or well-fixed long stems) are

often treated with long-term prophylactic antibiotic therapy.

Postoperative Result

Postoperatively the patient completed 6 weeks of intravenous ceftriaxone and oral rifampin before being transitioned to oral trimethoprim/sulfamethoxazole. At follow-up 6 months later, his knee was functioning well, inflammatory markers had normalized, there were no signs of infection, and oral antibiotics were discontinued. At follow-up examination 3 months later, both inflammatory markers and clinical exam remained normal.

Clinical Results

Several factors influence the outcome of periprosthetic joint infection treatment including host status, surgical technique, antibiotic regimen, and duration of infection [8]. Infections can be classified into either an acute or chronic infection. Acute infections can be further subclassified into acute postoperative or acute delayed infections. Acute postoperative infections occur within 4 weeks of surgery and likely are a result of wound colonization at the time of surgery or from a superficial wound infection that spreads to the joint. Acute delayed infections arise in a previously well-functioning joint with an acute onset of symptoms. In cases with an identifiable source, the term acute hematogenous infection is preferred.

In chronic infections, there is an increased association with biofilm formation that often requires a two-stage exchange with an antibiotic spacer to successfully eradicate the infection [9]. However, in acute postoperative or acute delayed infections, debridement with component retention can be successful in definitively treating periprosthetic infections. Timely treatment in the operating room minimizes further biofilm maturation and potentially improves overall success rate. Antibiotics should be held until cultures have been obtained either preoperatively or intraoperatively. In cases where preoperative antibiotics are administered, ultrasonification of an explanted polyethylene insert or other modular parts that can be replaced has been shown to

increase the chance of identifying the pertinent organism [10]. Meticulous debridement and surgical technique are critical to successfully eradicating the infection.

Several studies have reported the results of debridement and component retention for acute infections (<28 days). Infections were controlled in 155–284 knees (range 24–100%) [3, 11–13]. Our own group reported the outcomes of our staged technique as described here in a series of 20 patients. Eighteen of the 20 patients were treated successfully after completion of the second-stage debridement and 6 weeks of IV antibiotics [5]. Ten of the patients were on oral antibiotics for an average of 9.0 months (1.2–21.6 months). Eight of the patients were compromised hosts and subsequently kept on long-term prophylactic antibiotic therapy despite any signs or symptoms of persistent infection. In our updated, unpublished results, we noted similar success with this protocol. Thirty-eight of 44 knees (86%) were successfully treated. Primary knees that became infected, not surprisingly, had a better outcome when compared to revision knees (89% vs. 82%). Duration of symptoms was significantly associated with success vs. failure. Those with successful outcomes had a mean 4.1 days of symptoms prior to debridement vs. a mean of 11.2 days of symptoms for those that failed. Organism type was not a predictor of success or failure.

Several previous debridement and component retention studies have shown inferior results with periprosthetic staphylococcal infection [14, 15]. However, these studies did not regularly use an antibiotic regimen in combination with rifampin. A randomized controlled trial comparing antibiotic therapy with and without combination rifampin therapy found a 100% cure rate with rifampin compared to a 58% cure rate without rifampin [16]. In another study using combination rifampin therapy, staphylococcal infection was not an independent predictor for failure [17]. In our own retrospective study in which we used rifampin, only one of the eight patients with a staphylococcal infection failed treatment [5]. Based on these results and other studies, we do not think staph-

ylococcus infections including MRSA are a contraindication to two-stage debridement and component retention [16, 18, 19].

Two-stage debridement with antibiotic beads and component retention is also considered safe as serum levels of antibiotics remain low and the risk of systemic side effects is low. Although there have been case reports of acute renal failure and ototoxicity with the use of antibiotic-loaded bone cement spacers for the treatment of chronic periprosthetic joint infections, there have been no reports with the use of antibiotic-loaded bone cement beads in two-stage debridement and component retention [20, 21]. The lack of systemic side effects with the use of beads is likely because only one mix of antibiotic-loaded cement is used, whereas with spacers two or more are used depending on the amount of bone loss. However, in cases of severe renal dysfunction, or where individual allergies to any of the antibiotics in the standard mix are noted, the operating surgeon may elect to modify the antibiotic dosing that is used after consultation with medical specialists.

Finally, recent studies have shown an increased infection-free survivorship with the use of extended oral antibiotics after both two-stage exchange and one-stage debridement with component retention [22, 23]. Patients that underwent a single-stage debridement and those infected with *Staphylococcus aureus* had the greatest benefit. Based on these findings, we routinely use extended oral antibiotics after a two-stage debridement with component retention and believe that 6 months of oral antibiotic should be considered for all patients if oral antibiotic can be tolerated and is effective for the identified organism.

In summary, treatment outcomes for periprosthetic joint infections are dependent on several factors including host status, surgical technique, antibiotic regimen, organism, and duration of infection. To optimize outcomes only patients with a clearly defined acute infection (either postoperative or acute delayed) should be considered for debridement and prosthesis retention. We favor a two-stage debridement with antibiotic-loaded bone cement beads and component retention because of the superior reported results.

However, in cases where the patient may not tolerate two operations, a single debridement may be considered. Based on current evidence, staphylococcal infections are not a contraindication to debridement and component retention with combination rifampin therapy. Use of extended oral antibiotics after two-stage debridement and component retention can improve infection-free survivorship. Chronic suppressive antibiotic therapy should be considered in patients that are poor hosts, immunosuppressed, have an increased risk of recurrent infection, or cannot tolerate a one- or two-stage revision.

Key Points

- Debridement with component retention is indicated in patients with acute postoperative or acute delayed infections less than 4 weeks in duration.
- A thorough debridement is the key to successful treatment and eradication of the infection.
- A staged debridement with interval use of antibiotic-loaded bone cement beads provides the required MIC levels to kill residual biofilms that a single-stage debridement cannot.
- Antibiotic-loaded bone cement is considered safe as there have been no reports of systemic toxicity in patients receiving antibiotic bone cement beads alone.
- Use of extended oral antibiotics after debridement and component retention can increase infection-free survivorship.

Option 2: One-Stage Revision Arthroplasty in the Management of Infected Total Knee Arthroplasty

Thorsten Gehrke, Akos Zahar, and Mustafa Citak

Case Presentation

History

An 83-year-old male patient admitted to the ENDO-Klinik Hamburg with a painful and swollen left knee. Four years prior admission, a primary total knee arthroplasty was performed due to osteoarthritis in an external hospital.

Postoperatively, prolonged wound secretion of the distal part of the wound was conspicuous. Therefore, multiple revision surgeries including VAC (vacuum-assisted closure) therapy and secondary wound closure were necessitated. The performed joint aspiration revealed a growth of *Enterococcus faecalis*. The patient received over a time period of 3 weeks systemic antibiotic therapy with amoxicillin and clavulanic acid followed by oral antibiotics with ampicillin for 7 days. Four years after index surgery, the patient presented to our clinic with a painful swelling and redness on the left knee. The walking distance was with approximately 200 m restricted.

Physical Examination

On admission, the body mass index (BMI) was 31 kg/m^2 (1.75 m; 95 kg). Apart from hypertension and cardiomyopathy with an ejection fraction of 49%, no other systemic illnesses were noted. The clinical examination on admission showed besides the swollen left knee and effusion of the knee joint a restriction of the range of motion (ROM). The ROM of the left knee was 0–10–90° for extension and flexion. There were no clinical signs for instability or neurological deficits. The anteroposterior and lateral views of the left knee illustrate radiological signs for loosening (Fig. 9.14). The joint aspiration of the left knee showed the growth of *Enterococcus faecalis*.

Surgical Procedure

Preoperative Planning and Surgical Approach

In every case, preoperative plain radiographs (anteroposterior and lateral views of the knee and tangential view of the patella) and anteroposterior standing long-leg radiographs are performed. Prior revision surgery, every patient receives an aspiration of synovial fluid in order to exclude a periprosthetic joint infection (PJI) based on our standardized hospital protocol. The joint aspiration is the most relevant preoperative diagnostic procedure in any case of a planned one-stage exchange. The preoperative identification of the bacteria defines which antibiotic-loaded acrylic

Fig. 9.14 Presents the total knee arthroplasty with radiological signs for loosening of both components, (a) anteroposterior view, (b) lateral view



cement is required and is the main factor to plan the one-stage exchange arthroplasty. The aspiration should always take place under strict sterile conditions. In case of ongoing antibiotic therapy, the antibiotics should be withheld for 14 days prior to the aspiration. The authors do not recommend the infiltration of local anesthetics into the joint, since the bacteriostatic characteristics of the agents might cause false negative results.

Radical Debridement and Removal of All Hardware

In general, radical debridement of all infected tissue and the meticulous removal of all hardware are of enormous importance to achieve a successful one-stage exchange procedure. The patient is positioned on the operating table in supine position. The debridement begins already by excising the old scar (Fig. 9.15). In case of draining sinus, this must be radically excised down to the joint capsule. The surgical approach is performed based on the experience and preference of the surgeon. In this case, we used the medial parapatellar approach. First, extraarticular debridement of the joint capsule



Fig. 9.15 Intraoperative image shows the excised old scar

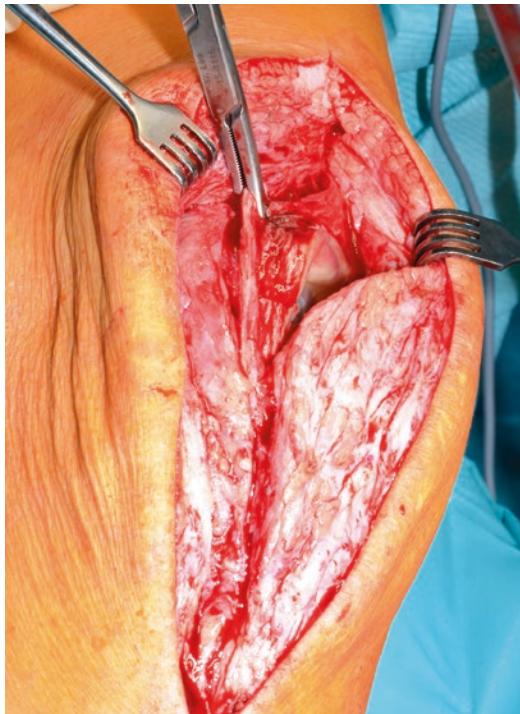


Fig. 9.16 Intraoperative situs presenting the resection of infected tissue

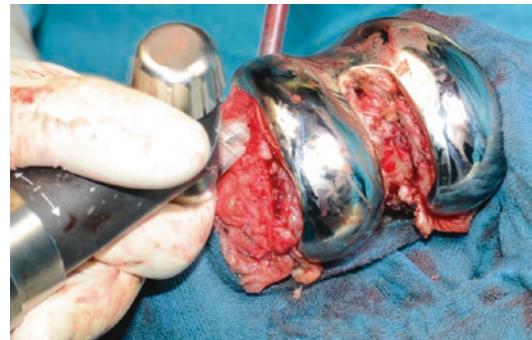


Fig. 9.18 Implant-cement interface loosening of the femoral component using an oscillating saw

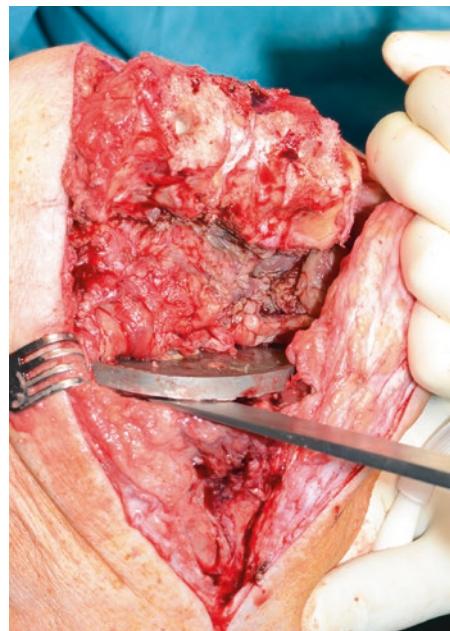


Fig. 9.19 Implant-cement interface debonding of the tibial component using an osteotome



Fig. 9.17 All infected tissue has to be excised. This figure illustrates the resection of infected tissue around the femoral component

and the synovium is performed. The joint is then opened and radically debrided including a complete synovectomy. All non-bleeding tissues and related bone need to be radically excised (Figs. 9.16 and 9.17). The aggressive soft tissue resection includes also the debridement of collateral ligaments and the excision of all infected tissue around the patella region and

in the patella surface. Therefore, we do not recommend to use a tourniquet during the debridement process to allow adequate visualization of the infected tissues/bone down to the viable tissue. After finishing the radical debridement of the surrounding tissues, all hardware need to be removed. It is important to have proper instruments on the operating table to make the removal easier. In the presented case, the debonding of the implant-cement interface of the femoral and tibial components was done using an oscillating saw (Fig. 9.18) or an osteo-

tome (Fig. 9.19). The mobilized tibial and femoral components are then removed with direct blows using a punch (Figs. 9.20 and 9.21). After removing of all foreign materials, the cement is removed completely. Then, the debridement of bone and posterior soft tissues is done including all areas of osteolysis and nonviable bone (Fig. 9.22). Five samples of biopsy material are taken during the debridement from all relevant areas of the operation site for combined microbiological and histological evaluation. After complete implant removal and debridement, the irrigation is performed with pulsatile lavage with 0.02% polyhexanide solution (Lavasept, B. Braun Melsungen AG, Melsungen, Germany). Then, the polyhexanide-soaked swabs are placed over the wound area before new operative setup is made. The new operative setup includes the redraping of the surgical field and to change light handles, suction tips, and surgical gowns and gloves (Fig. 9.23). For reimplantation, new instruments are brought into the operating room.



Fig. 9.20 Removal of the femoral component with direct blows using a punch

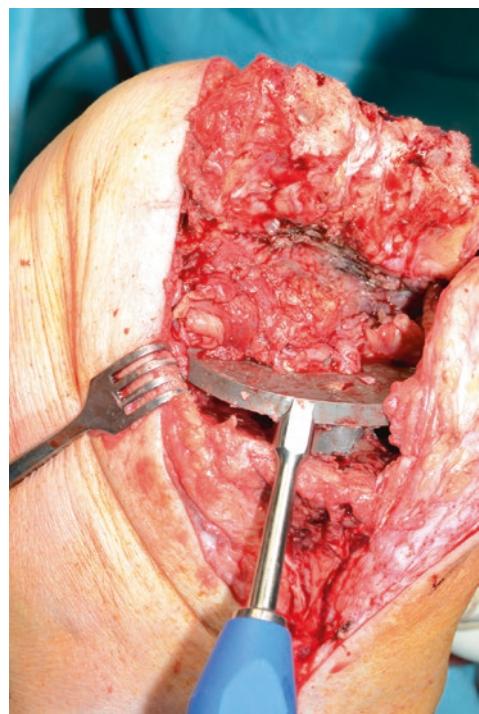


Fig. 9.21 Removal process of the tibial component

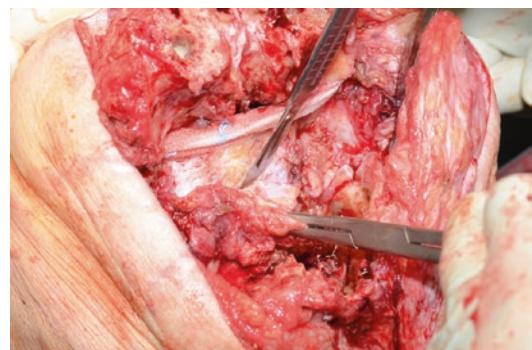


Fig. 9.22 Radical debridement of the posterior aspect of the knee



Fig. 9.23 The new surgical setup before reimplantation

Reimplantation

After taking the last microbiological sample, the systemic antibiotic therapy is started by administering a first dose of intravenous ampicillin and sulbactam according to the recommendation by our microbiologist. Then, the reconstruction of the joint is carried out with implantation of a cemented rotating hinge knee implant (LINK Endo-Model, Waldemar Link GmbH & Co. KG, Hamburg, Germany) after preparing the tibia and femur with appropriate resection blocks (Figs. 9.24 and 9.25). Antibiotic-loaded cement is used for both the fixation of the new implant and reconstruction of bone defects. We prefer not to use bone allograft; instead we recommend to fill the defects with cement or Trabecular Metal (Zimmer Biomet Inc., Warsaw, IN, USA) cones. The premixed gentamicin- and clindamycin-loaded bone cement (COPAL, Heraeus Medical, Wehrheim, Germany) is mixed with 2 g vancomycin per 40 g cement



Fig. 9.25 Intraoperative image during the hardening process of the cement. The 120 g premixed gentamicin- and clindamycin-loaded bone cement (COPAL, Heraeus Medical, Wehrheim, Germany) is mixed with 2 g vancomycin per 40 g cement

of maximum 2 g vancomycin per 40 g cement. In this case, the femoral component was cemented with 120 g and the tibial component with 80 g antibiotic-loaded cement. After hardening of the cement and irrigation, a primary multilayer soft tissue closure was achieved and drainage is inserted into the joint.

Postoperative Course

Anteroposterior and lateral plain radiographs of the left knee were performed immediately after surgery (Fig. 9.26). Postoperative systemic antibiotic administration with ampicillin and sulbactam (3 g TID) is followed for 14 days. The patient is mobilized with full weight bearing with crutches on the surgery day. The wound drainage is removed 48 h after surgery. Intensive physiotherapy is applied daily under sufficient analgesia to achieve best possible ROM. The patient is discharged 18 days after one-stage exchange arthroplasty. On discharge, there is no wound healing disorder, and the ROM of the left knee measures 0–0–100 for extension and flexion.

Clinical Results

The two-stage exchange arthroplasty has become the golden standard worldwide, although the actual data yielded no clear evidence for superior



Fig. 9.24 Preparation for the femoral component using a resection block

Fig. 9.26 Postoperative plain radiographs of the left knee illustrating the cemented rotating hinge knee (LINK Endo-Model, Waldemar Link GmbH & Co. KG, Hamburg, Germany)



results of the two-stage procedure [24, 25]. The ENDO-Klinik has established the one-stage procedure in the 1970s. Since then, we followed the one-staged approach in our clinic in over 85% of all our periprosthetic joint infections. The main requirement to perform the one-stage exchange arthroplasty is the known germ with known susceptibility based on microbiological diagnostics. Until now, a limited number of studies have evaluated the outcomes of one-stage revision technique [26–33]. Nevertheless, the results are comparable to the two-stage revision technique. For instance, the reported success rates of one-stage revision technique vary between 75% and 98% depending on the time of follow-up [26–33]. Recently published long-term outcome studies of the one-stage technique are comparable to the two-stage revision arthroplasty [29, 32, 33]. For example, Zahar et al. reported on the successful outcomes in the management of infected TKA with the one-stage procedure in a collective of 70 patients [33]. In their study, the 10-year infection-free survival was 93% [33]. Other long-term success with 10- or 12-year follow-up presented success rates higher than 90% after one-stage

revision arthroplasty [29, 32]. In a recent published article, Nagra and colleagues found no significant differences in risk for reinfection following one- or two-stage exchange arthroplasty in infected knee arthroplasty [34]. Moreover, the authors concluded in their study that recent studies suggest one-stage exchange arthroplasty may provide superior outcomes including reinfection rates and functionality in selected patients [34].

Key Points

- Well-defined intrahospital infrastructure and meticulous preoperative aspiration regime are essential.
- Radical debridement and removing of all hardware materials are mandatory.
- Collaboration with a microbiologist is crucial to choose the ideal antibiotic-loaded cement and the postoperative systemic antibiotic therapy.
- Postoperative specific patient care plays an important role.
- Successful one-stage exchange technique delivers certain advantages:

Need for only one operation
Reduced systemic antibiotics
Shorter hospitalization
Overall lower costs

and osteomyelitis of the right foot secondary to type II diabetes, which ultimately resulted in a below-the-knee amputation on the right side. He was on long-term antibiotic suppression with amoxicillin at the time of presentation to our center.

Option 3: Use of Static Spacer for Treatment of Infected Total Knee Arthroplasty as a Two-Stage Procedure

Majd Tarabichi and Javad Parvizi

Case Presentation

History

A 65-year-old gentleman presented to our clinic with a 2-year history of severe left knee pain. His index arthroplasty was performed on the left knee in 1999. He subsequently developed a periprosthetic joint infection with methicillin-resistant *Staphylococcus aureus* (MRSA) 1 year postoperatively requiring a two-stage revision arthroplasty. He then underwent revision arthroplasty in 2009 for aseptic failure and developed a foot drop. Other significant history includes a left femur fracture in 1969 during the Vietnam War, which was treated with traction,

Physical Exam

Physical examination reveals a pleasant gentleman who is 1.7 m tall, 73.7 kg with a body mass index of 25.5 kg/m^2 . He is alert, conscious, oriented, and in no acute distress. The patient walks with a severe limp with the use of a cane. Examination of the left knee shows a healed left knee incision, with no swelling or drainage. The skin around the incision is hyperpigmented. The knee is tender to palpation. The left knee range of motion was severely limited with 5° of extension and 60° of flexion. On further examination, the knee was found to have gross laxity with more than 20 mm of translation with varus and valgus stress as well as anteroposterior laxity and a severe varus deformity.

Radiographs and Advanced Imaging

Radiographs of the left knee show loosening of both the femoral and tibial components. Further imaging shows malunion of his left femur fracture (Figs. 9.27 and 9.28).

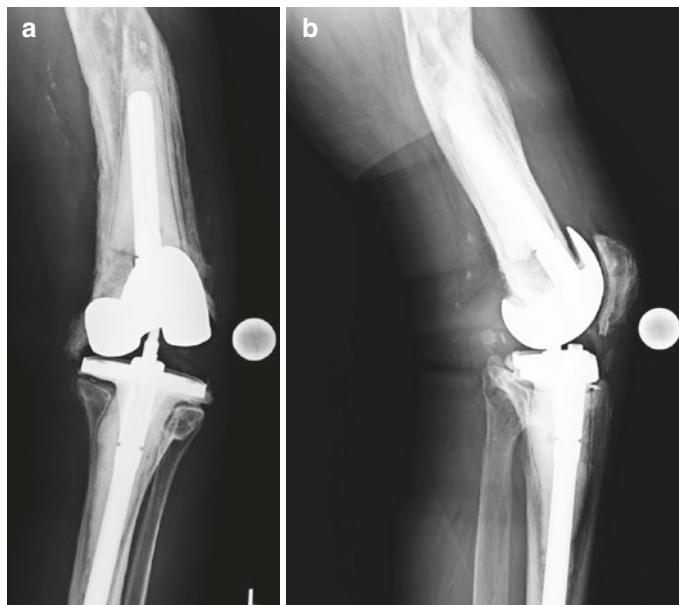


Fig. 9.27 Preoperative anteroposterior (AP) (a) and lateral (b) radiographs of the patient's knee



Fig. 9.28 Further imaging showing the deformity in the femur due to previous fracture

Surgical Approach

- Erythrocyte sedimentation rate (ESR): 14 mm/h
- C-reactive protein (CRP): 0.3 mg/dL
- Synovial fluid white blood cell count: 261 cells/ μ L
- Synovial fluid neutrophil percentage: 30.7%

Although the patient's laboratory studies were not elevated, the patient's previous history of infection was concerning as well as a history of long-term antibiotic suppression, which is known to falsely decrease the above laboratory values [35]. Thus a high index of suspicion for infection was maintained going into surgery. At the time of surgery, the patient's tissue was suspicious for infection. In light of the overall clinical picture, the decision was made to proceed with a two-stage revision arthroplasty.

First-Stage Spacer Insertion

The patient was taken to the operating room where spinal anesthesia was induced. A tourni-

quet was utilized for this case. Once the extremity was draped and skin was prepared, a midline incision was made and parapatellar approach was utilized, extending the exposure both proximally and distally to ensure adequate visualization. A medial parapatellar arthrotomy was performed to gain access to the joint. A moderate amount of fluid was encountered in the joint, which was sent for culture, leukocyte esterase [36] testing, and other molecular testing. The first component to be removed was the polyethylene insert, which greatly improved visualization and access to the joint by taking tension off the soft tissues. This is generally done by using an osteotome as a lever to remove the insert. Attention is then focused to the femoral component.

When working on the femoral and tibial components, it is vital to work diligently on the cement-implant interface in order to minimize bone loss when removing these cemented components. Using an osteotome we start to divide the cement-implant interface anteriorly and then gradually proceed to work around the fixation pegs, chamfers, and condyles. Care should be taken to work on both the medial and lateral sides of the implant. If one works on simply one side of the joint there is risk of increased bone loss as the trajectory of the osteotome or sawblade becomes more difficult to control, the further one goes into the cement-implant interface. We now proceed to remove the tibial component. This is typically done with the use of an oscillating saw or osteotome to debond the implant from the cement-implant interface.

It is important to note that while the surgeon is working on the tibial side, the knee should be maintained in sufficiently high flexion to ensure adequate exposure of the tibia. The stems on both the femoral and tibial sides were both found to be grossly loose and were removed without difficulty while attached to components. Severe bone loss from the distal femur was observed on the femoral component at the time of removal. Additionally, it was observed that the patient's malunion of his femoral fracture was contributing heavily to his deformity, and hence a realignment osteotomy was performed at the apex of the deformity. In light of the

severe femoral bone loss, and the need for realignment osteotomy, a static spacer was determined to be best for the patient. Extensive debridement of the bone and soft tissues was performed. Reverse curettes are particularly useful in the case of the intramedullary canals which may be difficult to access.

We then proceeded to fashion a static spacer. The senior author uses an intramedullary nail (460 mm, DePuy Synthes, Warsaw, IN, USA) to maintain the position of the knee with antibiotic-loaded bone cement molded around the knee to fill in the gaps in the intramedullary canals and form a spacer between the femur and the tibia. The key measurement that should be made in the design of a static spacer's dimensions is to use the explanted polyethylene component as a guide to determine the thickness of the spacer. The spacer was fashioned using two 40 g bags of bone cement, with 2 g of vancomycin and 3.6 g of tobramycin added to each bag. Prior to implantation of the spacer, the knee and intramedullary canals were irrigated extensively with 9 L of antibiotic-impregnated irrigation solution. The spacer was then implanted, spanning the knee joint, and was also used to fix the realignment osteotomy that was performed. Closure of the wound was then initiated, and an occlusive, silver-impregnated dressing was then used to cover the wound. Postoperative radiographs

showed the spacer to be in good position (Fig. 9.29).

Postoperative Outcome

The patient's postoperative course was unremarkable and was discharged to a rehabilitation facility on postoperative day 2, partially weight bearing. As his cultures and results of molecular testing did not reveal any organism, no antibiotic therapy was administered in the interim period between the two stages. The patient was successfully reimplanted 6 weeks after his first-stage procedure. At 3-month follow-up, the patient's incision was healed with no erythema or drainage from the incision. On examination of the knee, range of motion was improved to 0–80° of flexion and was stable to varus and valgus stress, with excellent patellar tracking. Radiographs showed well-aligned and well-fixed femoral and tibial components, with no evidence of loosening or fracture (Fig. 9.30).

Clinical Results

Irrespective of the choice to use a static or articulating antibiotic cement spacer, the goals of treatment of an infected prosthetic knee remain the same, namely, the eradication of infection while salvaging as much of the knee joint's function as possible. Both spacers serve to deliver local antibiotics and provide appropriate soft tissue ten-

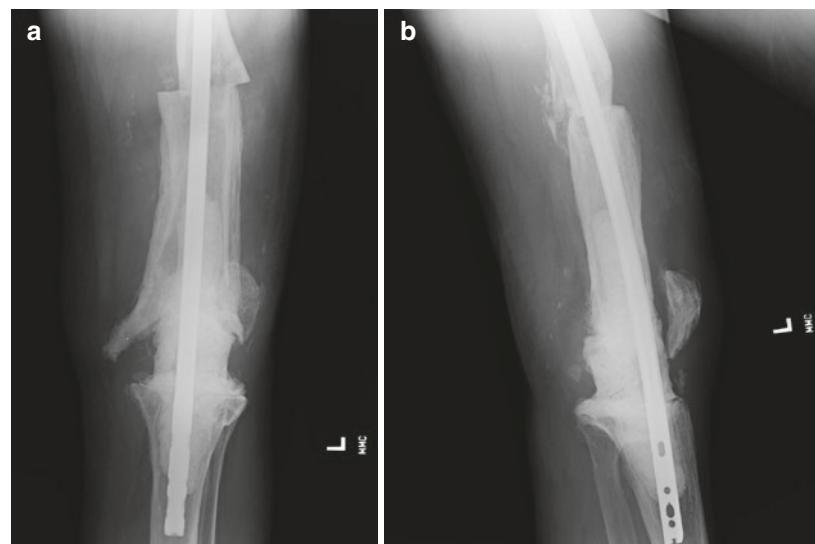


Fig. 9.29 Postoperative anteroposterior (AP) (a) and lateral (b) radiographs showing the spacer to be in good position

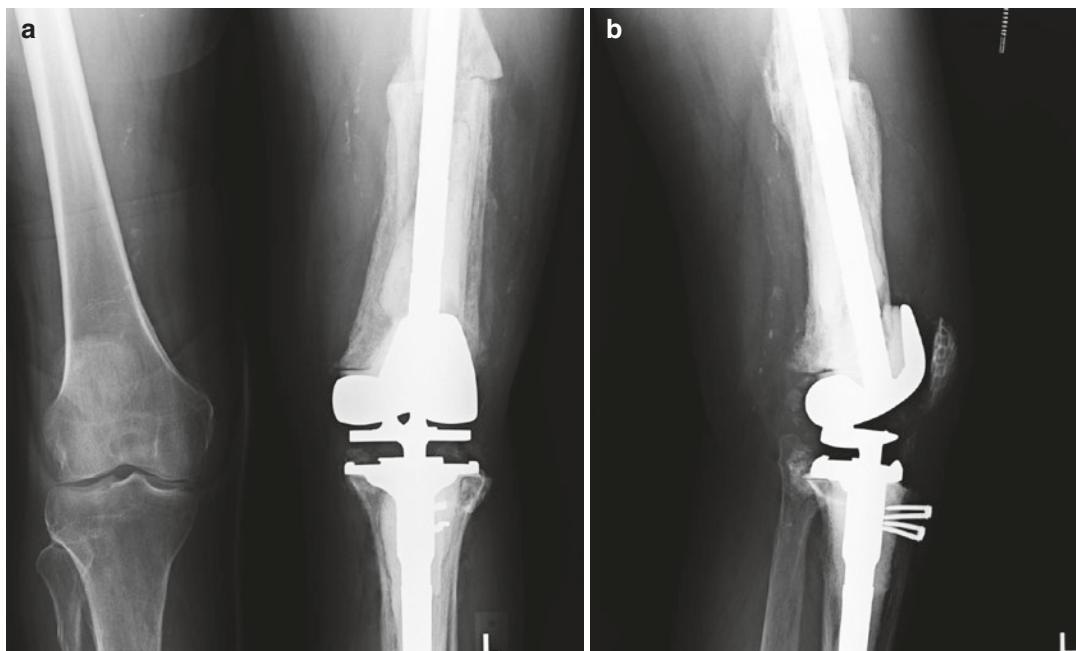


Fig. 9.30 Postoperative radiographs (**a, b**) following the reimplantation procedure. Components are well aligned and well fixed

sion to prevent contractures. As infection eradication is the primary goal in the treatment of an infected total knee, this perhaps should be the chief parameter by which dynamic and static spacers should be judged. With regard to reinfection rates, two recent systematic reviews concluded there was no significant difference in reinfection rates [37–39].

Articulating spacers have also been promoted in recent years for a variety of other reasons as well including minimizing bone loss, improved function of the knee, and ease of exposure at the time of reimplantation. Static spacers have been thought to cause more bone loss, and this thought to be due to bony erosion and migration of the actual spacer itself. Conversely, migration and subluxation of an articulating spacer itself, which is not an infrequent occurrence, have also been shown to be associated with bone defects and the use of constrained implants at the time of reimplantation surgery [40]. Furthermore, while Fehring et al. did note increased bone loss in their static spacer group, there was a possibility that the poor design of these static spacers may be associated with bone loss [41].

Improved patient outcomes have also been claimed with the use of articulating spacers. This hypothesis may be most likely due to increased range of motion. However, several studies, including three systematic reviews, have found no difference in patient-reported outcomes between static and dynamic spacers.

Static spacers have been claimed to make exposure more difficult at the time of reimplantation surgery. This has been thought to be due to shortening of the quadriceps [42], as a result of the limb being locked in extension for a prolonged period of time. Park et al. reported the need for extensile exposure during reimplantation surgery in four more patients who received static spacers than those who received articulating spacers; however, this difference was not significant [43].

While the decision to use a static or dynamic spacer ultimately lies with the surgeon, there are some indications in which a static spacer must be used. These include extensive bone loss and soft tissue deficiency, precluding the use of a dynamic spacer. Thus we strongly urge the surgeon to be able to recognize these cases in order to be adequately prepared.

Key Points

- Maintain high suspicion for infection in patients with a history of infection and/or multiple surgical procedures.
- Be familiar with extensile exposures that may be required in the multiply operated knee, which can be very stiff.
- Gradual debonding of components from the cement mantle is essential to minimizing bone loss, thus making future reconstruction less complicated.
- While the choice of spacer type is largely up to the surgeon, be familiar with situations which may be best suited for a static spacer (soft tissue deficiency, extensive bone loss).

Option 4: Two-Stage Procedure with Mobile Spacer

David N. Shau and George N. Guild III

Case Presentation

History

An 80-year-old female underwent primary right total knee arthroplasty at an outside hospital 1 month prior to presentation in adult reconstruction clinic. The orthopedist who performed the index primary knee replacement requested assistance in treating an acute periprosthetic joint infection. The indication for the index procedure was severe osteoarthritis with varus deformity. During the initial total knee arthroplasty, the orthopedic surgeon elected to place two suture anchors into the inferior pole of the patella due to concerns over the integrity of the patella tendon. Postoperatively the patient had pain, erythema, and intermittent drainage without wound dehiscence. At 2 weeks postoperatively, the patient was readmitted to outside hospital for intravenous (IV) antibiotics for 5 days and then discharged with oral cephalexin. The patient is not diabetic, does not smoke, and has normal immune status (Cierney A host).

Physical Examination

The patient is 5'9" tall with weight of 200 lb, BMI 29. Overall alignment of the right knee is

neutral and with an antalgic gait requiring a walker for ambulatory assistance. Supine examination of the knee revealed a passive range of motion (ROM) from 10 to 85° with a similar active ROM. There was no extensor lag and quadriceps strength was 4/5. There was a single midline incision with moderate erythema and no drainage or dehiscence at time of exam. A moderate joint effusion was present. There was no coronal plane instability in extension or flexion. The pedal pulses were palpable and sensation intact other than lateral cutaneous sensory loss lateral to the midline incision.

Radiographs and Advanced Diagnostic Evaluation

At the time of the office visit, the right knee was prepped and draped utilizing alcohol and Betadine, and 25 cm³ of serosanguinous fluid was removed and sent for testing. Serum labs were also collected and sent for testing. The results are as follows:

Serum testing

- White blood cell count 4.0
- Erythrocyte sedimentation rate 89 mm/h
- C-reactive protein 41.85 mg/L

Synovial fluid

- Cell count 8500 cells/µL
- Neutrophils 85%
- Culture: methicillin-resistant *Staphylococcus epidermidis*

The initial X-rays of the right knee reveal a cemented, well-fixed, and well-positioned posterior stabilized femoral component and tibial component. There are two suture anchors in the inferior pole of the patella (Fig. 9.31).

The diagnosis of acute periprosthetic joint can be difficult, and guidelines have been developed to guide the treating surgeon [44] (Tables 9.1 and 9.2). In this case, the clinical diagnosis of acute periprosthetic joint infection was made based on lab work, cultures, and physical examination. The decision to proceed with two-stage exchange for acute periprosthetic joint infection is contro-

Fig. 9.31 Plain radiographs of the right knee preoperatively, including (a) anteroposterior and (b) lateral, revealed a well-fixed cemented total knee arthroplasty. There are two suture anchors in the inferior pole of the patella

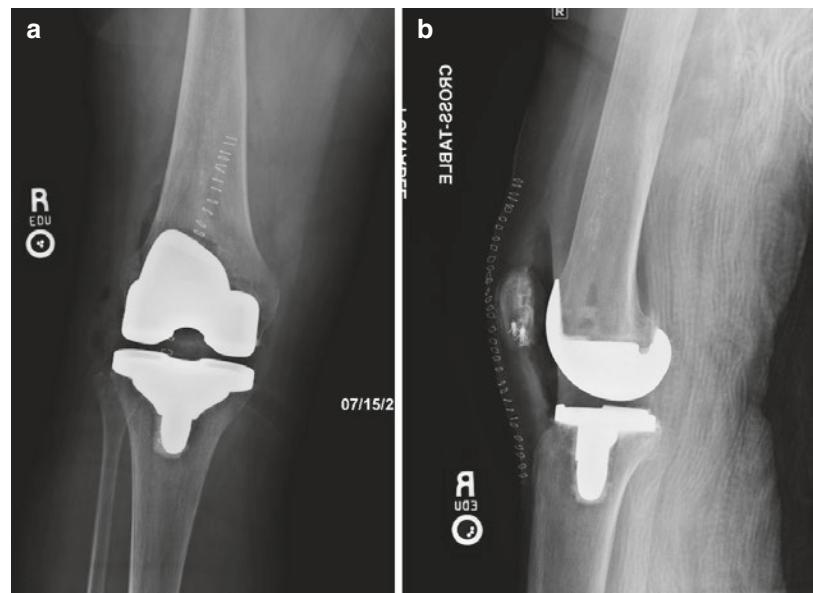


Table 9.1 Definition of periprosthetic joint infection according to the International Consensus Group (From Parvisi and Gehrke [44], with permission)

One major or three minor criteria from below define periprosthetic joint infection (International Consensus Group) ^a	
Major	Two positive periprosthetic cultures with identical organisms, OR A sinus tract communicating with the joint, OR
Minor	Elevated serum C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) Elevated synovial fluid white blood cell (WBC) count OR ++ change on leukocyte esterase test strip Elevated synovial fluid polymorphonuclear neutrophil percentage (PMN%) Positive histological analysis of periprosthetic tissue A single positive culture

^aPeriprosthetic joint infection may be present without meeting these criteria, and clinical judgment should be used to reach the diagnosis

Table 9.2 The threshold of the minor diagnostic criteria for periprosthetic joint infection (From Parvisi and Gehrke [44], with permission)

Minor criteria	Acute periprosthetic joint infection (<90 days)	Chronic periprosthetic joint infection (>90 days)
Erythrocyte sedimentation rate (mm/h)	Not helpful, no threshold	>30
C-reactive protein (mg/L)	>100	>10
Synovial white blood count (cells/ μ L)	>10,000 90	>3000 >80
Synovial polymorphonuclear (%)		
Leukocyte esterase	+ or ++	Same as acute
Histological analysis of tissue	>5 neutrophils per high-power field in five high-power fields	Same as acute

versarial and multifactorial. Current recommendations for acute two-stage exchange are poor host, >3 weeks of duration, poor soft tissue envelope, loose prosthesis, and drug-resistant organism

[45]. Patients who have a short duration of symptoms, immune competence, robust soft tissue envelope, symptoms <3 weeks, stable prosthesis, and sensitive organisms may be candidates for

irrigation debridement with component retention in selected cases. This particular patient had symptoms >3 weeks and methicillin-resistant *Staphylococcus epidermidis*, thus meeting indication for an acute two-stage procedure.

Surgical Approach

When presented with multiple previous scars, the most lateral incision should be utilized to avoid a large lateral flap due to the medial to lateral vasculatome of the knee. Transverse scars should be crossed perpendicularly. Any draining sinus tract or eschar should be meticulously debrided. If there are concerns about soft tissue viability, particularly on the proximal medial tibia, consideration should be given to plastic surgical consultation for rotational flap coverage. It is advantageous to have appropriate soft tissue coverage at time of articulating spacer to allow for robust closure at second stage, rather than flap coverage at time of second-stage reimplantation.

An extensile approach to the knee should be utilized, and there is no role for minimally invasive surgery in the treatment of infected total knee arthroplasty with two-stage exchange. A median parapatellar approach is most commonly utilized. The initial exposure is aimed at reestablishing the medial and lateral gutters with removal of synovium and debriding the suprapatellar pouch. Everting the patella is generally not necessary nor recommended to protect the patella tendon. The lateral patella-femoral ligament should be released, and the adherent patella tendon at the proximal tibia can be undermined to allow patella subluxation laterally (patellar peel technique). A large medial release should be performed to allow for tibial external rotation that will facilitate exposure as well as protect the extensor mechanism. With this technique, more extensile exposures (e.g., quadriceps snip, tibial tubercle osteotomy) are not commonly required.

Five cultures are routinely performed to confirm the organism and sensitivity profile. Specifically, one synovial fluid, one femoral tissue, one tibial tissue, one femoral canal swab, and one tibia canal swab are obtained. Cultures should be performed prior to a thorough debridement.

Component Removal

Polyethylene Insert Removal. Once adequate exposure is obtained, the polyethylene insert should be removed. If a modular polyethylene insert was utilized, it can often be removed with a quarter-inch osteotome. Rotating platform polyethylene inserts may be cut with an oscillating saw for removal. For monoblock tibia designs (e.g., all polyethylene, monoblock cementless porous metal), an oscillating saw can be used to cut the interface and/or remove the fixation post.

Femoral Component Removal. Femoral component removal is typically achieved with a handheld micro-sagittal saw (Fig. 9.32) and thin flexible osteotomes at the bone-cement interface. Angled osteotomes are useful for the posterior condylar portion as well as the intercondylar notch to minimize bone loss. Once free, the femoral component should be removed with a punch or femoral extractor. If a cruciate retaining knee was utilized at the index procedure, a box should be cut for the new femoral component, which will also facilitate debridement.



Fig. 9.32 Femoral component removal achieved with a handheld micro-sagittal saw as shown in this figure. Thin flexible osteotomes may also be used at the bone-cement interface for femoral component removal

Tibial Component Removal. An oscillating saw is used at the bone-cement interface as well as thin flexible osteotomes. The posterolateral tibial can remain bonded; if not freed appropriately, periprosthetic tibial fracture can occur upon implant removal. Tibial keels can often prevent access to this portion of the tibial tray, and a long thin osteotome from posteromedial to posterolateral can be utilized to free this area. Stacked wide osteotomes can also be useful in implant removal (Fig. 9.33). Levering of osteotomes should be avoided. Once free, the knee can be brought to extension and a punch placed on the anterior tibial implant to allow for safe removal. An oscillating saw is then used to remove 1–2 mm of proximal tibia bone for further debridement. If there is an intra-articular angulation of the tibia (revising a varus knee), an intra-articular correction can be performed at this time.

Patellar Component Removal. The patellar component can be removed with an oscillating saw at the bone-cement interface and the lugs removed with a high-speed burr. If a metal backed

patella is present, a metal cutting saw may be necessary for implant removal.

Debridement

One of the most important factors in direct control of the surgeon to eradicate infection is a thorough debridement. Meticulous sharp debridement of the soft tissues and cement and removal of foreign material are essential to infection eradication and are often the most time-consuming portion of the procedure. Care should be taken while debriding the posterior compartment, with protection of the neurovascular bundle. The femoral and tibial canals should be hand reamed with straight reamers. Once a thorough debridement has been achieved, a Betadine lavage (17 mL in 500 cm³ normal saline) for 3 min is performed, followed by 6 L of normal saline.

Bone Loss and Articulating Spacer Construct

Bone loss is typically characterized utilizing the Anderson Orthopaedic Research Institute Criteria (AORI) classification (Table 9.3) [46, 47].

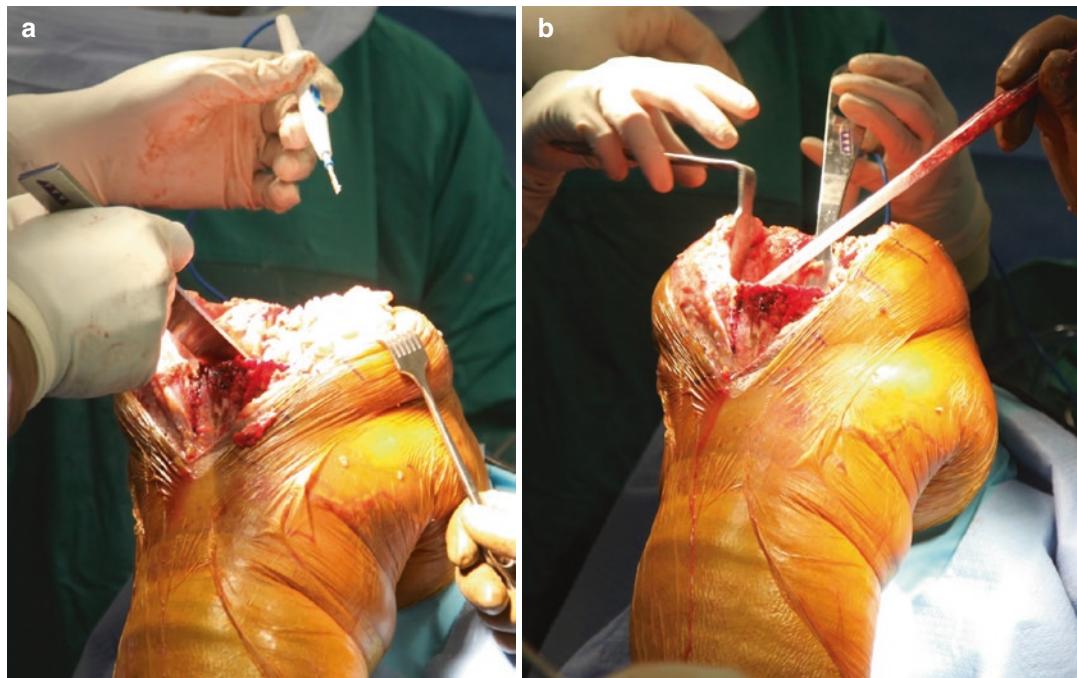


Fig. 9.33 Tibial component removal achieved with thin flexible osteotomes and an oscillating saw. Stacked wide osteotomes (a) can also be utilized in tibial component removal (b)

Relative contraindication to articulating spacer utilization is type III femoral bone loss [39], as well as a significantly compromised soft tissue envelope (consider static spacer). The authors' preferred method of articulating spacer is to utilize a new cobalt-chromium femur and an all-polyethylene tibial component without a keel. The previous sized implants are used to determine the approximate size of the new femur and polyethylene insert. The trial femoral component should be placed onto host bone and evaluated for overhang and appropriate rotation referencing the transepicondylar axis. Posterior condylar offset should be restored with the component. A tibial polyethylene trial should be selected that provides adequate bony coverage with rotation referencing one-third of the tibial tubercle. A polyethylene insert should be selected so that the knee achieves full extension with stability throughout an arch of motion. A posterior stabilized design or a semi-constrained tibial insert can be used to confer appropriate coronal stability (Fig. 9.34).

Cement Dowels

The medullary canals for the femur and tibia can be colonized in 30% of periprosthetic knee infections [48]. For this reason, cement dowels are



Fig. 9.34 A tibial polyethylene trial should be selected that provides adequate bony coverage with rotation referencing the medial one-third of the tibial tubercle. A polyethylene insert should be selected so that the knee achieves full extension with stability throughout an arch of motion. A posterior stabilized design or a semi-constrained tibial insert can be used to confer appropriate coronal stability

Table 9.3 The Anderson Orthopaedic Research Institute (AORI) classification [46, 47]

Type	Description	Treatment
1	Minor bone defects with intact metaphyseal bone, stability not compromised	Cement fill, impaction allograft
2A	Metaphyseal bone damage involving one femoral condyle or tibial plateau	Cement fill, augments, small bone graft
2B	Metaphyseal bone damage involving both femoral condyles or tibial plateaus	Cement fill, augments, small bone graft
3	Massive bone damage involving large portion of femoral condyles or tibial plateaus and can involve collateral ligaments or patellar tendon	Bulk allografts, custom implants, megaprosthesis, porous tantalum, metaphyseal sleeves, rotating hinge

fabricated with high-dose antibiotic bone cement. Two 10 cm^3 syringes are filled with high-viscosity bone cement with excellent antibiotic elution characteristics (Palacos, Zimmer Biomet, Warsaw, IN, USA). One pack of cement is used to make the dowels with 2 g of vancomycin and 3.6 g of tobramycin. The cement is allowed to cure in the syringes, and once hardened, the syringe tips are cut off with an oscillating saw. The cement dowels are then extruded with the plunger (Fig. 9.35).

Implantation

Two packs of 40 g poly(methyl methacrylate) (PMMA) bone cement are utilized to cement the femoral and tibial components into place. Two grams of vancomycin and 3.6 g of tobramycin are added per bag of cement. If the bacteria and sensitivity are known, the antibiotic regimen can be adjusted, but it is important to maintain high-dose antibiotic cement (4–5 g

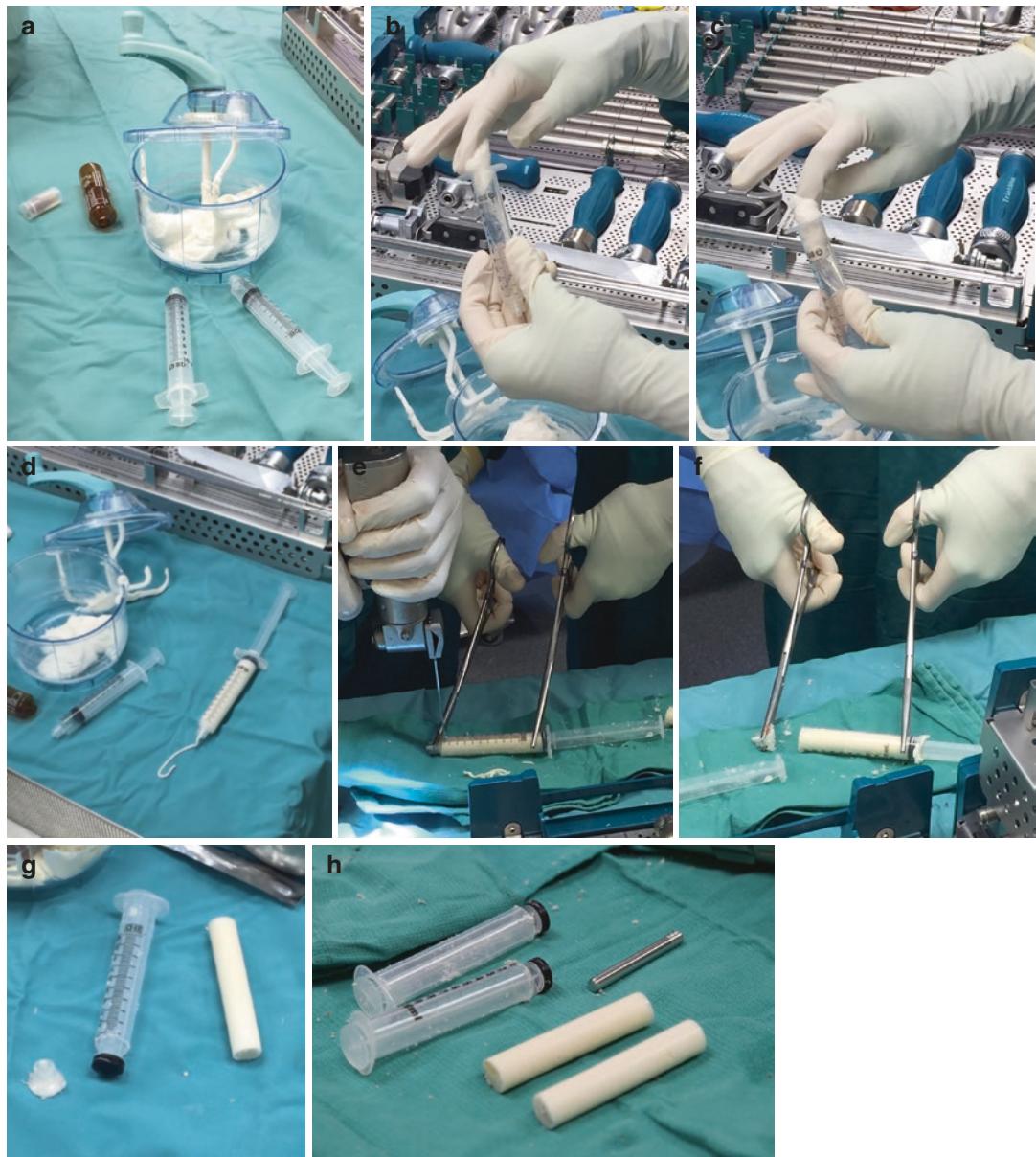


Fig. 9.35 Cement dowels are fabricated with high-dose antibiotic bone cement (a). Two 10 cm^3 syringes are filled with high viscosity bone cement with excellent antibiotic elution characteristics (Palacos, Zimmer Biomet, Warsaw, IN, USA) (b, c). One pack of cement is used to make the

dowels with 2 g of vancomycin and 3.6 g of tobramycin. The cement is allowed to cure in the syringes (d), and when hard the syringe tips are cut off with an oscillating saw (e, f), and the cement dowels are extruded with the plunger (g, h)

per 40 g cement bag). The cement is mixed and placed on the femoral host bone. The cured femoral cement dowel is placed through the doughy cement, which will unitize the dowel to the femoral cement. The femoral prosthesis

is then impacted onto the femur, and the doughy cement is placed onto the proximal tibia. The cured tibial cement dowel is placed through the doughy cement on the proximal tibia to unitize the construct. The tibial all

Polyethylene is then impacted onto the tibia. The knee is brought to extension to compress the cement (Fig. 9.36).

Closure

A drain is not utilized to maintain the eluted antibiotics in the knee. If a tibial tubercle osteotomy was performed, it should be closed with three cerclage wires. Large monofilament suture is typically used to close the arthrotomy, with smaller monofilament suture and staples on the dermis and skin. The postoperative X-rays are shown (Fig. 9.37).

Postoperative Protocol, Rehabilitation, and Results

Patients are allowed full weight bearing with a cobalt-chromium on polyethylene articulating spacer with active and passive ROM 0–100° similar to a postoperative protocol for a revision total knee arthroplasty. If there is concern over

wound healing, ROM and weight can be adjusted on a case-by-case basis. The authors have found that full weight bearing and ROM after a well-functioning articulating spacer does not typically impede wound healing. Postoperative protocols are not altered if a quadriceps snip was performed. An occlusive dressing is applied and typically removed on postoperative day ten unless saturated. Postoperative physical therapy is typically provided at home for 3 weeks and then as an outpatient for an additional 3 weeks. Bracing is not usually required due to the relative stability of this type of articulating spacer.

An infectious disease specialist is consulted the day of surgery to aid in determining appropriate IV antibiotics and length of treatment with a standard duration of 6 weeks in most cases.

Clinical Results

Several controversies exist regarding differences between static and articulating spacers and among different articulating spacer constructs. Infection eradication rates between static and mobile spacers have been equivalent in the literature with approximately 90% infection eradication rates in some studies [37, 38]. The idea that placing a new cobalt-chromium femur with polyethylene insert increases infection rates has been debunked in several studies [49, 50]. High-dose antibiotic cement should be utilized for infection eradication (>4 g per 40 g of cement) [48]. Strong consideration should be given to using intramedullary antibiotic-impregnated cement dowels due to 30% canal colonization and to preventing mobile or static spacer dislocation [48]. Although knee outcome scores have not showed statistical differences between static and mobile spacers, several studies do show increased ROM in patient who underwent mobile space implantation [39]. Mobile spacers have also been shown to create less bone loss than static spacers graded by the AORI [51]. Ease of reimplantation has also been reported with the use of mobile spacers requiring fewer extensile exposures (quad snip, tibial tubercle osteotomy [TTO]) during second-stage reimplantation [39]. With regard to relative contraindication to utilizing mobile spacers, cau-

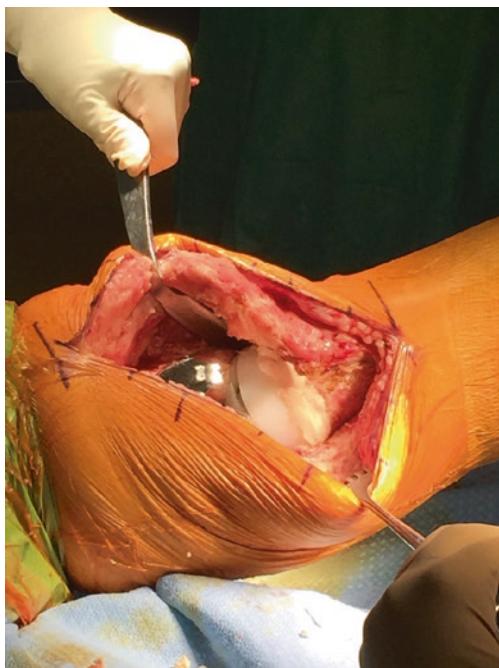
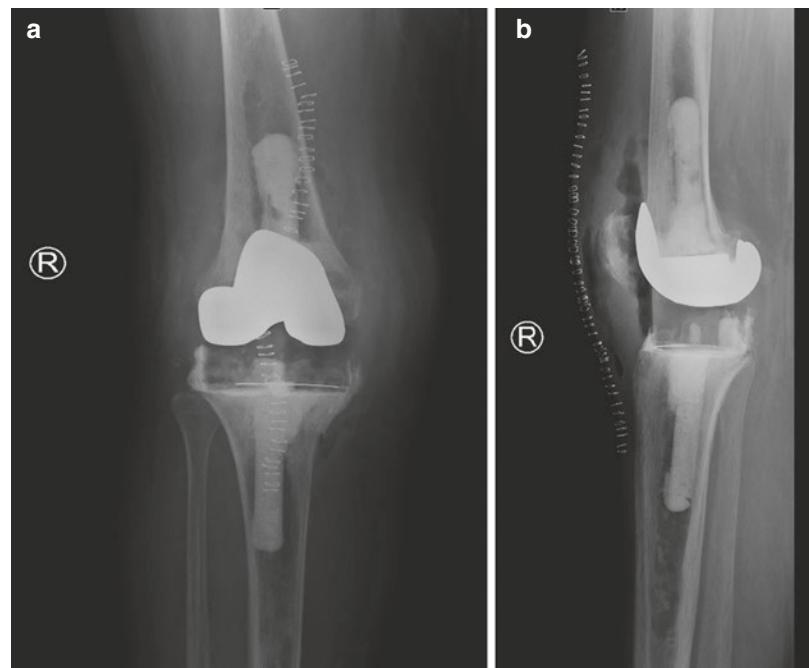


Fig. 9.36 Doughy cement is placed onto the proximal tibia, and cured tibial cement dowel is placed through the doughy cement on the proximal tibia to unitize the construct. The tibial all polyethylene is then impacted onto the tibia, and the knee is brought to extension to compress the cement

Fig. 9.37 Plain radiographs of the right knee postoperatively, including (a) anteroposterior and (b) lateral views, demonstrated well-fixed femoral and tibial components with maintained alignment



tion should be used in AORI type 3 femoral bone loss and when the soft tissue envelope is compromised and needs plastic surgery flap coverage [39]. Controversy persists regarding the optimal mobile spacer construct. A recent study comparing different mobile spacer constructs reported that metal-on-polyethylene spacers resulted in increased interim ROM and avoid spacer fracture as a complication versus cement-on-cement mobile spacers [52]. A well-functioning metal-on-polyethylene spacer may also allow for serendipitous single-stage exchange in some patients [53].

Key Points

- The diagnosis of acute periprosthetic function can be challenging. The physical exam, serum lab work, intra-articular lab work including alpha defensin, and cultures are useful in establishing the diagnosis.
- The use of a two-stage exchange in managing acute periprosthetic infection is controversial, but it should be considered in the event of poor host, >3 weeks' duration, poor soft tissue envelope, loose prosthesis, and drug-resistant organism.
- The surgical technique may require an extensive exposure for safe component removal and spacer implantation, including a quadriceps snip or tibial tubercle osteotomy.
- Well-fixed components should be removed with a micro-sagittal saw and flexible osteotomes to minimize bone loss and prevent peri-prosthetic fracture.
- Strong consideration should be given to utilizing a mobile spacer to improve interim joint function, facilitate reimplantation, and decrease interim bone loss, with equivalent infection eradication rates to fixed spacers.
- Strong consideration should be given to using high-dose (>4 g per pack) antibiotic cement for both spacer cementation and intramedullary dowels using the above technique.
- Consideration should be given to using a metal-on-polyethylene spacer to eliminate the incidence of cement spacer fracture, allow for increased interim ROM, and give the potential for a serendipitous single-stage exchange.

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Introduction

Giles R. Scuderi

The primary goal of total knee arthroplasty (TKA) is to create a well-aligned and well-balanced knee. Femoral sizing and component alignment, as well as the balance of the extension and flexion gap, are requirements for a well-functioning TKA. Distal femoral preparation, sizing, and component placement, with attention to proper alignment in the coronal, sagittal and rotational planes, are essential in creating a well-balanced implant. The intent is to create a consistent flexion gap and restoring posterior condylar offset. The etiology of instability is due to failure to balance the flexion and extension gaps, and flexion instability develops when the flexion gap is larger than the extension gap [1].

Instability after TKA is an important cause of early revision and can present as frank dislocation or, more commonly, with subtle clinical symptoms and signs. While there are different degrees of instability, flexion instability is evident when the knee is stable in full extension but is ligamentously lax in flexion. Flexion instability can complicate both cruciate retaining and posterior stabilized TKAs [2, 3]. While some of these cases present with frank dislocation of the knee prosthesis, the majority have subtle findings such as startup pain, especially while negotiating stairs, a sense of instability without giving way, recurrent joint effusions, above-average range of motion, and diffuse periarticular tenderness, primarily at the insertion of the pes anserinus tendon along the proximal medial tibia.

Management of isolated flexion instability after TKA starts with thorough preoperative assessment to rule out other causes of pain, clinical examination to assess flexion laxity, and radiographic assessment to determine reduced posterior condylar offset, excessive posterior tibial slope, and malrotation of the femoral component, leading to asymmetric flexion instability. When one or more identifiable radiographic findings are present, femoral and tibial component revision should be considered. In select cases, when no apparent radiographic cause can be identified, an isolated tibial polyethylene insert exchange, thicker and possibly with a more constrained articulation, along with posterior capsular

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release, may be attempted. If this is chosen as a solution for flexion instability, it is important to determine whether it eliminates excessive flexion laxity without overstuffed the extension gap and creating a flexion contracture. When well-balanced and equal flexion and extension gaps cannot be achieved with isolated tibial component exchange, then revision of the femoral and tibial components should be performed. Revision TKA with an unlinked constrained implant is usually successful for the management of isolated flexion instability [4].

The following case reports will describe the indications and surgical techniques for managing flexion instability. The clinical outcomes for the specific technique will also be reviewed.

Option 1: Tibial Component Revision for Flexion Instability

Zachary P. Berliner and José A. Rodriguez

Case Presentation

History

We present the case of a 62-year-old male with a past medical history significant for HIV, asthma, GERD, smoking, multilevel disc disease, and osteoarthritis of the left knee. The patient's left knee troubles began at the age of 17, with an episode of osteomyelitis of the distal femur. The infection was treated with incision and drainage (I&D) and kept him hospitalized for approximately 1 year. He later recovered well and returned to an active lifestyle that included running and playing basketball.

At age 55, while on the job at a warehouse in New Jersey, the patient fell from a 5-foot-high loading platform. He sustained several injuries, including a rotator cuff tear and multiple disc herniations. His left knee suffered medial meniscus and ACL tears, as well as osteochondral injuries. He underwent arthroscopy at the time and inevitably developed post-traumatic arthritis. He proceeded to undergo left total knee replacement (TKR) 6 years later, in August 2012, under the

care of another surgeon. He received a posterior stabilized implant.

Two months postoperatively, the patient presented with increased pain and swelling. Arthrocentesis yielded 20 cm³ of sanguineous fluid with no evidence of infection. Blood work was negative for infection, showing a white blood cell (WBC) count of $7.24 \times 10^3/\mu\text{L}$ (microliters) with 50% polys, Interleukin-6 of 5 pg/mL, and erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) of 58 mm/h and 0.2 mg/L, respectively. His symptoms were attributed to overly aggressive rehab, and his regimen was tailored to maximize muscle strength and improve stability.

At 8 months postoperatively, the patient continued to have pain and difficulty in ambulating. Physical exam was significant for an effusion, warmth, and a limited range of motion (0–90°). Arthrocentesis yielded 20 cm³ of cloudy fluid that was negative on gram stain and anaerobic culture, with WBC, glucose, and protein all within normal limits. There were no crystals. He was started on pain management with daily oxycodone and was referred to our clinic for a second opinion.

On presentation to our office, the patient complained of severe knee pain, stiffness, and a sensation of "knee motion and cracking" within the joint. He described swelling as relapsing and remitting throughout his postoperative course. At the time, the patient's ambulation was limited by severe pain to just five city blocks.

Physical Examination

Physical exam disclosed an antalgic limp. On superficial inspection, well-healed incisions related to his I&D and TKR were seen. Four large keloid scars were also visible—likely secondary to his arthroscopy. Though the joint lacked an effusion, the surrounding tissues were boggy and swollen. There was significant tenderness at the mediolateral joint line and retropatellar space. Range of motion was approximately 7–110°. Clinical alignment was approximately 6° of valgus. Varus and valgus stress produced openings of approximately 10° and 5°, respectively. Anterior drawer disclosed 5–10 mm of translation.

While seated with his knee flexed, the patient's tibia would significantly passively distract. It was reducible onto the femur with application of an upward, axial force. Sulcus sign was positive with knee flexion and applied inferior displacement of the tibia. There was no extensor lag. Muscular exam was significant for atrophy of the quadriceps tendon, as well as tightness of the quadriceps, hamstrings, and iliotibial band.

Radiographs and Advanced Imaging

Radiographs showed bony remodeling changes of the femur consistent with drainage from old osteomyelitis. Total knee implants appeared well-fixed, although a medial tibial lucency was present, suggesting a synovitic process (Fig. 10.1). The proximal tibia cut surface was situated just below the level of the fibular head, suggesting a large resection during the index procedure. Figure 10.1 illustrates the valgus positioning of the component relative to the upper tibia (approximately 3°), and Fig. 10.2 shows 13° of posterior slope. A posterior translation stress view demonstrated posterior dislocation of the tibial post relative to the femoral cam (Fig. 10.3).

Both clinically and radiographically, his knee displayed flexion instability. Contributing factors



Fig. 10.1 Anteroposterior (AP) view, left knee



Fig. 10.2 Lateral view, left knee, demonstrating excessive posterior tibial slope

included malpositioning of the tibial component—valgus with excessive posterior slope—and ligamentous laxity, especially laterally. Given the well-fixed condition of his femur, and his history of osteomyelitis, we felt hesitant to alter the femoral component. As such, our plan was to correct the tibial component alignment and position and then perform a trial reduction with increased constraint. This would allow us to assess the need for any femoral revision.

Surgical Approach

Intraoperatively, all components were confirmed to be well-fixed. Our suspicions for instability were then verified: both a downward sloping tibial plateau and an incompetent lateral collateral ligament (LCL) were producing a flexion laxity and frank posterior dislocatability of the tibia under the femur.

In order to subluxate the tibia anteriorly in front of the femur, the medial collateral ligament (MCL) was lifted subperiosteally down to, but not including, the pes anserinus insertion and posteriorly to the level of the semimembranosus capsular insertion. This allowed progressive external rotation of the tibia relative to the femur.



Fig. 10.3 Posterior translation stress view, left knee

The polyethylene was removed, giving more circumferential access to the tibial cement bone interface. The interface was then developed with osteotomes and an oscillating saw, and the tibial component was extracted with a bone tamp.

The old cement was removed piecemeal. The tibial canal was reamed with a 10-mm reamer to obtain secure fit and stability while correcting slope and coronal alignment. Trialing of components in this corrected alignment yielded an anterior drawer of 3–4 mm with markedly improved sulcus sign. The MCL was competent, with 2 mm of opening on valgus stress. The LCL remained lax, but the addition of the constrained liner controlled for translation under varus stress and rotation. Our patient had a flexion contracture of 5°. In light of this stability testing, we decided not to proceed with femoral revision.

The proximal tibia had sufficient cancellous bone for primary cementation, but given the posterior void after correction of the slope, we chose to fully cement the stem. After placement of a cement restrictor, the cement bed was prepared, and the tibial canal and metaphysis were irrigated and dried. Cement was injected once it had reached a toothpaste consistency and was then digitally pressurized into the cancellous bone. In



Fig. 10.4 Anteroposterior (AP) view, left knee post-revision surgery

order to obtain optimal positioning, the component was held in place until the cement polymerized. Optimal stability was obtained with a 14-mm constrained condylar knee (CCK) liner. The use of the CCK liner necessitated deepening of the femoral notch with a high-speed burr.

The postoperative radiographs (Figs. 10.4 and 10.5) demonstrated correction of the tibial surface to 90° relative to the tibial shaft in both planes, with a buildup of cement posteriorly at the joint line and a well-fixed, cemented stem.

Postoperative Result

The patient had a successful and uneventful postoperative course. At 2 weeks, his physical exam disclosed a minimal anterior drawer of 3 mm, as well as 5° of flexion contracture. At 6 weeks, he had much improved range of motion with flexion to 115°. His knee was excellently stable to anterior and posterior forces, as well as to rotational stress. Though he still ambulated with a mild limp at 3 months, his pain was much improved.

Clinical Results

Instability after total knee arthroplasty is responsible for 10–20% of all total knee revision cases



Fig. 10.5 Lateral, left knee, post-revision surgery, demonstrating 0° of posterior slope

[5–8]. Flexion instability, in particular, occurs in approximately 1% of all TKAs [9, 10]. Attributable to improper balancing of the flexion–extension space, flexion instability results from an increased gap in flexion [7]. Mechanical precipitating factors include excessive posterior slope, overresection of the posterior femoral condyles, and malrotation of the femoral or tibial component (in asymmetric cases) [9–11].

Though commonly described in posterior cruciate ligament retaining devices, flexion instability has also been described in patients with posterior stabilized (PS) implants, as in our case [2, 8, 10]. Our patient's symptoms were consistent with the literature, as such patients are known to experience pain, recurrent joint effusion, a feeling of instability, diffuse peri-retinacular tenderness, and difficulty with stairs [11]. And though the jump distance required of the tibial peg in current PS knees generally prevents frank posterior dislocation [8, 11], our patient did display posterior tibial dislocation at 90° of flexion (see Fig. 10.3). In all, the excessive, sloping, tibial resection and valgus positioning of the component had combined to create a situation of symptomatic, functional flexion instability.

Revision surgery for flexion instability without dislocation in PS knees has been illustrated as successful in the literature. Schwab et al. reported on ten such cases between 1995 and 2001, demonstrating postoperative improvements in pain, stability, and overall patient satisfaction [2]. The authors advocated for complete revision and argued against isolated tibial polyethylene (PE) exchange, noting that isolated PE exchange could result in overstuffed in extension [2, 12, 13].

In 2014 a similar report that included patients treated by the senior author analyzed 12 cases treated with complete revision and 7 cases treated with isolated PE exchange [9]. Both groups saw improved clinical results, with no significant differences between the two [9]. Of note, any case with identifiable issues of alignment had those issues corrected. Reconstruction was considered suitable if anterior drawer was less than 5 mm, sulcus sign was eliminated, and flexion contracture was no more than 5°, regardless of the type of reconstruction performed [9]. In addition, constrained liners were used whenever the tibial tray allowed, highlighting the utility of increased rotational and coronal stability in PS knees with flexion instability [8, 9]. Using these criteria, 18 of 19 patients (95%) saw resolution of their symptoms after their first revision surgery [9]. One patient, who underwent isolated PE exchange, required revision to a custom-made, constrained insert with an extra 2 mm of thickness, which was successful [9].

Key Points

Isolated tibial component exchange can be effective in managing flexion instability if:

1. The femoral component alignment and rotation are optimal.
2. There is a correctable tibial alignment or slope issue.
3. A varus/valgus constrained implant can be used.
4. Intervention can yield objective improvement in stability testing without a flexion contracture beyond 5°.

Option 2: Flexion Instability—Complete Revision

Gregg R. Klein and Michael A. Kelly

Case Presentation

History

A 64-year-old active tennis player presents 11 months after primary total knee arthroplasty (TKA) for osteoarthritis performed at an outside institution. He reports he has not done as well as he would have liked after his knee replacement. His early postoperative recovery was not overly difficult. In fact, he was able to obtain 110° of flexion by 2 weeks, and his physical therapist told him he was doing great. Over the past 11 months he had done multiple courses of physical therapy without significant improvement. He denies any wound issues or signs of infection during his postoperative course. His biggest complaint is chronic pain, swelling, and fullness of the knee. It is better first thing in the morning but worse as

the day goes on. Heavy activity makes him even worse. He also reports difficulty going down stairs. He cannot pinpoint the exact location of his pain but reports primarily to the proximal tibia both medially and laterally. He has been unable to return to tennis. He has tried, but after 10–15 min of doubles he has severe swelling which sets him back for a few days each time he tries to play (Fig. 10.6).

Physical Examination

On physical examination knee range of motion (ROM) is 0–135° of flexion, and alignment is neutral. The extensor mechanism is intact with good quadriceps strength. There is a moderate effusion with a well-healed wound. There is diffuse tenderness over the anterior aspect of the knee most pronounced over the pes anserine bursa. In full extension there is good stability to varus and valgus stress. At 30° of flexion there is physiologic opening but no gross instability. With the leg hanging over the examination table at 90° of flexion, there is approximately 10 cm of anterior translation of the tibia on the femur.

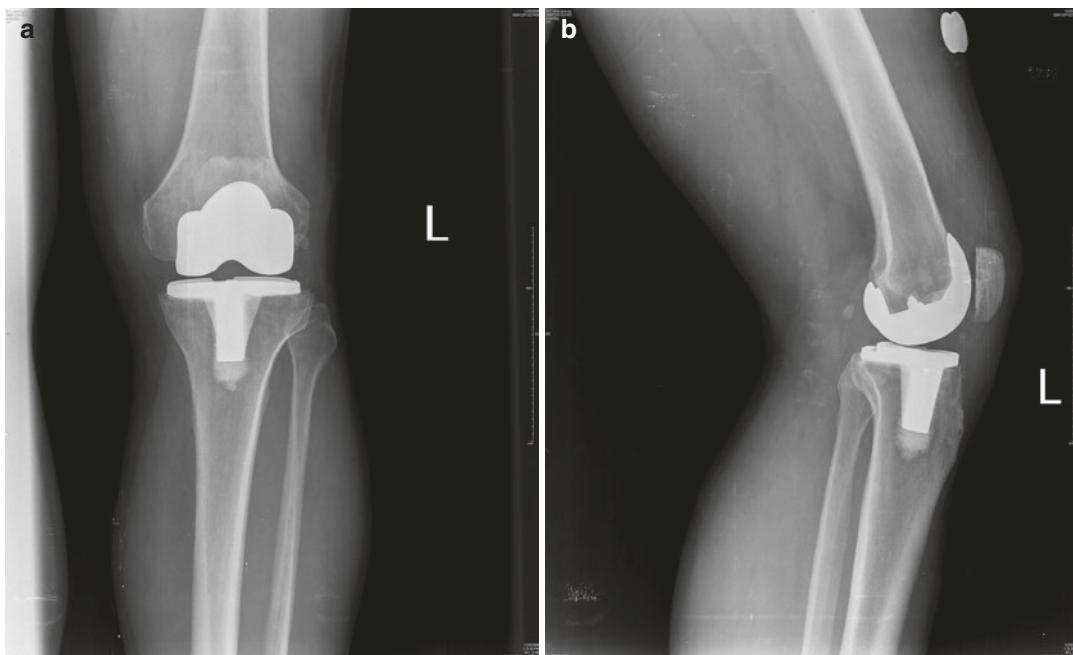


Fig. 10.6 Anteroposterior (AP) (a) and lateral (b) radiographs of the left knee showing a cemented posterior stabilized arthroplasty. Note the small femoral component and decreased posterior femoral offset

There is a firm mechanical endpoint with posterior stress on the tibia. Laboratory values including erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are normal.

Previous reports and images from the previous surgery were reviewed. Prior to the primary TKA, the patient had a 15° flexion contracture with a mild varus deformity. Radiographs showed a varus deformity with end-stage arthritis of the medial compartment and moderate patellofemoral changes.

Diagnosis

The patient shows signs of flexion after TKA. Instability can be subdivided into four general categories: (1) axial (varus/valgus) instability, (2) recurvatum (hyperextension), (3) flexion (antero-posterior), and (4) global instability. More specifically this patient's knee is showing signs of flexion instability. The knee appears stable to varus/valgus stress has full extension without recurvatum and exhibits laxity at 90° of flexion. Flexion instability can be defined by an imbalance in the flexion gap that is larger than the extension gap.

The diagnosis of flexion instability may be subtle as demonstrated in this patient by effusions or swelling and diffuse pain or may exhibit frank dislocation which is less common today given the modern generation of implant sizes and posterior stabilized (PS) post configurations. They will often but not always report the swelling is better with rest and worse with activity. Pain going up and more specifically down stairs is often reported. In addition, pain over the pes anserinus and retinaculum is often encountered [3]. Other subtle signs of instability include giving way and anterior knee pain [2, 14]. It is important to carefully question the patient as they may confuse patellofemoral instability with tibiofemoral instability.

It is helpful to obtain documents and details regarding the previous surgery and the implants used. Flexion instability after cruciate retaining (CR) TKA is different from PS. The timing of the instability is also important. It can occur initially from the time of the surgery due to malalignment, malposition, inadequate gap balancing, or ligamentous damage such as over-release or damage

to the posterior cruciate ligament (PCL). Late presentations may be due to PCL rupture; polyethylene wear or component loosening is common. Often instability can be magnified by malalignment [15].

The physical examination is important. Knee range of motion is often good or excellent, and patients report that they were able to obtain ROM early and easily. Varus/valgus stability should be examined at 0°, 30°, and 90° of flexion. In full extension the posterior capsule is tight, and the collateral ligaments may give a false sense of tightness. At 30° the capsule is lax and the collateral ligaments can be more reliably evaluated.

At 90° of flexion anterior-posterior stability should be tested. This is done with the patient sitting at the edge of the examination table and the knee flexed 90° with the leg hanging over the edge and the foot unsupported. A traditional anterior and posterior drawer test can be performed. It has been shown that 5 mm of anterior-posterior translation is necessary for physiologic knee range of motion. More than 5 mm can indicate instability [16]. This examination should be repeated with the contralateral knee as every patient exhibits different amounts of normal or physiologic laxity. Cruciate retaining knees should be evaluated for a posterior sag indicating a rupture of the PCL. On rare occasions a PS knee may exhibit a sag indicating a post fracture. In the quadriceps active test, the flexed knee reveals a reduction of the tibia from its previously subluxated position to a neutral position as the firing the quadriceps will pull the tibia forward.

Radiographs should be carefully evaluated for component position and alignment and gross loosening. Component sizes, specifically recreation of posterior femoral offset and tibial slope should be noted. Most commonly pathology will be seen on the lateral view including posterior subluxation of the tibia under the femur with a normal appearing anteroposterior (AP) view [17]. Stress radiographs can be helpful in making a diagnosis of instability.

It is essential to rule out infection by obtaining a ESR and CRP. A preoperative aspiration can be revealing as a bloody effusion or hemarthrosis may indicate instability. Fehring has reported on

a series of knee revisions and found a high number of red blood cells (mean 64,000/mm) in unstable knees [14].

Surgical Approach/Technique

Any extensile surgical approach can be used as long as the surgeon can obtain adequate exposure to the knee for safe component removal and revision. A medial parapatellar approach was used in this patient. Preoperative understanding of the reasons for the flexion instability (Table 10.1) will help the surgeon preoperatively plan (implant choice) and intraoperatively correct the pathology.

Often there is more than one “error” that can contribute to an unstable knee. Placing the femoral component too anteriorly or using a component that is too small will result in a flexion gap that is larger than an extension gap. This error is often compounded by a preoperative flexion contracture. A preoperative flexion contracture will accentuate the tight extension space and loose flexion gap of the knee. A tibial articular surface that adequately balances the extension gap to obtain full extension will result in a loose flexion gap. Conversely, a tibial articular surface thick enough is used to fill the flexion gap a postoperative flexion contracture will occur. The flexion contracture can be balanced by performing a posterior capsular release and if necessary resecting additional distal femoral bone. However, too much distal femoral resection can elevate the joint line resulting in mid-flexion instability, patella baja, or PCL imbalance (in CR knees).

Anterior placement of the femoral component can be avoided by carefully evaluating the amount of posterior condyle resected. Posterior referenc-

ing instrumentation can be helpful to ensure an appropriate amount of posterior condyle is being resected. With these systems there is a risk of either notching or overstuffing the anterior compartment. It is crucial to ensure that the femoral component is sized based on anteroposterior dimensions and not medial-lateral (ML) dimensions. Some patient’s anatomy (frequently female) have relatively narrow medial-lateral dimensions and will result in overhang when sized appropriately in the AP dimension. If the component is downsized to match the ML dimension, too much posterior condyle could be sacrificed, and a flexion gap that is larger than the extension gap will occur. Fortunately, most modern implant designs have multiple femoral sizes with modified ML dimensions that make these errors less common.

At the time of revision surgery, the components should be removed carefully to minimize additional bone loss or deformity. Care should be used not to use a femoral component that matches the remaining bone stock. This is particularly important in the multiply operated knee or a knee in which significant bone loss occurs with component removal. This will result in a femoral component that is too small and thus will result in a large flexion gap. The femoral component should be sized independent of the remaining bone stock with attention to balancing the flexion gap. This is often obtained by upsizing the femoral component and using posterior augments to fill the bone defects posteriorly. It has been shown that the use of posterior augments will result in a more balanced construct with better results [18, 19]. Another option is to use an offset femoral stem to “posteriorize” the femoral component relative to the femoral shaft axis. It may be necessary to slightly notch the anterior cortex when using a posteriorly placed offset stem. This will result in the posterior condyles being more posterior and will tighten the femoral gap. This technique can be helpful if the next larger femoral component is too large in the ML dimension and impinges on the retinaculum or collateral ligaments. The goal of all the above techniques is to adequately restore the posterior femoral condylar offset to improve stability of the arthroplasty.

Tibial component position also can have an effect on flexion gap stability. Excessive tibial

Table 10.1 Causes of flexion instability

Undersized femoral component
Femoral component placed too anterior
Malrotation of femoral component
Undersized femoral component used to match bone defects during revision total knee arthroplasty
Spine/cam properties
Excessive tibial slope
Excessive ligament releases (varus or valgus knee)
Late posterior cruciate ligament (PCL) rupture
Over-release of PCL
Polyethylene wear

slope can result in flexion space laxity. It is important to understand the “characteristics” of the tibial component in the knee system being used. Each implant requires a specific amount of tibia slope for the tibial osteotomy, and every implant has a defined amount of slope built into its components. In general CR knees have more tibial slope than PS knees. At the time of revision an intramedullary cutting guide can be helpful in recreating tibial slope. Today, most revision knee systems have a tibial component that requires a neutral or 0° cut, and the slope will be built into the component itself.

Malrotation of the femoral component can also contribute to flexion instability. Too much external rotation of the femoral component will result in a smaller flexion gap laterally than medially and result in medial flexion gap instability. The opposite is true with too much internal rotation of the femoral component and then will result in a tighter medial joint space than lateral in flexion and thus flexion gap instability laterally.

When gap balancing or soft-tissue balancing proves to be unattainable, constrained revision implants may be necessary. Different levels of component constraint include standard CR

implants that are ultracongruent, PS implants, PS-plus implants, varus/valgus constrained implants, and hinged components. The minimum amount of constraint that is necessary to achieve a well-balanced knee should be used, as increasing constraint causes load transmission to the prosthesis-host bone interfaces that may increase rates of loosening. It is important to understand, that using more constrained implants such as PS-plus or varus/valgus constraint will theoretically not solve isolated flexion instability. Balancing the flexion and extension gaps is imperative.

Postoperative Results

In this patient both the femoral and tibial components were revised. The femoral component size was increased, and posterior augments were used. The proximal tibial was prepared with an intramedullary alignment guide aiming for 0° of posterior slope. In this tibial component, the slope is built into the tray. Radiographs are shown in Fig. 10.7. At 1 year follow-up the patient reported his swelling and pain were resolved. His ROM was $0\text{--}125^\circ$, which was slightly less than prior to revision, but he was happy and has returned to playing doubles tennis. Interestingly,

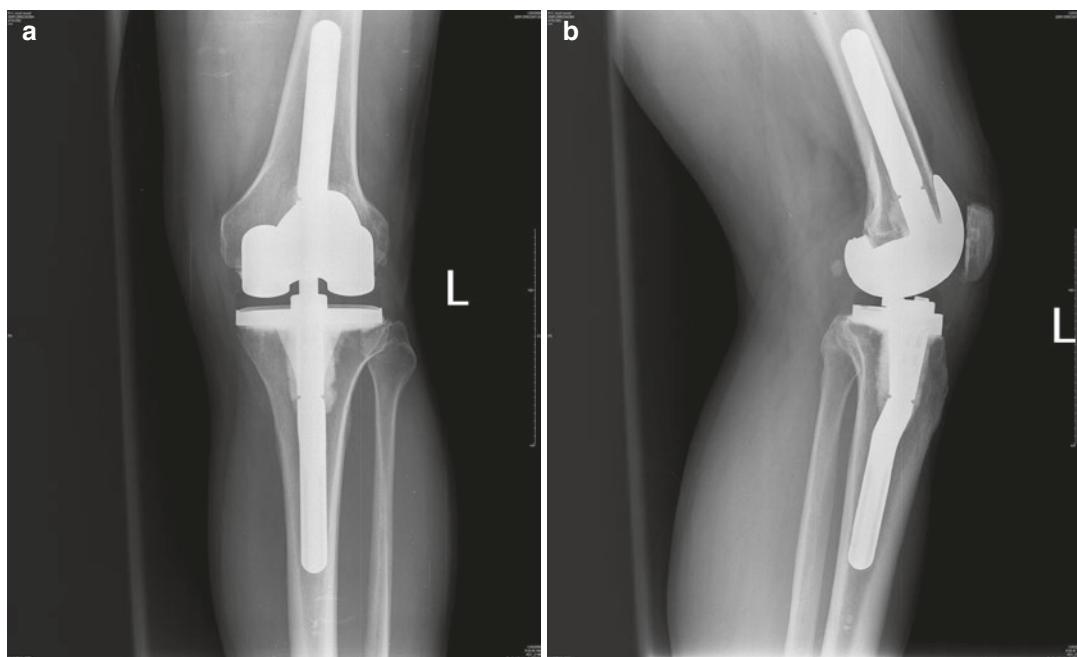


Fig. 10.7 Anteroposterior (AP) (a) and lateral (b) radiographs after a revision arthroplasty. The femoral component was upsized, and posterior augments were used. Note the restoration of the posterior femoral condylar offset

he reported that he had more difficulty obtaining flexion during his physical therapy after the revision.

Clinical Results

There are few revision TKA studies focused solely on flexion instability. Historically, the clinical results reported for TKA failures diagnosed as flexion instability are often included as a subset of revision TKA performed for all causes. Instability is the third most common cause for failure of TKA [20]. Aseptic loosening and sepsis are generally more commonly reported in most large series. It seems clear that the clinical results of revision TKA are superior in the subset of patients with aseptic loosening when compared to the results for instability, septic loosening, and stiffness. van Kempen et al. demonstrated that clinical outcomes of revision TKA are dependent on the failure diagnosis [21]. They noted the best overall outcomes of revision TKA in patients with aseptic loosening of components and worst in those with stiffness following primary TKA. Outcomes for revision TKA for instability, malposition, and septic loosening diagnoses had intermediate results. These groups of patients may have more pain and a higher complication rate following revision TKA.

Grayson et al. reviewed 177 failed TKAs following revision TKA, and 92 patients with the failure diagnosis of flexion instability, infection, and loosening/osteolysis were reviewed excluding the diagnoses with small numbers. This allowed comparisons of functional improvement and patients expectations in these patients. Patients revised for flexion instability were more likely than the other two diagnoses to report that their expectations were not met. While their functional improvement was satisfactory, their preoperative functional level was higher than infection or loosening group [22].

Pagnano et al. [3] described flexion instability after CR TKA. They described 25 painful primary PCL retaining total knee arthroplasties revised for flexion instability. Twenty-two knees were revised to posterior stabilized implants and three with tibial polyethylene liner exchange. Knee Society Scores improved to average of 90

(82–99 points), and function scores average 45–100 points in the PS revision TKA group, a 86% successful outcome. Two of the three liner exchanges suffered recurrent instability requiring a second revision. This early observation and recommendation to limit tibial polyethylene linear exchange for flexion instability have been voiced by others. However, there are reports of successful results with PCL retaining tibia liner exchange to an ultracongruent tibial polyethylene for pure PCL insufficiency or attenuation [23].

Kannan et al. [19] recently reported on patient reported outcomes following revision TKA for flexion instability. Of the 37 TKAs, 24 were CR TKAs, and 13 were PS TKAs. Twelve of the knees had already undergone a procedure for unexplained pain elsewhere, and the majority of cases were performed by an experienced TKA surgeon. No patient received an isolated tibial poly exchange, and 70% of patients noted a perceptible improvement with CR knees demonstrating a trend to better reported outcomes than PS knees in this series. The re-revision rate was low (1 of 37), but the number of reoperations (7 of 37) for diagnoses of patellar clunk and stiffness was significant. CR TKAs revised by an experienced TKA surgeon showed a trend toward better outcomes.

Flexion instability in a PS TKA may be a difficult diagnosis [24, 25]. While frank dislocation of the tibial component may occur occasionally, a more subtle presentation described earlier in this chapter is far more likely [9]. Schwab et al. [2] reported on a series of PS TKAs that were well-fixed and well-aligned that demonstrated symptomatic flexion instability. They demonstrated successful revision TKA results with revision of both femoral and tibial components at a mean of 40 months. Abdel et al. [26] reviewing cases of flexion instability after TKA further emphasized the difficulties with the clinical diagnosis particularly in the PS TKA. They reviewed 60 TKAs in 60 patients who underwent revision TKA for flexion instability associated with well-fixed components from a TJA registry. Nearly, one third of these patients had PCL substituting TKAs. The mean follow-up was 3.6 years (2–9.8 years). They emphasized the correction of poste-

rior condylar offset, decreased posterior tibial slope, correct femoral component rotation, and joint line restoration were the contributing factors to satisfactory postoperative clinical results. There was a statistically significant improvement in Knee Society Score (34–82 points) *and* function (37–84 points). There were no cases of reported instability nor recurrent effusions.

Azzam et al. [18] reporting on a series of revision TKAs for instability demonstrated the superior results of revision of both femoral and tibial components compared to isolated poly exchange. This review included coronal, flexion, and combined instabilities with 75% of the 68 knee PS TKAs. Sixty per cent (6/10) of knees with isolated polyethylene exchange had recurrent instability compared to 12.5%. The success rate in this series of revision surgery for instability in mostly PS TKAs was 80%.

In summary, there are several common themes in the clinical results of revision TKA for flexion instability after primary TKA. Isolated polyethylene exchange is to be discouraged in the majority of cases as mostly poor results have been reported. An accurate diagnosis is necessary and may be difficult especially with PS TKAs. A stepwise approach to revising the femoral and tibial components as outlined in this chapter is critical to revision TKA success. Surgeons should counsel their patients preoperatively regarding the proper postoperative expectations which may be less than other revision TKA diagnoses. A complete TKA modular system with allowance for increasing prosthetic constraint should be available for this surgery.

Key Points

- The diagnosis of flexion instability can be difficult to make and is often subtle.
- Findings can differ in cruciate retaining vs. posterior stabilized knees.
- Often more than one surgical “error” can contribute to flexion instability.

Flexion gap larger than extension gap

Femoral component too anterior

Femoral component too small

Excessive tibial slope

Malrotation

- Revision surgery.

Do not match femoral component to deficient bone stock.

Restore posterior femoral condyle offset with augments.

Balance flexion and extension gaps.

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Alfred J. Tria, Marcel A. Bas, Stephen Stephan,
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Introduction

Alfred J. Tria

Instability after TKA remains one of the major reasons for revision surgery [1]. The causes relate both to the soft tissues and to the implant positioning. TKA is a procedure that is dependent upon balanced flexion and extension gaps [2, 3], appropriate overall limb alignment [4], and appropriate positioning of the implants to the underlying bone [5]. Some of these principles have been questioned and reevaluated in the recent past [4, 5]. Thus, the surgeon must make the correct diagnosis for the patient's symptoms and eliminate any possibility of recurrence after

revision. At times it may be possible to revise one of the components. However, because the operative procedure is a combination of bone and soft tissue surgery, it is imperative to address all of the problems at the same time, and this often requires complete revision of the implant. The case presentations in this chapter review the possible approaches to instability and discuss the results.

Option 1:Tibial Component Revision

Marcel A. BasStephen Stephan, and Matthew S. Hepinstall

Case Presentation

History

The clinical presentation of moderate global instability is illustrated by the case of a 63-year-old female with fibromyalgia who presented for evaluation of left knee pain, weakness, and

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generalized instability. She had episodes of buckling 2 years after left total knee arthroplasty (TKA) performed elsewhere. She complained of crepitus under the kneecap, instability on all surfaces, and moderate generalized knee pain. She reported difficulty with stairs and the need to use a bannister. She was limited to walking 5–10 city blocks and found the knee to be her major source of pain and disability, despite multiple lesser complaints related to fibromyalgia. She had received opinions from two other orthopedists, one of whom recommended polyethylene exchange, while the other recommended revision of all components.

Physical Exam

Lumbar and left hip examinations were normal. Left knee examination demonstrated neutral alignment and borderline stability in full exten-

sion with moderately increased laxity to valgus stress. There was moderate mid-flexion laxity to varus and valgus stress. Figure 11.1 depicts medial laxity to valgus testing at 15° of flexion. There was greater than 5 mm of anterior drawer at 90° of flexion with palpable condylar lift-off with varus and valgus stress in this position. Small effusion was seen. Figure 11.2 demonstrates preoperative anterior drawer testing at neutral and greater than 5 mm of anterior translation, respectively. Peripatellar crepitus was palpable with active extension of the knee from the flexed position. Arc of motion ranged from full extension to 140° flexion. Quadriceps strength was normal on manual muscle testing, and there was no extensor lag. Skin examination revealed a well-healed midline surgical scar. Neurovascular examination demonstrated normal distal sensation and motor power.

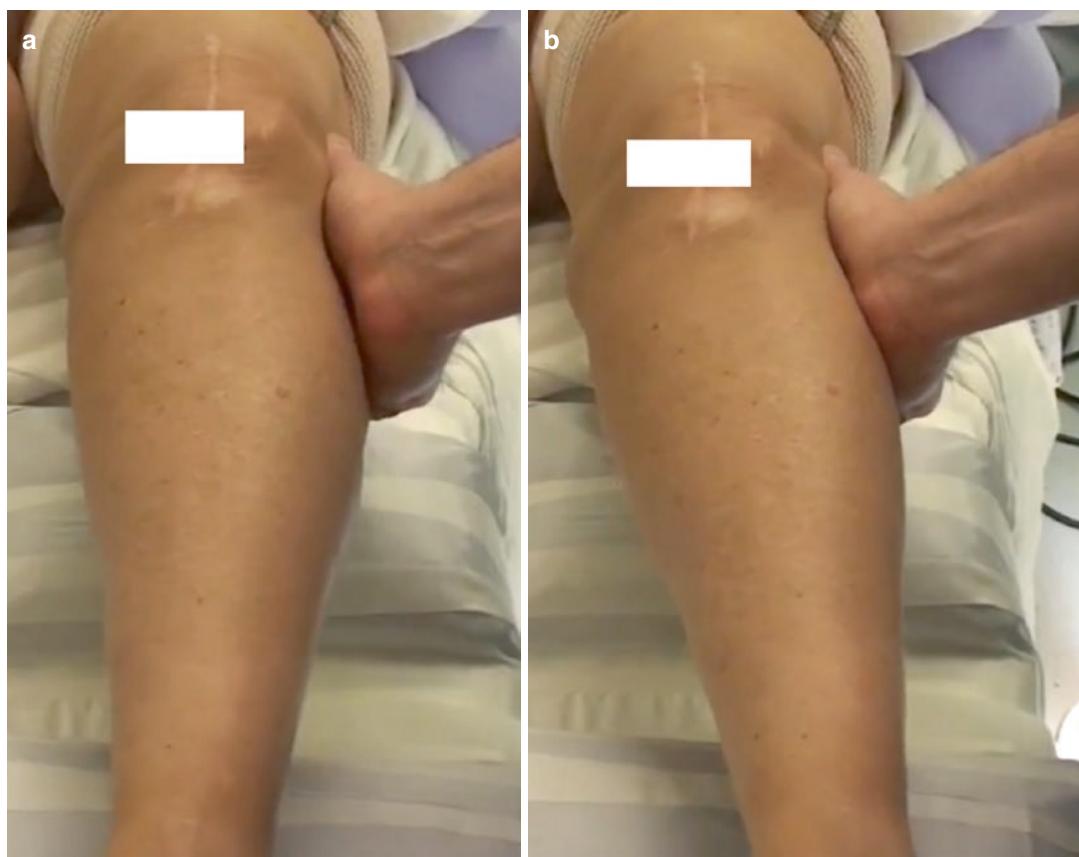


Fig. 11.1 (a) Medial and (b) lateral laxity in 15° of knee flexion

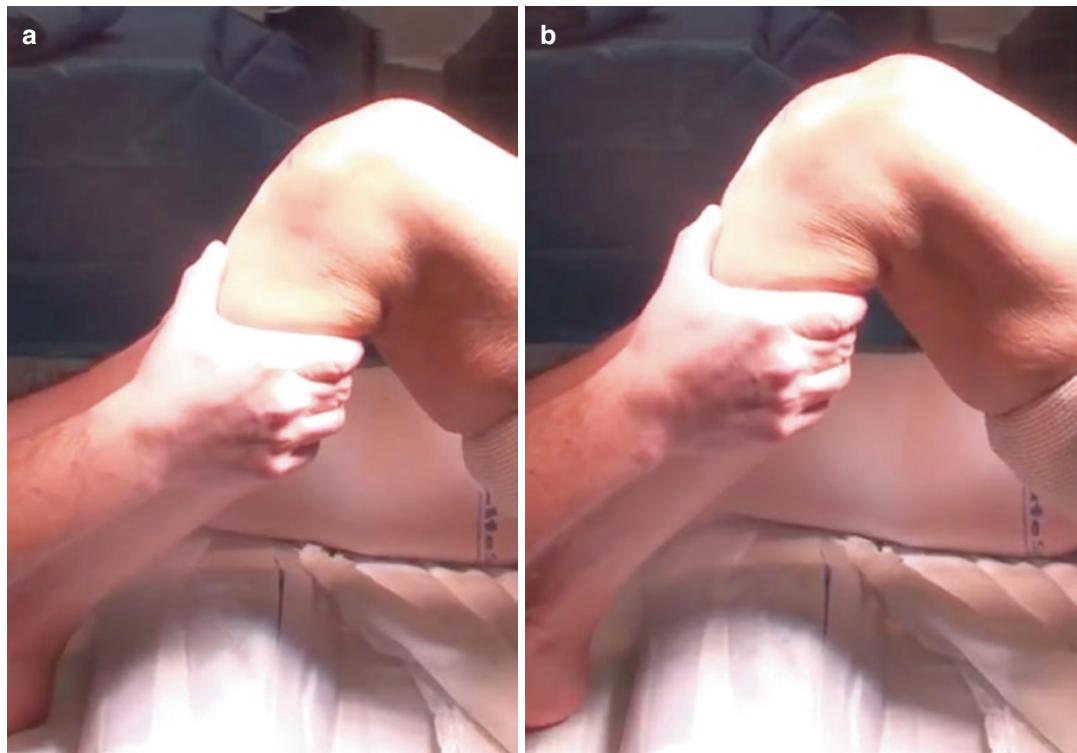


Fig. 11.2 (a, b) Preoperative anterior drawer examination at neutral and with greater than 5 mm of anterior tibial translation, respectively

Radiographs and Advanced Imaging

Standard anteroposterior radiographs of the knee were performed, along with lateral radiographs in flexion and extension and an axial view to assess patellar tracking, which was excellent (Fig. 11.3). Tibiofemoral alignment was approximately 5° of valgus, and both the tibial and femoral components were deemed to be acceptably aligned in the coronal and sagittal planes. Posterior condylar offset appeared adequate.

Surgical Approach

The patient was diagnosed with moderate global instability and concomitant peripatellar fibrosis. In the presence of central patellar tracking with well-fixed and well-aligned primary components that accept an articular insert with increased constraint, the patient was indicated for isolated tibial polyethylene insert exchange (ITPIE) to address tibiofemoral instability with removal of peripatellar scar to address concomitant patellar crepitus.

The knee was exposed using a midline incision through the existing scar and a standard medial parapatellar arthrotomy. Excision of the peripatellar scar was then performed to address crepitus, along with removal of scar tissue deep to the infrapatellar tendon to optimize mobility of the extensor mechanism and to facilitate exposure. Stability examination demonstrated approximately 2 mm of lateral opening and 3–4 mm of medial opening in mid-flexion. Anterior drawer again demonstrated greater than 5 mm of anterior translation. Anteromedial soft tissue release off the proximal tibia was performed proximal to the pes anserine. The medial collateral ligament was elevated off the tibia at the level of the joint line, maintaining the integrity of the distal attachment but allowing the tibia to be exposed with an incomplete *Ran-Sall maneuver* (named after its originators Ranawat and Insall)—rotational subluxation accomplished by external rotation of the tibia and hyperflexion of the knee [6]. The 9 mm tibial polyethylene

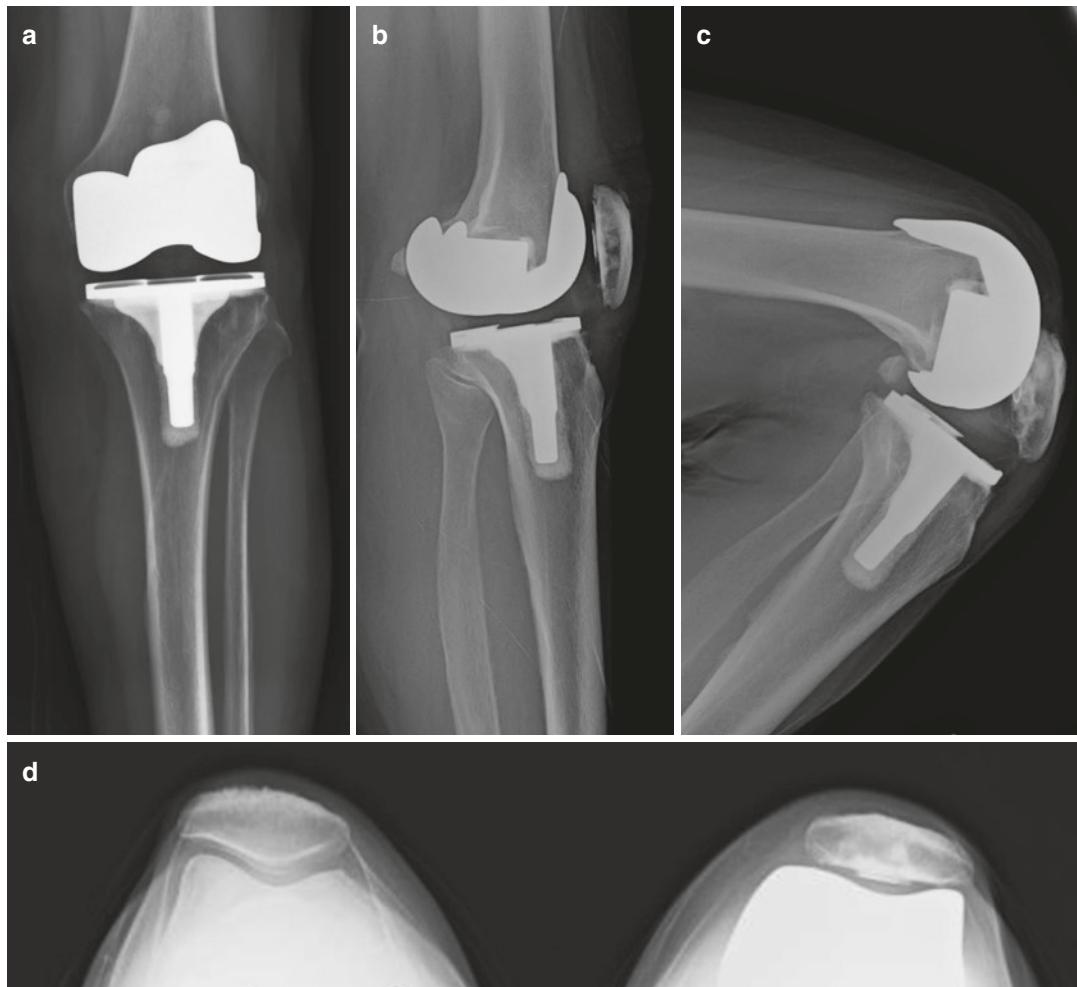


Fig. 11.3 (a–d) Preoperative anteroposterior, lateral flexion and extension, and sunrise view radiographs of a well-aligned, well-fixed left total knee arthroplasty

insert was removed and noted to be intact without any obvious wear. An 11 mm posterior stabilized (PS) trial demonstrated improvement in the anterior drawer to less than 5 mm, with no loss of flexion and excellent stability with varus and valgus stress showing 1–2 mm of opening medially and less than 1 mm laterally. Limited pie-crusting of the iliotibial band and the lateral collateral ligament was performed with an 18-gauge needle. Repeat trialing with a 13 mm PS insert resulted in 5° of flexion contracture, which was considered undesirable. A transverse capsulotomy was performed from the level of the prior insertion of the posterior cruciate ligament (PCL) to the posterolateral corner to ensure that capsu-

lar tightness was not a source of extension limitation. Repeat trialing with the 13 mm trial insert again did not achieve full extension. Based on this, an 11 mm varus-valgus constrained articular insert was used to optimize both range of motion and stability. Wound closure was performed in layers and a sterile antimicrobial dressing was placed. The patient ambulated on the day of surgery and was discharged home 2 days after surgery without complications or need for blood transfusion.

Postoperative Results

Within 3 weeks post-op, the patient had regained motion 0–120° and was walking without assistive

devices. At 1-year follow-up, the patient reported significantly improved knee pain and stability. She perceived an improvement in range of motion as she was better able to use the knee in deep flexion activities. Examination demonstrated a well-healed scar and no effusion, erythema, or ecchymosis. There was full range of motion at 0–130°, excellent stability, and no peripatellar crepitation. Strength was normal and there was no extensor lag. Figure 11.4 depicts postoperative anteroposterior and lateral radiographs in flexion and extension.

Clinical Results

The focus of this case is isolated tibial component revision for the treatment of global instability following TKA. This encompasses both ITPIE, as described above, and revision of the entire tibial component.

Instability is recognized to be one of the most common causes of TKA failure, accounting for 10–22% of all revisions [7–9]. TKA instability is defined as abnormal and excessive displacement of the articular elements that leads to clinical failure [10]. Multiple authors have classified types of

instability based on etiology and/or the arc of motion affected [9, 11, 12]. Tibiofemoral and patellofemoral instability may coexist, or one joint may be stable while the other is not.

Identifying the etiology of instability is the first step in treatment. Patellofemoral instability usually results from component malrotation, so fixing it requires correcting malrotation. Instability due to fixation failure requires revision of the loose component. Instability caused by component malalignment requires revision to correct component alignment. Instability due to ligament insufficiency requires increased articular constraint. Instability caused by mismatch of the flexion and extension gaps requires femoral revision to change the joint line, the posterior condylar offset, or both.

Isolated tibial revision is contraindicated when the femoral component is the primary source of instability, such as in cases of femoral loosening, malalignment, or malrotation and also in cases of grossly mismatched flexion and extension gaps. Femoral revision has historically been required to increase articular constraint, which is required in the setting of ligamentous insufficiency and can

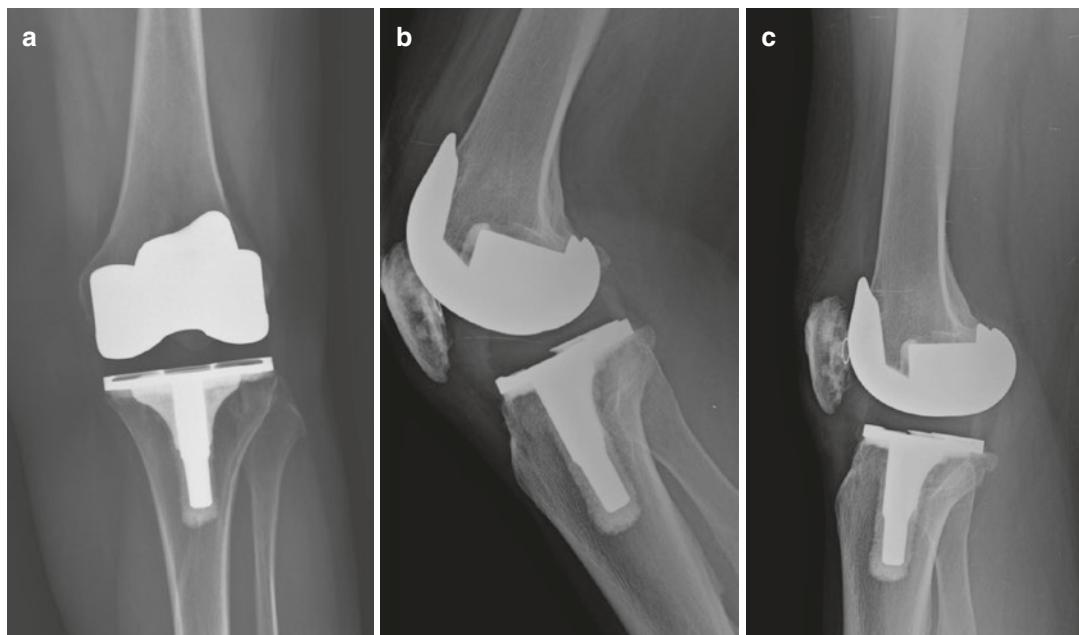


Fig. 11.4 Follow-up (a) anteroposterior and lateral radiographs, in (b) flexion and (c) extension 1 year after polyethylene liner exchange

be helpful even when ligaments are intact but attenuated. Newer implant systems often offer multiple levels of constraint compatible with primary femoral components, which has expanded the role of isolated tibial revision. PS implants can accept inserts that provide varus-valgus constraint, and cruciate-retaining implants can accept highly congruent or deep-dished inserts that increase rotational constraint and substitute for a deficient posterior cruciate ligament without use of a cam-post mechanism.

Isolated tibial revision is most often appropriate in the setting of global instability, which has been defined as having dynamic laxity on examination in multiple planes present throughout the entire arc of motion. This will often combine elements consisting of medial-lateral instability, anteroposterior instability, and rotational instability [9, 11–13]. Increased stability can be achieved by increasing the thickness and/or constraint of the tibial construct through ITPIE or component revision.

Unlike ITPIE, revision of the entire tibial component can also address instability related to tibial loosening, tibial malalignment, and tibial malrotation. Despite the greater versatility of full tibial component revision as compared to ITPIE, it is seldom the procedure of choice in the presence of tibial modularity and the absence of tibial loosening. A recent review of our institutional experience with revision TKA for instability without component loosening revealed that 36 of 90 cases were ITPIE, while only 2 of 90 cases were isolated revisions of the entire tibial component [14]. Review of the literature reveals a paucity of publications on isolated revision of the entire tibial component to address instability after TKA. Studies that do focus on isolated revision of the entire tibial component revision have included a mixed bag of diagnoses but have reported good results [15]. Whereas ITPIE can often be performed through primary exposures (Fig. 11.5), isolated revision of the entire tibial component requires more extensive exposure, for which a complete Ran-Sall maneuver [6] is typically adequate (Fig. 11.6).

With the development of the modular design TKA, ITPIE was initially viewed as a quick,



Fig. 11.5 Isolated tibial polyethylene insert exchange (ITPIE) can often be accomplished without extensive revision exposures

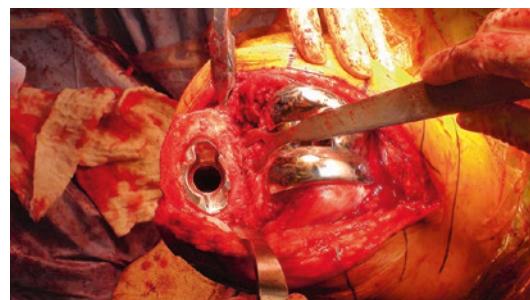


Fig. 11.6 Isolated tibial component revision requires a complete Ran-Sall maneuver [6] to accomplish adequate tibial exposure with femoral component retention

safe, bone-stock-preserving procedure for patients with well-fixed components [15, 16]. ITPIE has been used to treat instability, stiffness, and related findings such as effusions, pain, and early polyethylene wear [17, 18]. Early data regarding ITPIE revealed unpredictable results. Engh et al. reported that 8 of 48 knees (17%) undergoing ITPIE failed within an average of 5 years [19]. Willson et al. documented failure in 13 of 23 unstable knees (57%) treated by ITPIE [15]. Others have reported similar failure rates between 11 and 57%, with many authors recommending against ITPIE for the treatment of instability, stiffness, infection, pain, and polyethylene wear after primary TKA [15, 17–20]. The limitations of this body of literature are many. Reports of polyethylene exchange for wear and osteolysis were mixed with reports of polyethylene exchange for instability, etiology of instability was not documented, and strict indications for ITPIE were not defined.

Contrary to these reports, data from our center supports the use of ITPIE for instability following TKA as a viable revision strategy when strict indications are met as described here. We recently reported on 90 knees revised for symptomatic instability, with 40% of patients receiving ITPIE [14]. We observed similar failure rates between the ITPIE (19.4%) and component revision (18.5%) groups at mean 39-month follow-up. The most common cause of re-revision was recurrent instability in both groups. There was no difference between groups in clinical outcomes, range of motion, revision rate, or rate of clinical failure. Of the 36 knees treated with ITPIE, the average increase in polyethylene size was 4.4 mm. Seventeen knees (47%) received increased constraint in addition to a thicker insert. The subgroup with increased articular constraint demonstrated lower rates of re-revision when compared to those that only increased polyethylene size.

A key decision in the surgical management of instability is whether to maintain or increase the level of constraint [13]. Our experience suggests that when isolated tibial component revision is performed to address instability, an increased degree of articular constraint should be selected whenever permitted by femoral component design. Although others have suggested using the minimum level of constraint necessary to achieve ligament balance at revision surgery, even our cases in which both the femoral and tibial components were revised demonstrated higher failure rates if the level of constraint was not increased at the time of revision [14]. The choice not to increase constraint reflected an assessment that excellent stability was achieved through component revision. The higher rate of re-revision for instability in this group suggests that intraoperative assessment of soft tissue balance may be unreliable in this cohort. Soft tissues may dynamically remodel after revision TKA for instability, so we are now hesitant to perform isolated tibial revision for instability if the femoral component will not accommodate an increase in constraint.

Our positive experience with ITPIE is not unique. Jensen et al. reported on 27 revision TKAs that received ITPIE with mean follow-up

of 40 months [21]. The majority of revisions were performed in the setting of polyethylene wear. Clinical success was present in 80%, and revision rate was 10% at 31-month follow-up. They concluded that ITPIE and revision TKA have similar short-term survival, and ITPIE should be recommended for elderly patients with well-fixed and well-aligned prostheses without surface damage of the components [21]. Baker et al. demonstrated results of ITPIE in 45 knees with a mix of diagnoses, including polyethylene wear, stiffness, and instability [22]. Patient-reported outcome measures revealed significant clinical improvements following the procedure. Four of 45 (9%) required revision at minimum 2-year follow-up; all reoperations occurred secondary to femoral or tibial loosening in patients with osteolysis present prior to polyethylene exchange. When specific criteria were met, however, ITPIE provided improved knee function, quality of life, and patient-reported satisfaction [22].

In summary, the modern literature and our own experience suggest that isolated tibial component revision, and specifically ITPIE, is a viable strategy for the management of instability following TKA, especially when paired with an increase in constraint. When proper indications are followed, the results are comparable to revision of both tibial and femoral components. ITPIE is certainly not recommended for use with deficiencies in implant fixation, malalignment, malrotation, or ligamentous incompetence [8, 9, 12, 23, 24]. More often than not, inclusion of these factors into the etiology of TKA instability leads to revision of both the tibial and femoral components, which we have found to be necessary in 58% of instability revisions [20].

Key Points

- Isolated tibial component revision and ITPIE offer less invasive surgical alternatives compared to revision of both components for the treatment of global instability and have equivalent short- and intermediate-term outcomes in properly selected patients.
- Fixation and three-dimensional orientation of the femoral component must be acceptable if

isolated tibial revision is to be successful. Coronal and sagittal alignment must be acceptable, posterior condylar offset must be adequate to match the joint line in extension and create balanced flexion and extension gaps, and rotation must allow for balancing of the flexion gap and central tracking of the patella extensor mechanism.

- Fixation and three-dimensional orientation of the tibial baseplate must also be acceptable if ITPIE is to be successful.
- Results of isolated tibial component revision and ITPIE are most reproducible when the retained components allow the use of increased articular constraint.
- Soft tissues that feel “well-balanced” at the time of revision for instability can attenuate in the early postoperative period, resulting in recurrent instability.
- While others advocate using the minimal amount of constraint necessary to achieve intraoperative instability, our data show a higher rate of recurrent instability when constraint is not increased at the time of revision for instability.
- To mitigate the risk of recurrent instability, we routinely use the maximum constraint allowed by the retained femoral component in the setting of isolated tibial revision for global instability.

Option 2: The Complete Revision

Kevin I. Perry and Arlen D. Hanssen

Case Presentation

History

W.C. is a 67-year-old otherwise healthy male who presented with right knee pain and instability after total knee arthroplasty (TKA). He originally had a primary TKA done in 2009 at another institution for end-stage arthritis of the knee. He did well for several months after surgery, but developed gradually increasing pain and instability of the knee. He described a pain that was generalized in nature but was worsened with activities

like walking on uneven ground and going down-stairs. He stated that he was “unable to trust the knee” and that it felt like it was “going to give out” on him at times. He felt his knee was constantly swollen and that his swelling would increase with activity. He described a history of trauma to the knee many years prior to his initial TKA that resulted in an injury to his lateral collateral ligament (LCL) complex. The injury was managed conservatively in a brace and did not require surgery.

After his initial consultation, non-operative treatment was initiated with formal quadriceps and hamstring strengthening and a hinged knee brace. The patient felt his symptoms improved in the brace, but after 6 months, he no longer tolerated wearing it and was interested in definitive management of his instability.

Physical Exam

On exam, the patient had a well-healed midline incision about the right knee. He ambulated with a mildly antalgic gait favoring the right knee. He had excellent range of motion from 0° to 135°, but had significant asymmetric laxity of the knee in both the coronal and sagittal planes in full extension and with the knee flexed to 90° (Video 11.1). In extension, the knee opened approximately 4 mm on the medial side with valgus stress and 6 mm on the lateral side with varus stress. At 90° of flexion, the tibia translated approximately 1 cm anterior with an anterior drawer test. There was a moderate effusion in the knee and substantial soft tissue tenderness about the Gerdy tubercle and the pes anserine region. He had good strength and sensation and was neurovascularly intact distally.

Presenting Radiographs

The patient’s presenting anteroposterior (AP) and lateral radiographs (Fig. 11.7) demonstrated well-fixed implants without evidence of wear or loosening. The tibial component is in slight varus and the femoral component is slightly flexed, but the implants are otherwise unremarkable. Note the previous LCL complex injury with calcification along the lateral side of the femoral condyle (see Fig. 11.7a).

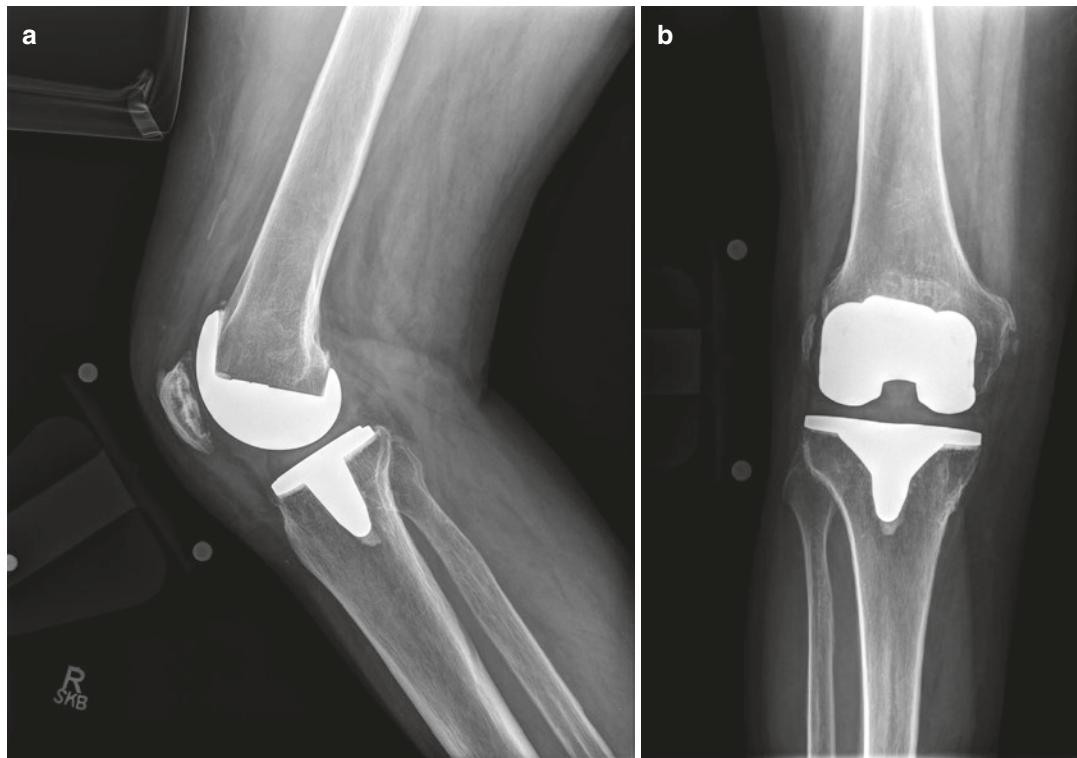


Fig. 11.7 Presenting anteroposterior (AP) (a) and lateral (b) radiographs

Surgical Approach

Due to the previous LCL complex injury, implant malposition, and the possible need for increased constraint, the decision was made to proceed with revision of both the femoral and tibial components. A preoperative erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were obtained to rule out infection, and both were within normal limits. In addition, a knee arthrocentesis was performed and confirmed the knee was aseptic prior to undergoing revision surgery.

Surgery was performed under a spinal anesthetic with the use of a pneumatic tourniquet. The patient's previous midline incision was utilized and a standard median parapatellar arthrotomy was performed. The polyethylene (PE) insert was removed and a thorough synovectomy was carried out for better exposure. The femoral and tibial components were then removed with the combination of flexible osteotomes and a saw with minimal bone loss noted on the femur. A

modest amount of central bone loss was present on the tibia after removal of the cement mantle, as expected. The patellar button was assessed, found to be well-positioned and well-fixed, and the decision was made to leave it in situ. At this point, the bony origin of the LCL complex was evaluated, and it was clear that it remained mobile with varus stress of the knee.

Implant Choice

Once the components were removed, attention was first turned to the tibia. The tibia was prepared for a press-fit stem to be cemented in hybrid fashion. A porous cone augment was utilized to fill the central defect in the tibia and provide additional fixation. After preparation of the tibia was completed, attention was turned to the femur. The femoral canal was reamed sequentially until good cortical contact was obtained. The distal femoral cutting block was then applied, and the distal femoral surface was touched up with a saw. A size 5 mm distal lateral

augment was found to provide appropriate coronal plane alignment and was applied to the 4-in-1 cutting block. The cutting block was then positioned with the knee in 90° of flexion, and rotation was set parallel to the proximal tibial surface. The guide was pinned in place and the anterior and posterior femoral surfaces and chamfers were prepared. A 5 mm posterolateral augment was necessary to achieve good host bone contact. A trial femoral component with a press-fit stem was then assembled and impacted onto the distal femur. Trial PE inserts were then utilized, and the knee was found open through the lateral compartment slightly both in flexion and extension. This appeared to be related to mobility of the LCL complex, and the decision was made to utilize a varus-valgus constrained (VVC) trial PE insert. This provided better lateral stability and accommodated for the mobile LCL origin throughout flexion and extension. Intraoperative radiographic assessment of the sagittal and coronal plane component alignment confirmed appropriate positioning of the implants, and the trials were then removed. The real components were then opened and assembled on the back table, and the symmetric tibial cone augment was impacted into the tibia utilizing an intramedullary impactor. The components were then cemented into place in hybrid fashion, cementing the surface and metaphyseal portions of the implants. Cementation of the real implants was carried out in a staged fashion, starting with the tibia. When the femoral cement finished curing, the VVC trial polyethylene was once again inserted, and the knee was found to provide full extension and stability throughout range of motion. As such, the real insert was opened and impacted into the tray, and the wound was thoroughly irrigated with normal saline and a dilute betadine lavage. The knee was then closed in layers and the patient was taken to recovery.

Postoperative Results

Postoperatively, the patient was made weight bearing as tolerated, and flexion and extension exercises were started on postoperative day one. The patient did remarkably well reporting no

issues with wound healing and improvement in his symptoms almost immediately after surgery. He returned to work 4 weeks postoperatively and has remained asymptomatic at 2-year follow-up. His 2-year follow-up radiographs are shown in Fig. 11.8a,b.

Clinical Results

Instability after TKA can have devastating effects on patient function and satisfaction after TKA. Global instability, in particular, is one of the most common forms of instability following TKA [25]. Global instability describes a pattern of gross laxity of the knee throughout range of motion. It has been attributed to multiple underlying etiologies such as attenuated soft tissues around the knee, severe flexion/extension gap mismatch [26], recurrent hemarthrosis or synovitis [11], and, occasionally, extensor mechanism failure [26]. If conservative treatment fails, global instability often necessitates revision surgery. Fortunately, revision TKA for symptoms related to global instability of the knee has demonstrated significant improvement in patient outcomes and TKA stability [11, 25, 27]. Firestone et al. [25] reported their results of 109 knee revisions done for instability, the majority of which exhibited a pattern of global instability. All patients in their series reported improved functional outcomes postoperatively, though two patients required reoperation for persistent symptomatic instability.

Luttjeboer et al. reported their results of 77 patients revised for instability after TKA, 32 of which were considered to have global instability. All patients in this series reported good clinical outcomes at 2-year follow-up. In addition, the authors demonstrated no difference in clinical outcomes between patients revised for extension, flexion, or global instability. Similarly, Song et al. [11] were able to demonstrate adequate coronal and sagittal plane stability in all 83 TKAs revised for instability, including 16 knees diagnosed with global instability. The authors utilized a causation-based approach to address the instability that included isolated polyethylene exchange, femoral component-only revision, tibial component-only

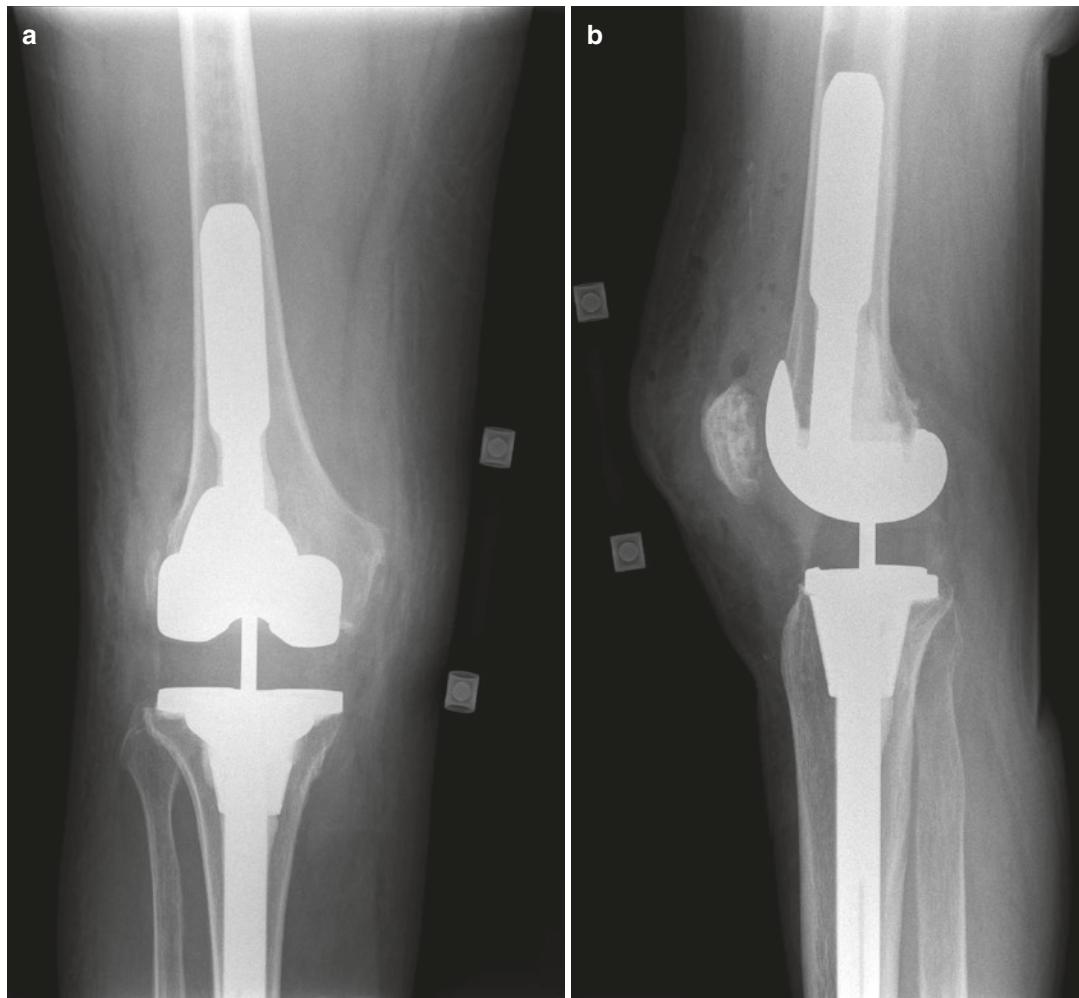


Fig. 11.8 Anteroposterior (AP) (a) and lateral (b) radiographs at 2-year follow-up demonstrating well-fixed, well-aligned implants without evidence of loosening or wear

revision, both component revisions, and extensor mechanism reconstruction.

Key Points

- Instability is common after TKA and has been the reported cause of failure after TKA in 10–27% of revision cases [12, 28–31].
- Instability of the knee is often multifactorial, and when considering revision TKA for instability, it is imperative to address all factors that may have contributed to the patient's instability. Specifically, the correction of the coronal, sagittal, and rotational alignment of the components, tibial slope, joint line position, posterior femoral condylar offset, and component sizing are all critical to obtaining stability of the knee [32].
- Though revision TKA for global instability may necessitate the use of a hinged knee arthroplasty, often correction of all contributing factors will achieve stability of the knee with less constrained designs. In general, the minimum amount of constraint needed to achieve stability of the knee should be utilized.

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Fred D. Cushner, David A. Crawford,
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and Robert Trousdale

Introduction

Fred D. Cushner

It is not uncommon for patients to describe a stiff knee in the immediate postoperative period. While they believe their knee is “stiff,” often these stiff knees have ROM of greater than 120° flexion. For the sake of discussion, this discussion will focus on knees with less than 90° of flexion in the immediate postoperative period. Lotke et al. were a bit more restrictive in their definition of stiffness. They considered a knee stiff if there was greater than a 15° flexion contracture and less than 75° of motion. With this definition, an overall incidence in over 1000 consecutive knees was 1.3%. As expected limited preoperative ROM was more likely to have postoperative limitations in this series.

It is no surprise that some knees are slow in gaining ROM. While the cause is multifactorial, there are several factors that play a role in postop-

erative ROM. One large factor is the presurgical ROM. Certainly knees with limited ROM are at more risk for having limited ROM after the procedure. Another major factor is postoperative pain control. It is no surprise that patients in significant pain are reluctant to advance their ROM in the immediate postoperative period. A large hemarthrosis can also limit ROM, but with the use of tranexamic acid, less blood loss is reported now during these TKA procedures.

The first attempt to regain ROM is the manipulation under anesthesia. Numerous studies show improved ROM with manipulation under anesthesia within the first 12 weeks of the postoperative period and up to 26 weeks following the procedure. It is commonplace at our institution to document with photos the preoperative and post-manipulation ROM achieved. While it is tempting to use a cell phone, these are often not protected images, and someone needs to get the photos from the cell phone into the chart. We prefer using the arthroscopy tower, and those photos obtained can easily be placed into the patient’s chart via a scanner when the surgeon returns to the office. The other benefit is that a copy of ROM obtained can be provided to the patient as well at the time of discharge. It is well known that final ROM obtained is different than what was obtained in the operating room under anesthesia. These photos serve as a visual proof that indeed better ROM was achieved.

The manipulation under anesthesia is not without risk. As previously stated, a manipulation

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under anesthesia does not guarantee significantly improved ROM. Another risk is a fracture. Although uncommon, it is indeed a risk of the procedure and should be discussed with the patient. There is a potential to tear the skin. It is for this reason; the manipulation is often not performed until the 6–8-week period, so no tears of the skin would occur. Of course, it may not be the bone that fails at the time of the manipulation. Isolated cases of patella tendon rupture have been noted. This is a difficult problem since a protected repair is then required that can lead to once again a stiff knee.

If the manipulation is not successful, other measures have been described as an attempt to improve ROM. A second manipulation can be performed with the addition of arthroscopy. If this is attempted, the arthroscopy is used to not only perform a lysis of the adhesions but the gutters are debrided to help enable an improved ROM.

Another option is dynamic splinting. These dynamic splints come both for flexion as well as extension deformities and can be used as stand-alone treatments or in conjunction with manipulations both with and without arthroscopy.

Revision for stiffness has been described in the literature with mixed results. Lotke, in his series, noted an increase in ROM from an arc of 54.6° to 82.2°. While ROM did improve in 93% of cases, overall ROM remained limited.

Scuderi at our institution also demonstrated only a modest improvement with revision TKA for stiffness. While pain improved in 73% of patients, the ROM only improved a mean of 13%.

As with most orthopedics, the best treatment is prevention. A good multimodal pain program, correct position of components, and proper soft tissue balance may help in preventing this complication.

Option 1: Tibial Component Revision

David A. Crawford and Keith R. Berend

Case Presentation

History

The case we present is of a 50-year-old male who presented with complaints of pain and stiffness 8 months after right primary total knee arthroplasty that was done at an outside institution. The patient reported his knee was stiff prior to his surgery. His perioperative course was uncomplicated following his index surgery, but did struggle to gain full motion. He was employed in a light labor position and had difficulty doing his job. He also had difficulty ascending and descending stairs as well as arising from a seated position. The patient had no history or symptoms of infection.

Physical Exam

The patient's height is 71 in. and weight is 230 lb with a BMI of 32.1 kg/m². He had an antalgic gait, and his right knee was unable to fully extend during the gait cycle. His surgical incision was well healed and there was minimal effusion. Right lower extremity alignment was 3° of valgus. Knee range of motion was 10–85°. The right knee was stable in both varus/valgus stress and anterior/posterior. Patellar tracking appeared appropriate. Infection labs to include WBC, CRP, and ESR were all normal as well. Knee aspiration revealed a WBC count of 35 with no growth of cultures. His knee society functional score was 38 and clinical score was 70.

Radiographs and Advanced Imaging

AP radiograph of the right knee (Fig. 12.1) demonstrated no evidence of tibial osteolysis or loosening. The femoral component width and alignment was appropriate. The tibial tray alignment was 90° to long axis of the tibial. Tibial component sizing was also appropriate with no overhang. There was 6mm of the joint line elevation compared to the contralateral side.

Lateral radiograph (Fig. 12.2) of the right knee demonstrated no evidence of tibial or femoral component loosening. There was 2° of anterior tibial slope.

Merchant patellar radiographs (Fig. 12.3) demonstrated a resurfaced patella with appropriate tracking. The patella appeared to be under resected with a bony thickness of 19 mm resulting in a composite reconstructed thickness of 28 mm.

Surgical Approach

Our patient presented with a knee that was stiff in both flexion and extension. In review of the radiographs, we identified a few potential sources of problems. The joint line was slightly elevated and there was not appropriate posterior slope for a CR design. The tibial polyethylene insert was 12 mm, which would not likely allow enough downsizing for isolated insert exchange and synovectomy to treat stiffness. Options were to revise either the femoral and tibial component or tibial component alone. We felt that we would be able increase our flexion and extension gaps by increasing our tibial resection and increase the flexion gap by increasing tibial slope and possibly addressing the PCL. Thus, we chose to proceed with an isolated tibial component revision. We also wanted to revise the

patellar component as the patellofemoral joint appeared overstuffed.

The patient's exam under anesthesia revealed right knee range of motion of 10–85°. The prior surgical incision was utilized followed by a medial parapatellar arthrotomy. As with all of our revisions, fluid was sent for stat cell count. The arthrotomy is carried down to the tibial tubercle, and medial release is performed to the posterior aspect of the medial tibial plateau. The anterolateral tibial was also exposed proximal to the patellar tendon insertion releasing any adhesions and removal of fibrotic tissue. It is vitally important in the stiff knee to perform thorough releases prior to translation of the tibia to prevent iatrogenic injury to the collateral ligaments or patellar tendon. The medial and lateral gutters were then carefully reestablished and any fibrotic tissue was excised. We started on the medial side and place two Kocher clamps on the normal portion of the joint capsule. A third Kocher is then placed on the fibrotic tissue deep to the normal capsule and the fibrotic synovium is excised. This tissue was sent for culture as well as tissue from behind

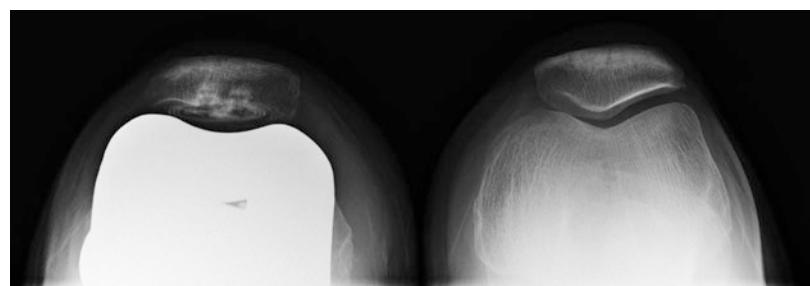


Fig. 12.1 Preoperative anteroposterior (AP) radiograph of the right knee

Fig. 12.2 Preoperative lateral radiograph of the right knee



Fig. 12.3 Preoperative Merchant radiograph of the right knee



the implants once removed. The lateral gutter was then reestablished in the same fashion as the medial side. The polyethylene insert was then removed and size of the insert was confirmed to be 12 mm. The patella was then held in an everted

position, and an internal release of the lateral retinaculum was performed using electrocautery along the lateral border of the patella.

If an attempt is going to be made to keep the tibial component and perform an isolated poly-

exchange, at this step the posterior knee is evaluated for retained osteophytes and release of the posterior capsule. To obtain joint distraction, we prefer using a rubber insulated lamina spreader to prevent damage to the tibial and femoral components. The lamina spreader is placed first on the lateral side of the joint in flexion and the medial posterior knee is debrided. The lamina spreader is then switched to allow work on the lateral side of the knee. Curved osteotomes and curettes are used to remove retained osteophytes and release the posterior capsule. The tibia is at this point translated anteriorly and any remaining necessary posteromedial release is performed. Trialing then follows. If the previous level of tibial resection and insert size allow, trial with a smaller insert. Consider recession or release of the PCL in cases with CR implants where extension can be achieved, but flexion remains tight. Some knee systems have anterior stabilized or ultra-congruent insert options that can be used to substitute for the PCL without the need to change to femoral component to accommodate a post. The final polyethylene is then implanted if balanced flexion and extension gaps can be achieved.

As in our case, when the level of the tibial resection and size of the tibial insert would not allow adequate downsizing of the insert, we proceeded with removal of the tibial tray for tibial revision. After the previously described medial and lateral exposure of the tibial tray, we began tibial tray removal with a small sagittal saw on the medial side being very careful to stay at the tray/cement interface. Depending on the tray design, this saw can often reach around the posterior aspect of the keel or I-beam to the lateral aspect of the tibia. The anterolateral side of the tray is then freed in the same fashion. The patellar tendon will limit the extent to which the saw can reach laterally. Osteotomes are then used to complete removal of the tray.

Once the tray was removed, we revised the tibial cut using our standard extramedullary guide. We referenced our preoperative X-ray and size of the previous insert to guide the level of resection as well as assess for any previous

malignancy in the coronal or sagittal plane. It is important to establish proper posterior slope for the component design being used as inadequate posterior slope (or anterior slope in this clinical example) in a CR design can contribute to a tight flexion gap and poor range of motion. Cement was removed from the tibial metaphysis, and the tibia was prepared for a 40 mm extension stem, which gave us an overall stem length of 80 mm from the base plate. Care was taken to ensure proper tibial rotation as internally rotating the tibial component not only can cause patellar maltracking but has also been implicated in stiffness [1]. With the tibial trial in place, standard insert trialing was performed. As mentioned previously, if the PCL is intact and the flexion gap is tight, the surgeon may consider recessing or releasing the PCL to increase the flexion gap. We did release the PCL in this case. Collateral ligament balancing was then confirmed. Once the flexion and extension gaps were balanced, the final tibial tray was cemented and the polyethylene inserted. We utilized a 14 mm anterior stabilized insert. The patella was also revised with increased resection so that the final implant and patellar thickness was 24 mm. We were able to achieve full extension and 120° of knee flexion with the arthrotomy closed and the tourniquet released.

In patients revised for a stiff knee, we utilize a high flexion postoperative protocol with a continuous passive motion (CPM) machine (Table 12.1). We also routinely schedule them for a manipulation under anesthesia at 6–8 weeks following revision.

Table 12.1 High flexion continuous passive motion (CPM) protocol begins immediately postoperative for 6 h in high flexion

Postoperative day	Range of motion (degrees)	Duration
Day 0	60–120	2 h
	30–120	2 h
	0–120	2 h
Days 1–14	0–120	2 h (3 × per day)

Standard CPM protocol resumed postoperative day 1 through postoperative day 14

Postoperative Results

Postoperative radiographs are shown in Figs. 12.4, 12.5 and 12.6. Postoperatively, the patient maintained full knee extension and underwent a manipulation under anesthesia 2 months after his revision and was able to achieve 115° of flexion. This did decline to 95° and remained stable. At 8-year follow-up, the patient had no pain in the knee and was able to walk 3 miles per day without assistive devices. His knee society functional score was 93 and clinical score was 100.

Clinical Results

Stiffness after total knee arthroplasty (TKA) is defined as inadequate range of motion (ROM) that limits a patient's functional activities. Patients may also have a sense of knee "stiffness"



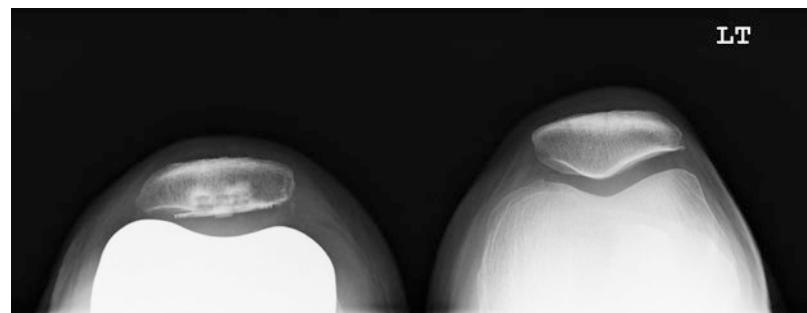
Fig. 12.4 Postoperative anteroposterior (AP) radiograph of the right knee



Fig. 12.5 Postoperative lateral radiograph of the right knee

despite having full knee ROM. While each patient may have a different target range of motion required for their specific functional activities, most surgeons strive to achieve full knee extension and at least 90° of knee flexion. Biomechanical studies have shown that patients require 67° of flexion during swing phase of gait and 80–90° of knee flexion to ascend/descend stairs and rise from a chair [2, 3]. The incidence of knee stiffness following TKA ranges from 1 to 12% [4–7]. The cause of knee stiffness after TKA is multifactorial including patient and surgical factors. The most important patient factor for prediction of postoperative range of motion is preoperative range of motion [8, 9]. Female gender and increased age have also been shown to

Fig. 12.6 Postoperative Merchant radiograph of the right knee



increase risk of stiffness after TKA [8]. Surgical factors include improper balancing of flexion/extension gaps, malpositioning and/or improper sizing of components, excessive joint line elevation, or incomplete osteophyte resection.

In deciding the treatment for the stiff total knee, the surgeon must first identify the cause. In cases where components are properly positioned and sized, an isolated synovectomy and liner exchange may be appropriate. Published results of this technique have been mixed. Babis et al. reported on seven patients who underwent isolated tibial insert exchange and arthrolysis. They found no improvement in knee society scores or range of motions and all patients remained painful [10]. Similarly, Wilson et al. showed only a 58% survivorship of isolated insert exchange with 30% of the unrevised patients still having pain and stiffness [11]. Other studies have shown reasonable success. In a systematic review, Ghani et al. reported successful outcomes with an average increase of 43.4° in knee ROM after open synovectomy and insert exchange [12].

There is no published literature on outcomes of isolated tibial revision for stiffness, but revision of both components has been studied. Studies have shown improvements in knee flexion of 17–35° after revision of both components [13–16]. Significant improvements in Knee Society scores and decrease in pain have been shown after revision of both components [13–16]. There still remain some patients who require subsequent MUA or second revision. Rates of MUA range from 15 to 49% [15, 17] and up to 25% of patients may require a second revision [16].

Key Points

- Preoperatively identify potential causes for the stiffness.
- Critically evaluate components for appropriate size and position.
- Reestablish medial and lateral gutters and perform medial and retropatellar release.
- Consider release of PCL in cases of CR knees if tight in flexion.
- Ensure proper tibial slope.
- Understand risk of continued stiffness and need for MUA or subsequent surgery after revision.

Option 2: The Stiff Total Knee Arthroplasty—Complete Revision

Stephen Petis and Robert Trousdale

Case Presentation

History

A 73-year-old male was referred to our clinic two and a half years following an uncomplicated cruciate-retaining right total knee arthroplasty (TKA). He complained of progressively worsening stiffness following the index procedure. Interestingly, he also complained of instability when ascending and descending stairs. Pain was present globally around the knee, which was worsened by activity. The ipsilateral hip and lumbar spine were asymptomatic.

The patient had exhausted nonoperative management with a trial of oral analgesia, nonsteroidal anti-inflammatories, and physical therapy.

The patient reported no prior operations to the affected knee. A manipulation under anesthesia had not been attempted. He denied nighttime pain or any constitutional symptoms.

It is important to generate a differential diagnosis before considering revision surgery for stiffness following TKA. Common etiologies can be segregated into intrinsic and extrinsic causes (Table 12.2). Additionally, it is important to combine a review of the previous operative reports with a concise history, as this can narrow the differential diagnosis.

Physical Examination

The patient had a well-healed midline incision, which did not exhibit any signs of infection. He stood with a neutral, mechanically aligned knee. He had an effusion based on positive patellar ballottement. The soft tissue envelope overlying the knee was mobile. Active and passive knee range of motion was from 30° of extension to 90° of flexion (Fig. 12.7). The patient was able to perform a straight leg raise without difficulty. Quadriceps muscle strength was graded as 5/5 based on the Medical Research Council grading

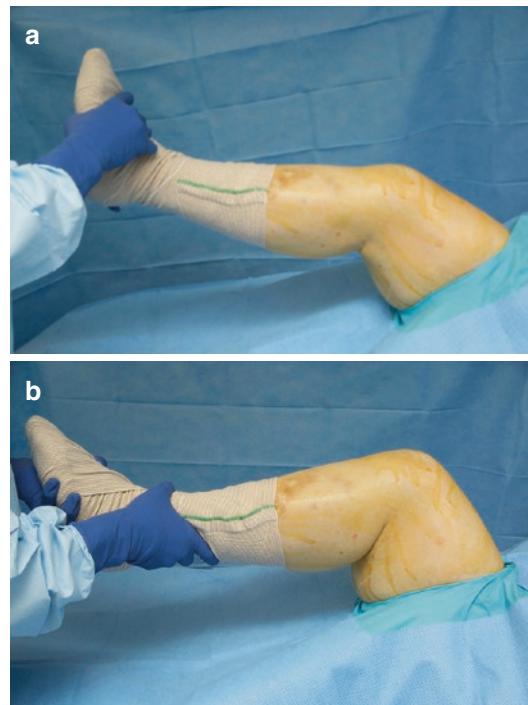


Fig. 12.7 Clinical photograph taken intraoperatively of the patient's knee (a) extension and (b) flexion under anesthesia

Table 12.2 Common etiologies of the stiff total knee arthroplasty

Intrinsic	Reconstructive changes: <ul style="list-style-type: none"> Tight PCL with cruciate-retaining designs Oversized femoral component Overstuffing patellofemoral compartment Flexion-extension gap mismatch Joint line elevation Malposition of components (rotation, flexion-extension, tibial slope) Inadequate bony resection (tibia, femur, osteophytes) Aseptic loosening of components Severe preoperative deformity Post-traumatic arthritis Preoperative joint ankylosis Previous knee surgery Periprosthetic joint infection
Extrinsic	Ipsilateral hip arthritis Ipsilateral lumbar radiculopathy Heterotopic ossification Overlying skin fibrosis (previous skin grafting, burns) Complex regional pain syndrome Poor compliance with rehabilitation program

system. Anterior-posterior translation greater than 10 mm was present with the knee positioned at 90° of flexion. There was greater than 5 mm of opening on the medial and lateral side of the knee with the knee in extension and flexion. Hip range of motion was pain-free. His neurovascular examination was normal.

It is critical to consider periprosthetic joint infection as a cause for stiffness following TKA. This diagnosis is made through careful history taking, physical examination, and ancillary investigations [18]. Documenting both active and passive range of motion ensures that a disrupted extensor mechanism is not a contributing factor to loss of motion. We recommend taking a photograph of the patient's range of motion preoperatively for accurate documentation before revision surgery. Examining the knee for concomitant instability is important, as ongoing instability can result in postoperative pain that can prohibit successful rehabilitation. Immobility of the anterior soft tissue envelope from previous scars or skin

grafting procedures contributing to loss of knee flexion may warrant the use of soft tissue expanders in select cases.

Radiographs and Advanced Imaging

A work-up to rule out infection revealed a leukocyte count of 6.1×10^9 cells per liter, an erythrocyte sedimentation rate of 2 mm/h, and a C-reactive protein of 3.0 mg/L. Plain radiographs revealed a well-fixed, cemented, cruciate-retaining TKA with a resurfaced patella. We routinely acquire full-length hip-knee-ankle radiographs in the setting of a painful TKA to assess component positioning, as well as mechanical and anatomic axis restoration. This radiograph can also help rule out hip arthritis that may be causing pain radiating to the knee. There was a nonprogressive radiolucency under the medial aspect of the tibial tray (Fig. 12.8).

Surgical Approach

The patient was positioned in the supine position under a general anesthetic. We examined the knee under anesthesia, which confirmed the aforementioned stiff arc of motion, as well as coronal and sagittal plane instability. A tourniquet was applied and inflated for cementation only to avoid tension on the thigh muscles during range of motion assessments.

The previous surgical incision was used. Careful elevation of medial and lateral subcutaneous flaps ensued. A standard medial parapatellar arthrotomy was performed. Upon entering the knee, an exuberant amount of arthrotic tissue was excised from the medial and lateral gutters, as well as suprapatellar region. We prefer to laterally subluxate the patella in the setting of revision surgery to avoid undue stress on the extensor mechanism. We have a low threshold to perform a

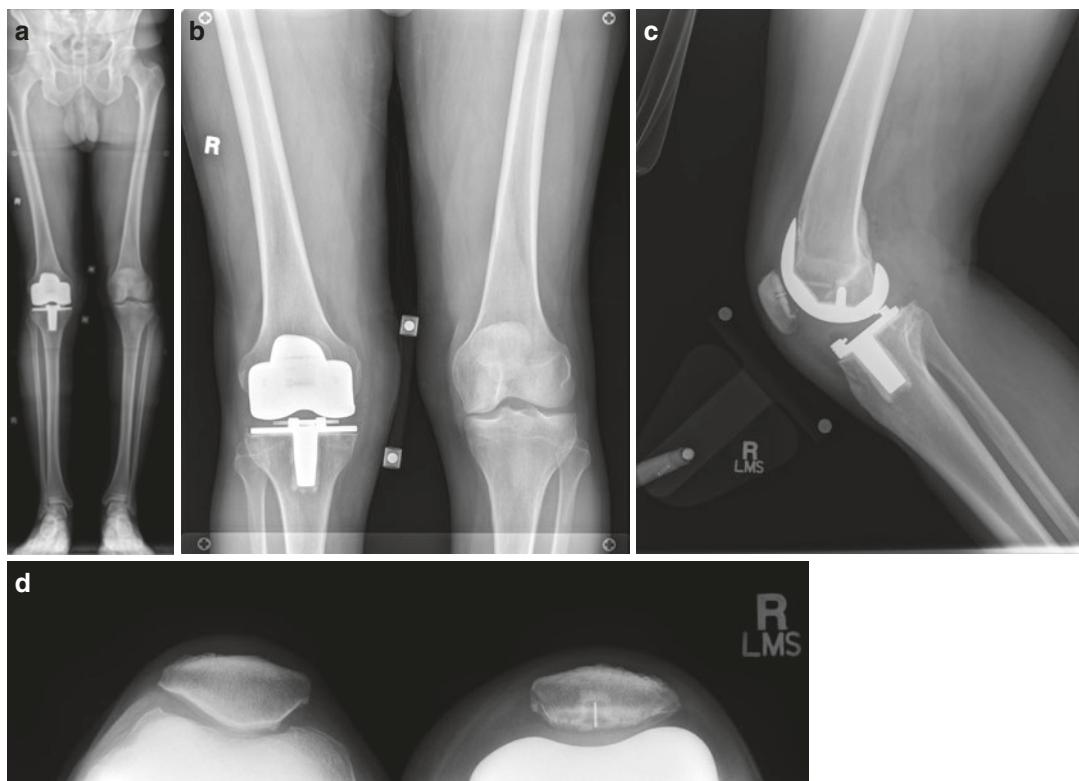


Fig. 12.8 Preoperative series of knee radiographs. (a) Three-foot standing hip-to-ankle films demonstrate well-positioned components. (b) Anterior-posterior radiograph demonstrating radiolucency under the medial aspect of

the modular tibial baseplate. (c) Lateral radiograph demonstrating a flexed femoral component with a resurfaced patella. (d) Skyline radiograph with a centrally located resurfaced patella

quadriceps snip in order to help mobilize the extensor mechanism during revision surgery. Other considerations include a Coonse-Adams V-Y turndown and tibial tubercle osteotomy. We routinely send tissue for pathologic analysis to rule out acute inflammation, which was negative.

The decision to revise both components was predicated on unmatched gap tightness in both extension and flexion. The presence of coronal and sagittal plane instability also necessitated revising the femoral component for more constraint options. The patellar component was not revised. However, consideration should be given to revising the patella if the patellofemoral compartment is overstuffed, if the patella was under resected, or there is poor congruency with the trochlear design of the revised femoral component.

We removed the femoral and tibial components without significant bone loss. The tibia was recut perpendicular to the mechanical axis. We prepare the tibia first to assess the symmetry of the flexion-extension spaces. The femur was carefully recut to maintain a neutral mechanical axis and to avoid elevating the joint line. Femoral rotation was assessed with the knee in flexion to ensure a rectangular flexion space. We determined that upsizing the femoral component would adequately fill the majority of the flexion space. An augment was used on the posterolateral femoral condyle to ensure external rotation of the femoral component and to help balance the flexion space in the setting of previous flexion instability. Excessive rotation of either the femoral or tibial component, as well as oversizing either implant, should be avoided in order to avoid tethering soft tissues, which can contribute to ongoing postoperative stiffness. We utilized a condylar constrained knee design given concomitant instability. A rotating platform tibial insert with cemented, stemmed components was used to reduce strain on the implant-cement, cement-bone interfaces. We routinely take an intraoperative photograph with the implants in situ to document restoration of range of motion.

Postoperative Result

Postoperatively, the patient's range of motion improved from terminal extension to 120° of

flexion (Fig. 12.9). Clinical exam revealed no evidence of coronal or sagittal plane instability. Radiographs demonstrated well-fixed, well-positioned components (See Fig. 12.10). His pain improved from eight preoperatively to one postoperatively based on a visual analogue pain scale.

Clinical Results

The incidence of stiffness requiring revision following TKA is reported between 1.3 and 18% [4, 19]. Treatment options include manipulation under anesthesia, open or arthroscopic arthrolysis, isolated polyethylene exchange, single component revision, or complete revision. Over the past several decades, results of complete revision for stiffness following TKA have been unpredictable (Table 12.3) [4, 14–16, 20–23]. Most studies report an improvement in knee range of motion and patient-reported outcome measures following revision surgery. However, the treating surgeon needs to educate patients that further procedures may be required, as our

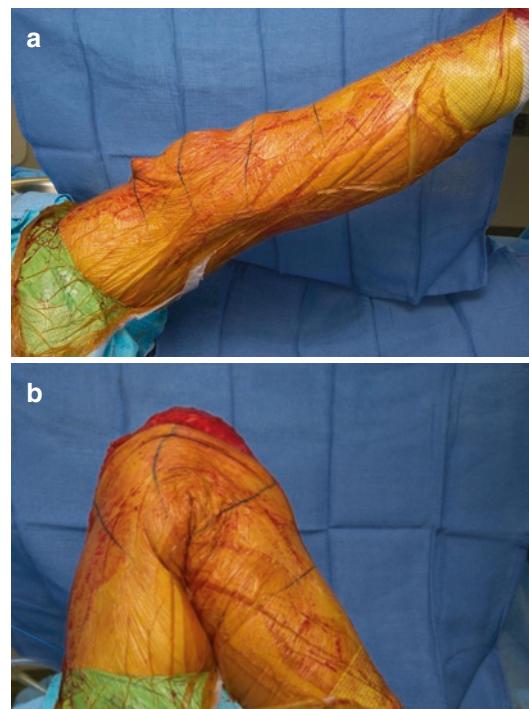


Fig. 12.9 Clinical photograph taken intraoperative demonstrating knee range of motion with the revision components in situ



Fig. 12.10 Postoperative knee radiographs. (a) Anteroposterior and (b) lateral radiographs demonstrating well-positioned, stemmed components with a condylar constrained knee design

review indicates that 9–36% of patients undergo further interventions to treat ongoing stiffness. This is largely due to difficulty in determining the exact cause of the stiffness, as well as heterogeneity in implant selection and difficulty of the revision surgery.

This review outlines the importance of diagnosis and patient selection in order to optimize success when revising the stiff TKA. Understanding the reason for failure allows the surgeon to utilize reconstructive principles to improve motion. Ruling out other potential etiologies such as concomitant arthritides, and modi-

fying patient factors such as poor compliance with rehabilitation, can help promote a favorable outcome.

Key Points

- A careful review of the patient's history, physical examination, and radiographs can help generate a differential diagnosis for stiffness following TKA.
- Always consider periprosthetic joint infection and extrinsic causes of stiffness in the work-up of a stiff TKA.

Table 12.3 Clinical outcomes of both-component revision for stiffness following total knee arthroplasty (TKA)

Authors	Number of TKAs	Mean preoperative range of motion (°)	Mean postoperative range of motion (°)	Patient reported outcomes scores (mean)	Interventions for recurrent stiffness	Complications
Nicholls and Dorr [20]	12	Extension: -32 Flexion: 44	Extension: -7 Flexion: 62	40% reported excellent or good result	4 repeat manipulations	Not reported
Haidukewych et al. [21]	16	40	73	Knee Society Score Pre: 28 Post: 65 66% of patients satisfied	3 repeat manipulations 1 re-revision	2 intraoperative femur fractures
Hartman et al. [22]	35	Extension: -13.5 Flexion: 67.1	Extension: -2.7 Flexion: 100.7	Knee Society Score Pre: 32.2 Post: 60.9	9 repeat manipulations 2 arthroscopic arthrolysis 1 open arthrolysis	Not reported
Kim et al. [4]	56	Extension: -11.3 Flexion: 65.8	Extension: -3.2 Flexion: 85.4	Knee Society Score Pre: 38.5 Post: 86.7	3 repeat manipulations 2 re-revisions	Not reported
Keeney et al. [14]	11	Extension: -21.6 Flexion: 72.8	Extension: -8.9 Flexion: 76.2	Knee Society Score Pre: 21.9 Post: 25.5 55% of patients satisfied	Not reported	Not reported
Kim et al. [16]	23	67	85	Knee Society Score Pre: 45.7 Post: 67.9	6 re-revisions	Not reported
Heesterbeek et al. [15]	35	60	85	Knee Society Score Pre: 43 Post: 61	7 repeat manipulations	1 wound dehiscence 1 tibial tuberosity fracture
Christensen et al. [23]	11	39.7	83.2	Knee Society Score Pre: 31.1 Post: 75.5	4 repeat manipulations	2 wound dehiscence

- Careful soft tissue handling and debridement of fibrotic tissue is paramount during revision TKA surgery.
- Be prepared to use extensile exposures to facilitate implant removal and reconstruction when revising the stiff TKA.
- Revising both components can help mitigate flexion-extension mismatch and provide options to deal with concomitant instability.
- Results following both-component revision for the stiff TKA are unpredictable. Be prepared to perform additional procedures to treat ongoing stiffness following revision surgery.

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Management of Tibial Bone Loss

13

Giles R. Scuderi, Thomas J. Parisi,
Douglas A. Dennis, David G. Lewallen,
Russell E. Windsor, and Danielle Y. Ponzio

Introduction

Giles R. Scuderi

Severe tibial bone loss is one of the most challenging aspects in revision total knee arthroplasty (TKA). Bone loss can be the result of (1) aseptic failure with component loosening, subsidence, osteolysis, and fracture, (2) septic failure with bone resorption and osteolysis, and (3) iatrogenic bone loss following component removal. Accurate assessment of the severity of the tibial bone loss is necessary, especially in the proximal metaphysis, since it impacts tibial component position and fixation. Despite several classification systems, the radiographic evaluation of the bone defects is often difficult and underestimated [1]. The final determination of tibial bone loss is

made at the time of surgery. The most useful classification system is the Anderson Orthopaedic Research Institute (AORI) classification that describes the severity of the tibial bone loss based upon the integrity of the metaphysis and whether one or both plateaus are involved [2].

The management of tibial bone loss in revision TKA is dependent upon the size and location of the defect (Fig. 13.1), as well as if it is a contained or uncontained defect [3]. Surgical options include cement filling, cement filling with screws, modular augments, impaction bone graft, structural bone graft [4], and metaphyseal sleeve and cones [5]. The goal is to establish a flat and stable platform for placement of the tibial component. AORI type 1 tibial defects have minimal bone loss with a good metaphyseal bone and can be

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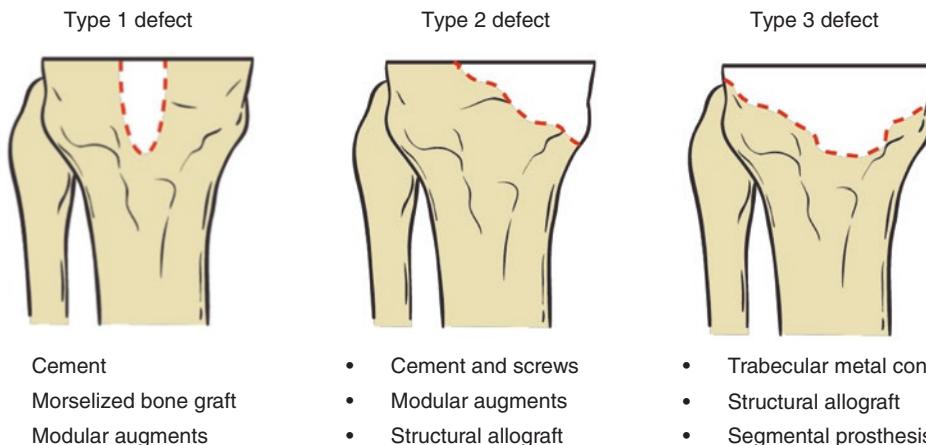


Fig. 13.1 The Anderson Orthopaedic Research Institute classification for tibial bone loss with management options

managed with cement fill or impaction bone grafting into the small cavity defects. AORI type 2 defects have more metaphyseal bone loss and are usually managed with modular augments or structural bone allograft. Type 3 defects extend distal to the tibial tubercle and are more challenging conditions that require trabecular metal cones, structural bone allograft, or a proximal tibial prosthesis. The following case reports will describe various surgical techniques for managing this challenging problem.

Option 1: Management of Severe Tibial Bone Loss: Tibial Bone Graft

Thomas J. Parisi and Douglas A. Dennis

Case Presentation

History

A 68-year-old female presented with progressive right knee pain and swelling. She had previously received a primary right total knee replacement (TKA) for end-stage rheumatoid arthritis 17 years prior to presentation. She was diagnosed with rheumatoid arthritis in her early 20s and managed with methotrexate and prednisone. Her TKA functioned very well until 1 year prior to presentation after which she developed pain, swelling, and progressive varus deformity. She denied any recent trauma, ill-

nesses, fever, or chills associated with the onset of her knee pain.

Physical Examination

Physical examination demonstrated a moderate effusion of the postoperative knee with a range of motion of 0–100°. The previous incision was well healed with no evidence of erythema or induration. The knee was malaligned in 5° of varus. Stability assessment showed moderate sagittal and coronal plane instability with a posterior sag sign. Patellar crepitus was present, but there was no extensor lag. Of note, the patient did have minimal paresthesias in the L5 distribution on the right side associated with a minimal reduction in ankle dorsiflexion strength. Otherwise, neurovascular examination was within normal limits.

Radiographs and Advanced Imaging

Anteroposterior, lateral, and Merchant patellar radiographs were obtained which demonstrated a cemented TKA with substantial osteolysis of the medial tibial plateau associated with varus alignment of the tibial component. Radiographs additionally suggested possible loosening of the patellar component (Fig. 13.2). Advanced imaging such as a CT scan to better assess the osteolytic lesion was not performed.

Surgical Approach

Extensive preoperative planning enhances success rates of revision TKA (See Table 13.1).

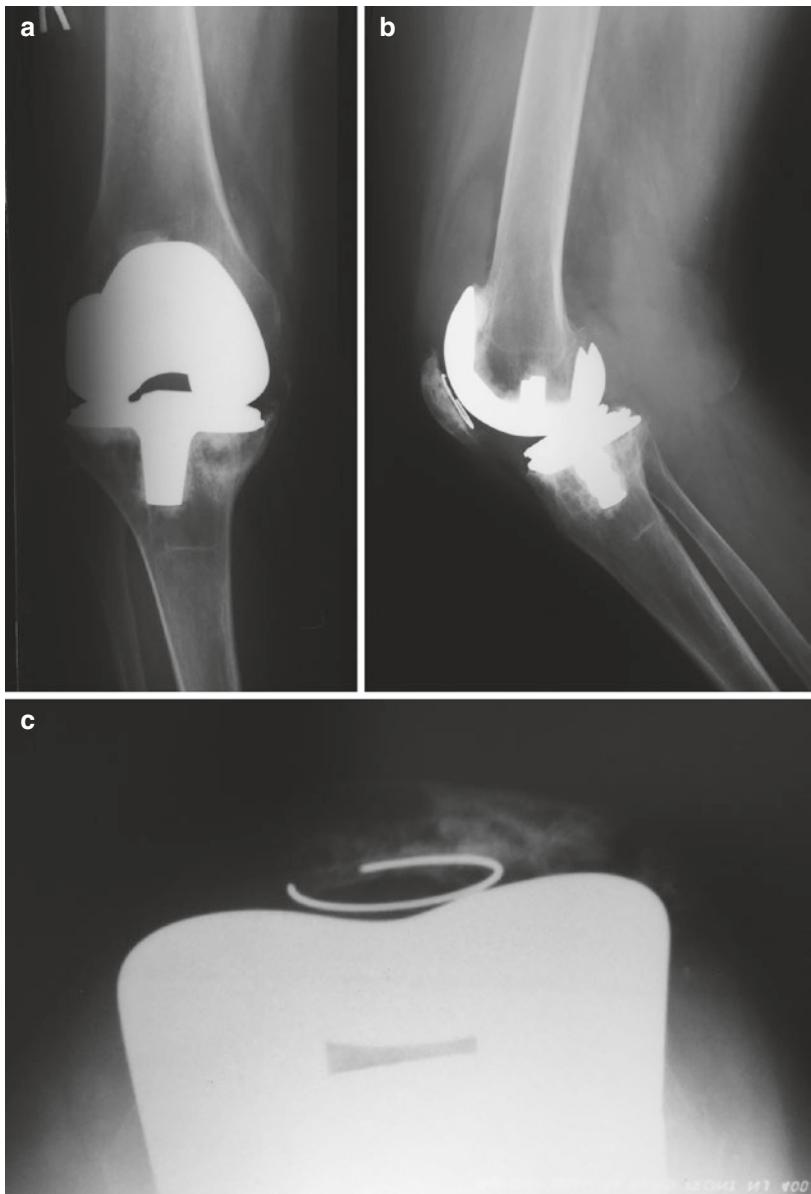


Fig. 13.2 (a) Anteroposterior (AP), (b) lateral, and (c) Merchant patellar radiographs of a failed total knee replacement with tibial component subsidence, medial tibial osteolysis, and patellar component loosening

Clinical and radiographic evaluation of the current case determined TKA failure due to multiple mechanisms including polyethylene wear with associated osteolysis, instability, and possible loosening of the tibial and patellar components. It is valuable to obtain early postoperative radiographs for comparison to assess for component migration which would confirm loosening.

These radiographs were unavailable for review. It has been shown that radiographs underestimate the true magnitude of osteolytic bone loss which is important when considering reconstructive options.

Initially, one must rule out a periprosthetic infection as a cause of failure in TKA [6]. As part of the preoperative evaluation, an erythrocyte

Table 13.1 Preoperative considerations

Rule out infection
ESR, CRP, and WBC count
Aspiration
Nuclear scanning (dual/triple isotope)
Assess defect
X-rays
Computed tomography with 3-dimensional reconstruction
Implant selection
Global instability/constraint
Diaphyseal-engaging stems
Metaphyseal cones or sleeves
Allograft selection
Femoral head, distal femur, proximal tibia
Anatomically matching specimen (orient trabeculae)

sedimentation rate, a C-reactive protein, and a white blood cell count were obtained. A preoperative knee aspiration was performed and sent for cell count, crystal analysis, and cultures. Studies suggest that a synovial white cell count greater than 1700 cells/ μL (range, 1100–3000 cells) or a polymorphonuclear cell percentage of greater than 65% (range, 64%–80%) is indicative of the presence of chronic infection [7–10]. It should be noted that cultures should be held for a minimum of 14 days in the event that a difficult-to-culture organism is present [11]. The preoperative workup for this patient was totally negative for infection. Other scenarios associated with bone loss include prosthetic loosening, component subsidence, and osteolysis as demonstrated in the presented case [6, 12].

Once infection is ruled out, the size, location, and type of bone defect (cancellous versus cortical; contained versus uncontained) need to be critically evaluated. While numerous bone loss classification systems exist, the authors favor the use of the Anderson Orthopaedic Research Institute (AORI) bone defect classification (Table 13.2) [13]. A review of preoperative radiographs suggests a 2B tibial defect in the current case. Realizing that plain radiographic films underestimate the true magnitude of bone loss, one can consider the use of advanced imaging such as a CT scan to further characterize the location and extent of bone loss which was not

Table 13.2 AORI classification of tibial bone loss [13]

Type 1	Minor, contained, cancellous bone defect within either tibial plateau. Metaphyseal bone is intact, and minor defects do not compromise the stability of a revision component
Type 2A	Moderate to severe cancellous and/or cortical defects of one tibial condyle. Metaphyseal bone is damaged with larger defects in one tibial condyle
Type 2B	Moderate to severe cancellous and/or cortical defects of both tibial condyles
Type 3	Combined cavitary and segmental bone loss of both tibial condyles. Metaphyseal bone is deficient with bone loss comprising a major portion of the proximal tibia

obtained in this case. Even with advanced imaging, however, surgeons must expect and plan for additional bone loss to occur during component removal. In addition to magnitude of bone loss, the location of the defect is important to assess what host bony support will be present. Contained bone defects provide greater inherent stability of reconstructive bone grafts than in segmental, non-contained defects.

Numerous reconstructive options are available to manage bone defects in revision TKA including filling the defect with cement with or without screws, angular or block prosthetic augmentations, highly porous metaphyseal cones or sleeves, and implantation of particulate or structural autograft or allograft. If bone graft is selected for larger defects, the amount of autograft is usually insufficient, and the use of allograft bone is required. In the era of management of the presented case, metaphyseal sleeves and cones were not yet available. It was felt that the depth of the osseous defect was greater than that in which the use of a block augmentation would suffice. For this reason, reconstruction with a structural bone allograft was chosen.

The use of a structural allograft reconstruction is typically indicated for defects larger than 1.5 cm in depth or those defects that exceed the coronal dimensions of a typical metal block augment [14]. One potential advantage of bone graft is bone reconstitution, especially in a younger patient who may be faced with additional revi-

sion operative procedures [12, 15]. Other advantages include the ability to easily contour the allograft to the host defect shape [16], the relatively low cost [6], and the potential for more physiologic load transfer if incorporation occurs [6]. Disadvantages include possible allograft resorption with late collapse, malunion or non-union [12, 17, 18], disease transmission (allografts) [18, 19], fracture [12, 15, 20], and infection [21].

Lastly, proper allograft selection is critical. Sizing is important to avoid difficulties with later wound closure. Allograft specimens most commonly used are femoral head, distal femoral, or proximal tibial allografts. When possible, it is wise to select an allograft type that matches the host defect (i.e., proximal tibial allograft for a host proximal tibial defect). Fresh-frozen allografts are thought to offer superior structural support compared to freeze-dried allografts [22]. A revision TKA system with increased prosthetic constraint should be available as cases with severe (type 2 or 3) tibial bone loss are often associated with collateral ligament insufficiency. Diaphyseal-engaging stems are usually necessary in conjunction with the use of a structural allograft to provide enhanced implant and allograft fixation and to off-load the allograft during osseous incorporation with the host. High-speed burrs are sometimes necessary to reshape the defect and allograft. Additional fixation devices such as screws and plates should be available.

The goals of revision TKA reconstruction are to (1) preserve host bone, (2) restore host bone, (3) restore knee stability with restoration of flexion and extension gap balance, and (4) restore the appropriate joint line. Of critical importance is to recreate a stable platform to support the new revision implant to assure long-term implant fixation. Additionally, when using allograft reconstruction, it is important to obtain rigid fixation of the allograft to assure osseous integration with the host bone.

The first challenge of any revision TKA surgery, especially in cases of massive bone loss, is to obtain adequate exposure. The surgeon needs to be prepared to perform an extensile operative

exposure in some cases, such as a rectus snip, a tibial tubercle osteotomy, or a medial epicondylar osteotomy [23–25] in this case. A standard medial parapatellar approach was used incorporating the previous skin incision, followed by an extensive intra-articular synovectomy.

Following exposure, careful component removal is essential to minimize the amount of host bone lost. The patellar and tibial components were grossly loose in the current case and easily removed. The femoral component was well fixed and required division of the cement-prosthesis interface with a combination of thin oscillating and reciprocating saws as well as thin osteotomes. Residual cement was then fragmented and removed under direct vision with cement chisels and a high-speed burr.

After components and cement were removed, the size and location of bone defects were precisely assessed. Smaller type 1 defects of each femoral condyle and a larger type 2B defect of the tibia, especially involving the medial tibial condyle, were encountered (Fig. 13.3). It was felt that the femoral defects could be easily managed with cavitary autografting and the addition of a modular cemented stem. The size of the tibial defect confirmed the preoperative plan of reconstruction with a structural allograft.

The host defect was then prepared by removal of all fibrous debris and avascular sclerotic bone to attain vascularized host bone without compromising structural integrity. The goal is minimal removal of host bone to shape the defect to maximize allograft stability and osseous contact with host bone. This can be accomplished with a combination of saws, curettes, reamers, and high-speed burrs. For implantation of a femoral head allograft, shaping of the host bone was attained with use of a small (<40 mm) acetabular reamer to make the defect hemispherical in shape (Fig. 13.4a, b). It is important to assess the level of the joint line at this time as there is a tendency to elevate the joint line with a tibial allograft [12].

The allograft was then contoured to match the host defect. All cartilage and soft tissue must be removed. The femoral head allograft used in the current case was contoured with the use of a

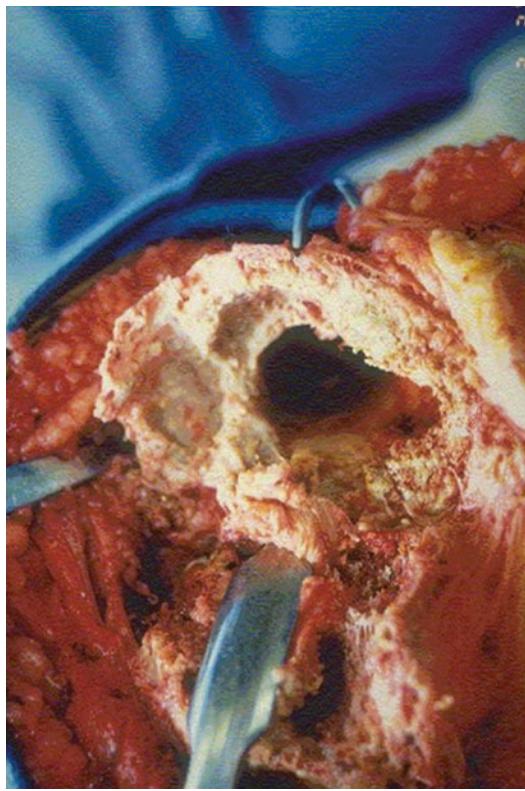


Fig. 13.3 Intraoperative photograph revealing a large type 2B defect of the medial tibial plateau

female hemispheric reamer (Allo-Grip, DePuy Synthes, Warsaw, IN, USA; Fig. 13.4c, d) [6–16]. When using this method of preparation, it is wise to ream the femoral allograft to a diameter that is 1–2 mm larger than the hemispherical host defect to provide a bit of press fit and enhance allograft-host fixation [6].

The fashioned allograft was impacted into the host defect (Fig. 13.4e). Placement of the allograft with the trabeculae oriented parallel to the axial loads that traverse the allograft increases strength of the construct. Due to the precision of reamer preparation, no significant gaps between the allograft and host bone were incurred. If gaps exist, particulate autograft or allograft should be packed into the gaps [12]. The allograft was temporarily fixed to the bone with a bone clamp. Temporary Kirschner wire fixation can also be used [24], but efforts to avoid placing holes in the allograft are wise as they create a stress riser which has limited potential to fill in and heal.

Final fixation of the allograft must be rigid to promote osseous integration and can be attained via axial screws or adjunctive plate fixation [6, 12, 15, 26]. Axial screw fixation was selected in the current case with the screw head countersunk below the level of the desired proximal tibial resection (Fig. 13.4f) which was completed with an oscillating saw and a proximal tibial cutting jig to restore the cancellous architecture of the proximal tibia (Fig. 13.5). Although the allograft adds structural support to the implant, it must be protected with the use of a diaphyseal-engaging intramedullary stem as a load-sharing device [27, 28]. The use of a high-speed burr is preferable to the use of power reamers to prepare for passage of the intramedullary stem through the allograft to avoid allograft fracture or compromising allograft fixation.

After placement, fixation, and contouring of the graft are complete, the rest of the knee is prepared and balanced using proper principles of revision knee arthroplasty. One must be careful during trialing and final implantation not to overly stress the allograft fixation.

Postoperative Result

Postoperatively, this patient was treated with routine physical therapy although weight-bearing was limited to toe touch with a walker for the first month, when 30 pound weight-bearing was permitted. At 3 months, the patient was allowed to fully weight-bear. Most authors recommend protected weight-bearing for a minimum of 6–8 weeks and may extend this time until radiographic signs of union are visible at the allograft-host interface [6, 12, 29]. Additionally, many recommend an articulated knee brace during initial rehabilitation which was not utilized since excellent knee stability was obtained intraoperatively [16, 26, 29–31].

Early postoperative radiographs demonstrated satisfactory fixation and position of both the allograft and TKA components (Fig. 13.6). At 1 year following the operative procedure, the patient exhibited 0–117° of knee motion with no significant pain, crepitus, or ligamentous laxity. At 4 years, the patient continued to be free of pain with knee motion of 0–115° and no evidence

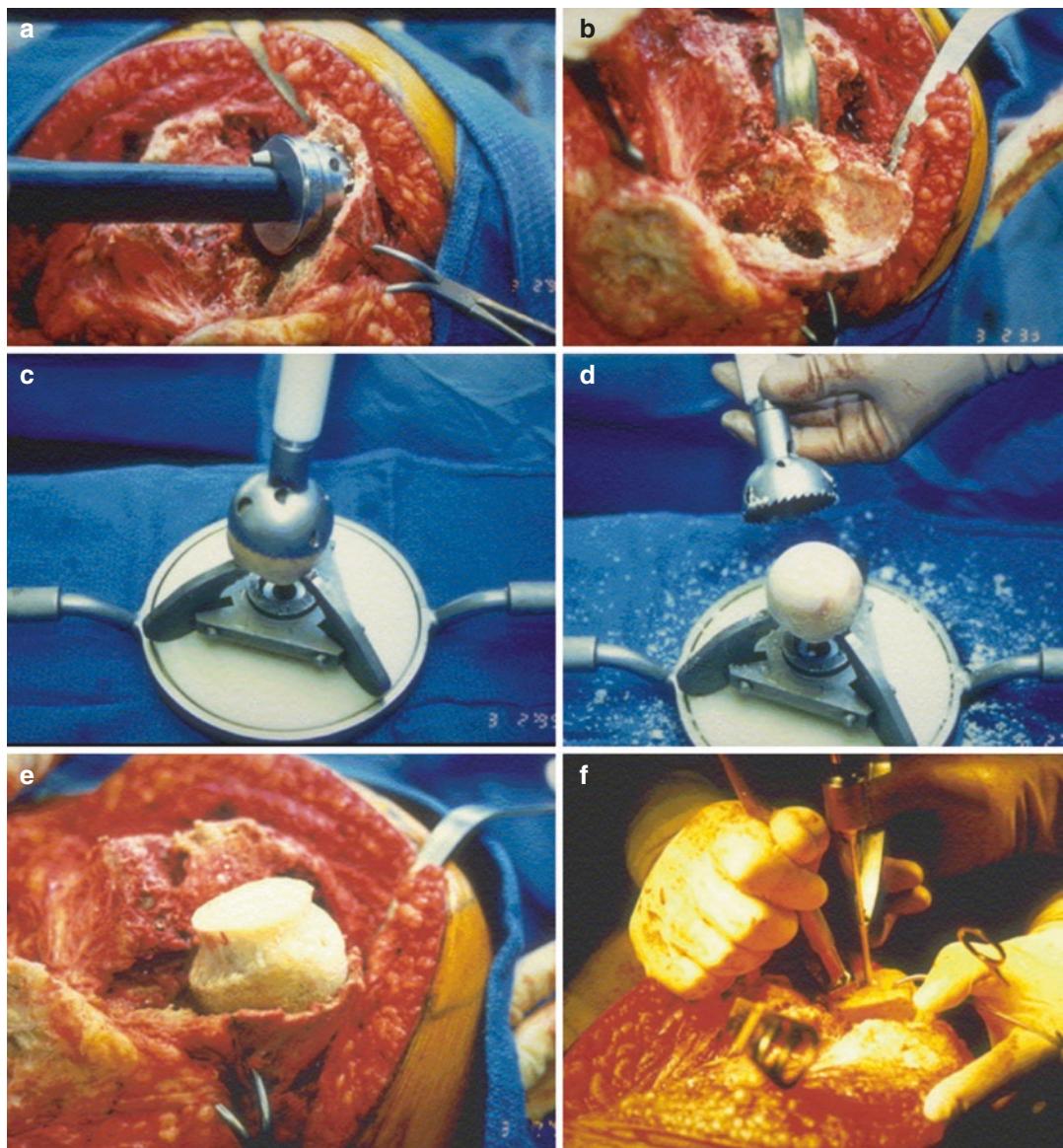


Fig. 13.4 (a) Intraoperative photograph of preparation of the host tibial defect with a small acetabular reamer. (b) Intraoperative photograph of the prepared tibial defect after reaming was completed. (c and d) Reaming of the femoral head allograft with a female hemispheric reamer

to remove soft tissue, cartilage, and subchondral bone. (e) Photograph of placement of the allograft into the reamed host defect. (f) Fixation of the allograft using axial screw fixation to host bone

of radiographic osteolysis or fixation failure. At latest follow-up evaluation at 15 years post-revision, the patient remained pain-free with preserved range of motion and knee stability. Radiographs at that time demonstrated incorporation of the allograft with no evidence of wear, allograft resorption, or loss of fixation (Fig. 13.7).

Clinical Results

The management of bone loss is critical in revision TKA. While the use of modular augments, metaphyseal sleeves and cones, and press-fit stems has become increasingly popular as treatment options in revision TKA, bone grafting remains a viable treatment option for treatment

of massive bone loss [30]. Multiple studies have demonstrated high union rates if rigid fixation is achieved although complications are frequent in these complex cases [7, 16, 24, 29]. Clinical sur-

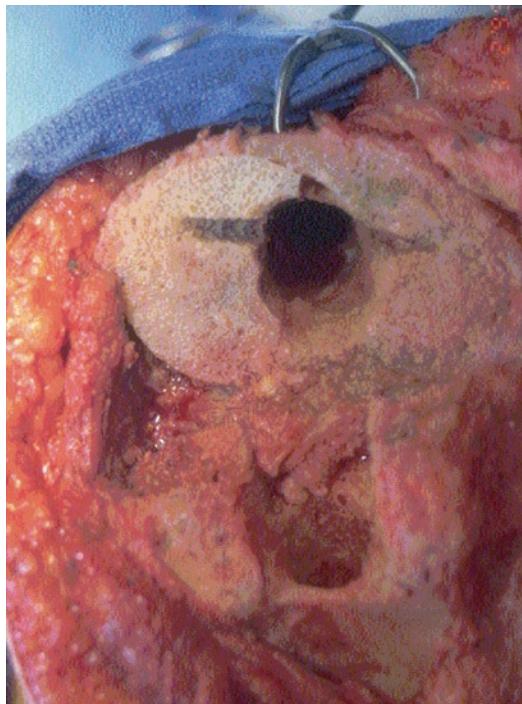


Fig. 13.5 Intraoperative photograph showing reconstructed tibial surface prior to implantation

vivorship of allograft use has varied from 72–100% at 5 and 10 years (Table 13.3) [12, 16, 17, 26, 29, 30, 32, 33].

Some concerns exist in regard to long-term outcomes for structural allografts due to possible complications such as graft malunion or non-union, collapse, resorption, fracture, and infection. However, literature review suggests structural allografts remain a relatively cost-effective option for certain patients and bone defect configurations [12, 34]. Some authors recommend that structural allografts remain a good option for type 2 and type 3 defects in either low-demand individuals to decrease risk of collapse or fracture prior to graft incorporation [21, 35] or in younger individuals with a high chance of union to preserve bone stock for future revisions [36]. Allografts also can be advantageous for massive bone defects that are larger than those simply managed with metaphyseal sleeves or cones.

Limited comparative reports of the use of structural allograft versus metaphyseal cones for management of bone loss in revision TKA have recently become available. Beckmann et al. performed a systematic review comparing structural allografts to porous metal cones in which they reviewed 195 structural allografts implanted into the tibia. Mean follow-up was 70.8 months, and

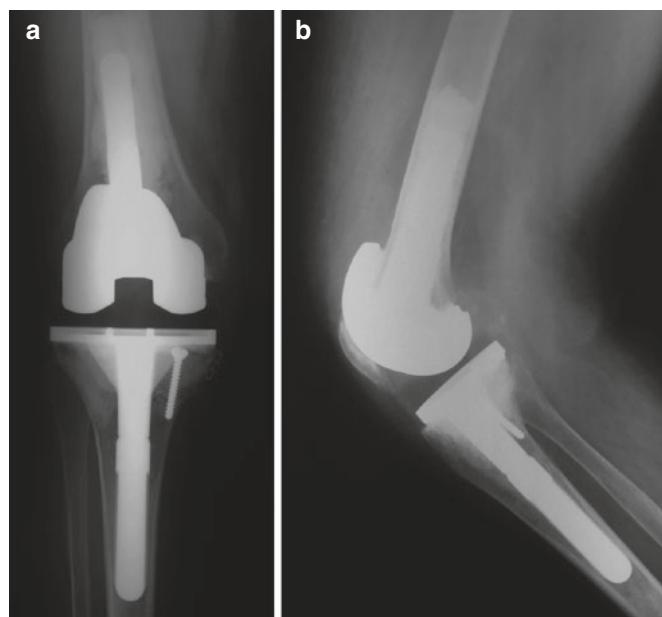
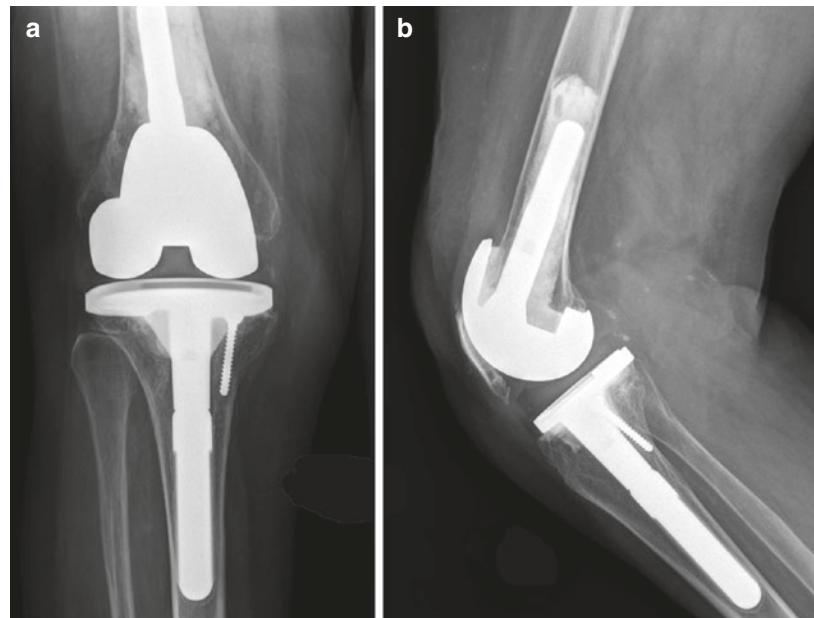


Fig. 13.6 4-week postoperative (a) anteroposterior (AP) and (b) lateral radiographs demonstrating restoration of proximal tibial bone

Fig. 13.7 15-year postoperative (a) anteroposterior (AP) and (b) lateral radiographs following revision total knee arthroplasty using a structural allograft



the overall failure rate of allografts requiring reoperation was 15.4% [37]. Logistic regression analysis found no significant difference in infection

Table 13.3 Clinical results of structural allograft use in revision total knee arthroplasty

Study (year)	Knees (no.)	Mean follow-up (months)	Survivorship (%)
Mow et al. [32] (1996)	13	46	92
Ghazavi et al. [18] (1997)	30	50	77
Clatworthy et al. [12] (2001)	52	120	72
Dennis [6] (2002)	32	50	86
Backstein et al. [40] (2006)	61	64	86
Engh et al. [26] (2007)	35	97	87
Bauman et al. [17] (2009)	70	60	81
Lyall et al. [33] (2009)	15	63	87
Chun et al. [16] (2014)	27	107	96
Wang et al. [29] (2013)	30	76	100
Sandiford et al. [30] (2016)	30	60	92

rates but significantly decreased loosening rates as well as a trend of lower overall failure rates in the porous metal cone group [37]. Sandiford et al. [30] evaluated 45 revision TKA cases which required augmentation of host bone with either a structural femoral head allograft (30 cases) or a porous metaphyseal cone (15 cases). No significant clinical differences were noted between the two cohorts. Five- and 10-year survivorship of the allografts were 93% (95% CI, 77–98) and 93% (95% CI, 77–99), respectively, vs. 91% (95% CI, 56–98) at a mean of 5 years in the trabecular metal cone group. No differences in complication rates were observed.

For those individuals who require immediate ability to weight-bear, structural allografts may not be the best option [36]. Additionally, while there are conflicting studies that show increased risk [21] or no increased risk of infection [38] with the use of allograft, many authors suggest avoidance of structural allografts in revision cases with previous infection [12, 35, 39, 40]. Reported rates of infection range from 0% to 10%, and reports of nonunion range from 0% to 4% [12, 18, 28, 41].

Concern regarding allograft transmission of disease is remote at best. Previous reports estimate the risk of transmission of HIV is less than 1 in 1.6 million [19], with only two cases of

HIV transmission as a result of musculoskeletal allografting [42]. However, even this remote risk has likely been lessened with the adoption of stricter screening programs that mandate screening blood tests for all donors, including titers to HIV 1 and 2, hepatitis B and C, syphilis, etc. [43].

Evidence regarding the incidence of resorption of allografts is conflicting. While resorption is cited as a possible disadvantage of using bone graft in multiple reports, the clinical significance of this relatively rare finding is less clear [12, 16, 17, 19, 20, 41]. Indeed, many of the larger case series had no failures secondary to graft resorption [16, 26, 29, 30]. Of those that did mention radiographic resorption, 1 paper had 4/52 grafts with resorption; 2 of 4 judged mild, 1 rated moderate, and only 1 rated severe [12]. Another report found 2 of 33 patients with adequate radiographs who demonstrated progressive radiolucent lines, neither of whom required revision surgery [17].

In summary, the use of structural allografts to reconstruct types 2 and 3 bone defects remains a viable option in revision TKA and can provide long-term osseous support and clinical success as demonstrated in the case presented here.

Key Points

- Indications for bone grafting
 - Small cavitary defects: morselized bone graft
 - Large uncontained defects: structural allografts
- Preoperative
 - Always rule out infection.
 - X-rays vastly underestimate the magnitude of bone loss.
 - Plan for constrained/stemmed implants.
- Technique caveats
 - The use of an extensile exposure may be required.
 - Rigid allograft fixation is mandatory. Geometric shaping of graft and host enhances mechanical interlock.
 - Additional fixation provided by axially placed screws and plates.

Use a diaphyseal-engaging intramedullary stem to reduce allograft loads during allograft incorporation.

- Cement implant to the allograft interface, but avoid cement penetration into the allograft-host bone interface.
- Postoperative
 - Articulated knee brace if supporting stability is inadequate
 - Partial weight-bearing for at least 6 weeks. Full weight-bearing after evidence of radiographic union (3–4 months)

ESR erythrocyte sedimentation rate, *CRP* C-reactive protein, *WBC* white blood cell.

Option 2:Tibial Augments and Cones

David G. Lewallen

Case Example

Physical Examination

The patient is a 72-year-old female without major comorbidities who, 13 years prior to presentation, underwent a primary right total knee arthroplasty (TKA) because of progressive pain and knee symptoms from osteoarthritis. A contralateral left TKA performed the same year had performed well without pain, but the right knee had become more and more painful and “unsteady” over the year prior to presentation. Her initial wound healing after the right primary TKA was uneventful, and she never had local or systemic signs to suggest infection involving the knee. Preoperative laboratory tests and aspiration of the knee were negative for signs of infection.

Radiographs and Advanced Imaging

Presenting X-rays showed clear evidence of tibial component subsidence and wide radiolucencies at the cement bone interfaces of a very thick tibial implant, suggesting excessive bone resection at the time of the primary TKA. There had been additional bone loss due to the osteolysis and varus collapse of the loose component (Fig. 13.8).

Fig. 13.8 Presenting (a) anteroposterior and (b) lateral radiographs of 72-year-old female with knee pain and instability symptoms. Excessive tibial resection at the time of the prior primary total knee arthroplasty is apparent with the thick polyethylene insert. The tibial component is radiographically loose and has subsided



Surgical Approach

The patient was advised to undergo revision TKA with a plan to use a large highly porous tantalum tibial cone for reconstruction of the deficient proximal tibia in order to allow stable mechanical support for the tibial component. Motion-free initial overall fixation of the tibial construct by the cemented undersurface of the tibial tray and the cemented (vs. cementless) stem extension on the tray allows subsequent biologic fixation from bone healing into the porous cone augments and off-loading of stress to the cement bone interface over the long term. Following reconstruction of the tibia, trial components are used to test soft tissue stability and balance. When tibial inserts over 20 mm are needed for balancing, addition of a block spacer under the tibial tray allows the use of a thinner tibial polyethylene, reserving the thicker sizes for large persistent gaps (despite use of a 10 mm block augment under the tray) or for use in a subsequent procedure required by late attenuation or stretch of the underlying damaged ligamentous structures. The potential need for varus-valgus constraint should be considered before surgery but with the final decision on level of constraint used made based on intraoperative assessment of ligamentous stability following balancing of the gaps.

Clinical Outcome

In this case bone loss at surgery following removal of the loose tibial component was, as expected, quite large and was both cavitary centrally and associated with a segmental defect anteromedially. After sizing the extent of the defect using plastic trials of the available tibial cone options, minimal burring of the bone around the central aspect of the tibial defect allowed stable impaction of the real large-sized porous tantalum cone (Fig. 13.9).

After completion of the tibial reconstruction and insertion of a tibial trial, and following the femoral side reconstruction and balancing of the knee in flexion and extension, in this case a 10 mm block was used on the underside of the tibial component. Morselized cancellous bone graft or any of a variety of bone graft substitutes can then be used to fill any small gaps between the cone and host bone. In this case a moldable bone graft substitute was used along the exposed anteromedial side of the cone to minimize soft tissue irritation (Fig. 13.10).

Postoperative Result

Postoperative radiographs at 6 weeks show restoration of limb alignment, good component posi-

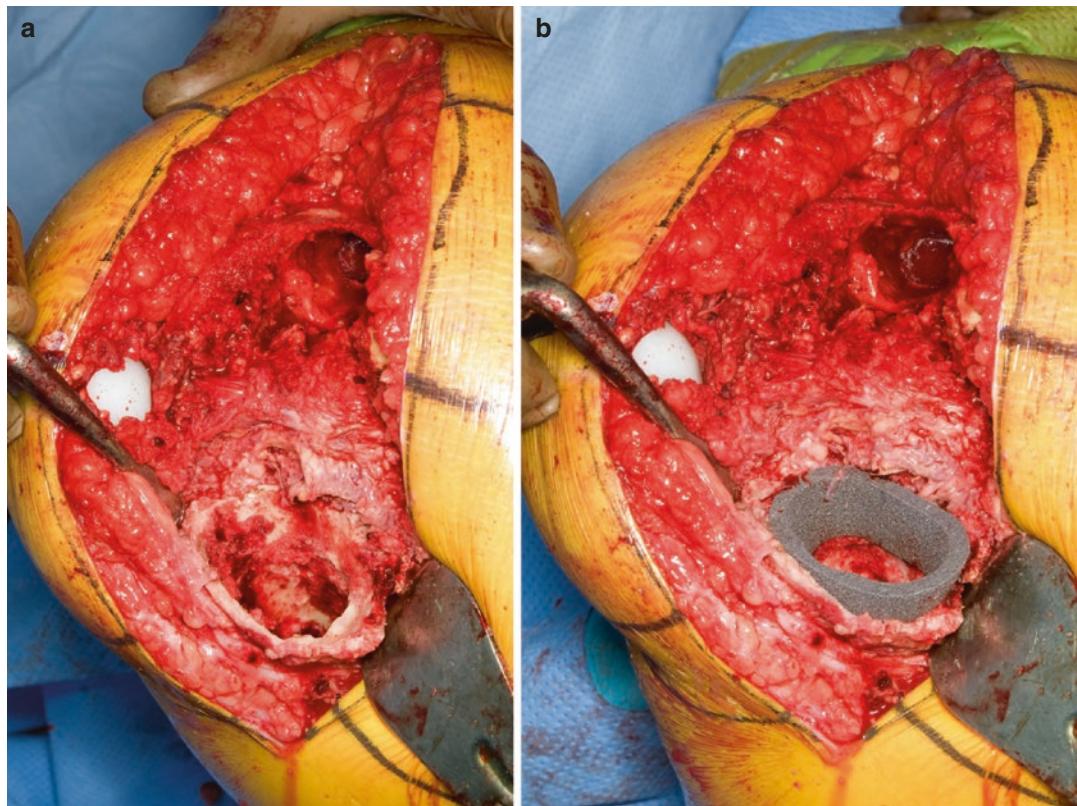


Fig. 13.9 Intraoperative views of the tibial bone defect before (*left*) and after (*right*) insertion of the porous tantalum cone. Note segmental bone deficiency along the anteromedial rim of the tibia

tion, and cemented fixation, with invagination of the tibial cone into the host tibial metaphysis and broad support for the underside of the tibial tray. Of note is the complete coverage of the medial aspect of the tibial cone by bone graft material. Position of the patella on the lateral view suggests satisfactory restoration of the joint line and along with the AP view shows the appearance of the varus-valgus constrained design needed to compensate for residual medial side ligamentous deficiency (Fig. 13.11).

This patient enjoyed an uneventful initial recovery and at 1 year demonstrated maintenance of excellent implant position and component fixation with no radiolucencies of any of the implant interfaces on any of the X-ray views (Fig. 13.12).

At most recent follow-up at 6 years after surgery, there continues to be good overall function, no pain, and no lucencies or component migration apparent (Fig. 13.13). Of note the bone graft

substitute has resorbed along the medial border of the cone, but the patient is not symptomatic.

Clinical Results

The initial concept of using highly porous tantalum augments to treat large structural bone defects originated with revision hip surgery and, specifically, the management of massive acetabular bone deficiency. Porous tantalum was initially attractive as a material in the development of implants for the treatment of bone defects due to the potential for avid bone ingrowth, favorable material properties, and the ability to bear physiologic loads [44, 45]. Dissatisfaction with the durability of results of traditional allograft reconstruction of the acetabulum due to late graft resorption and mechanical failure rates prompted the development of solid tantalum augments for use as a prosthetic structural allograft, which could allow bone ingrowth and provide mechanical support but

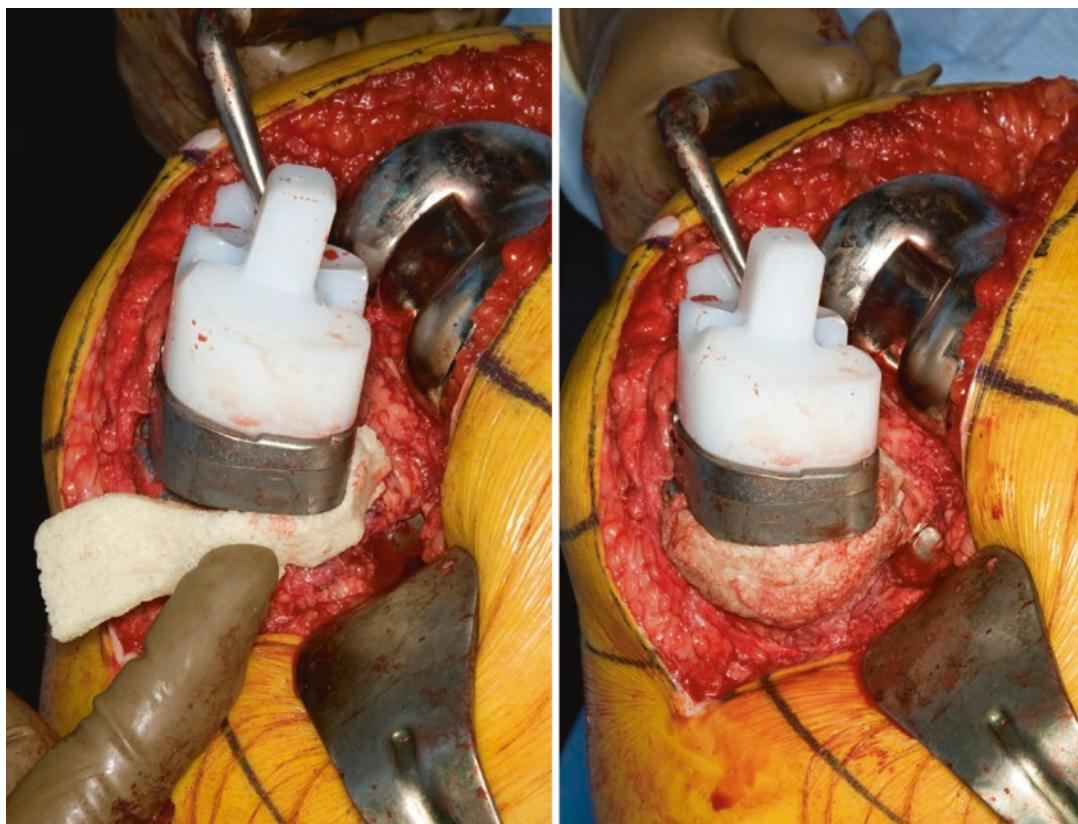


Fig. 13.10 Intraoperative views of the cemented tibial component with 10-millimeter block augment for buildup of the tibial tray in order to reduce the thickness of the polyethylene insert required for balancing of the ligamen-

tous structures. Note the tibial tray by the tibial cone and host bone and segmental bone defect grafting with a moldable bone graft substitute to reduce potential soft tissue irritation

would never resorb like allograft. Following early success with this technology for reconstruction of acetabular bone defects, it was a logical extension to try and use the available acetabular augment shapes in other locations [46]. The acetabular augments, which simulated the contour of a femoral head graft after preparation, were initially adapted for use in large femoral and tibial defects about the knee, which historically were also reconstructed on occasion using femoral head allografts. While use of these “prosthetic structural femoral head allografts” proved useful for some specific revision total knee cases, they were of limited use for only those periarticular defects at the knee where the dimensions and shape of the bone deficiency approximated that of one of the available acetabular porous metal augments, and even then modification of the implant during sur-

gery using metal cutting tools was commonly required to make them fit with the knee component stems and keels. It rapidly became apparent that a family of made-for-purpose, anatomically derived shapes contoured to fit the other components, specific to either the femoral or tibial side of the joint of the knee and available in multiple sizes, would be much more useful. This resulted in the design and availability of the less complex tibial cone shapes first, followed soon after by more complex femoral cone shapes.

After first becoming available for use in 2002, the initial results of the large porous tantalum cones were very encouraging: good clinical performance, excellent radiographic appearance with high rates of apparent union, and very good implant survivorship despite their use in the largest and most challenging of bone defect problems

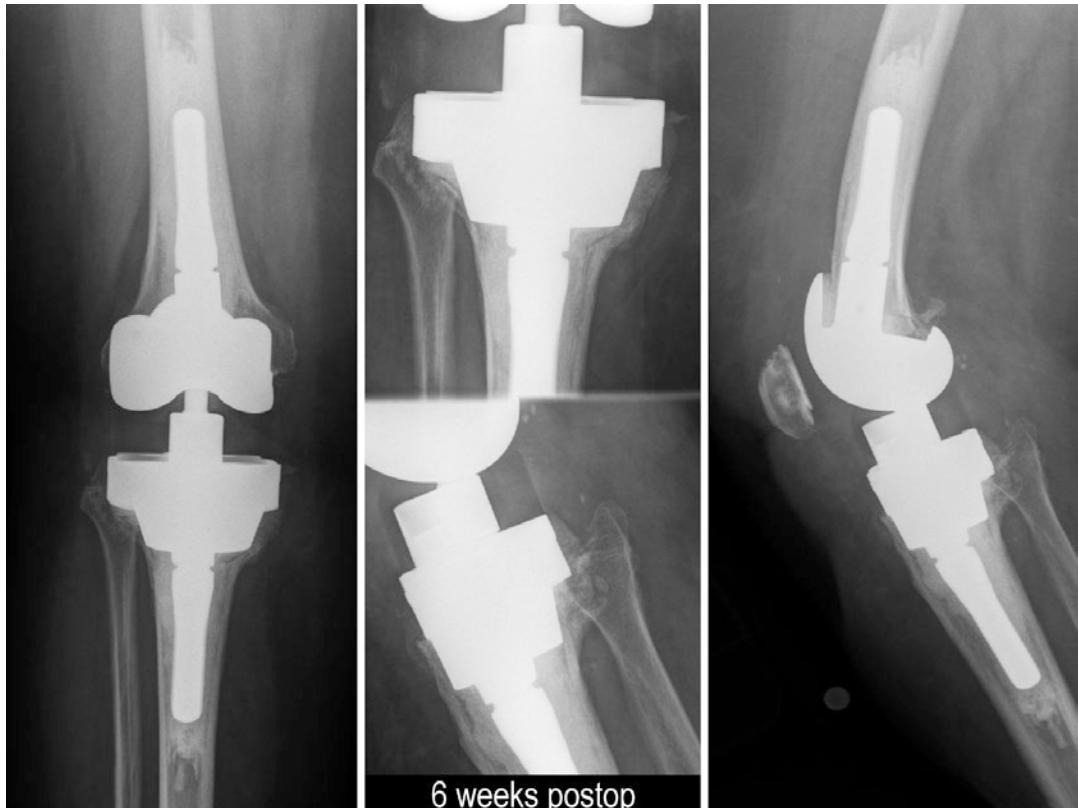


Fig. 13.11 Postoperative anteroposterior and lateral radiographs of the initial implant appearance at 6 weeks after surgery. Despite a major bone defect, the cone fixa-

tion in the metaphysis allows the use of an intermediate-length cemented stem. Note medial bone graft material visible on X-ray

[5]. Subsequent reports by other groups not directly involved in the design of the implants soon confirmed the success of this novel strategy for bone defect management on both the tibial side and subsequently on the femoral side as well and led to expanded usage in larger defect cases as a relatively routine adjunct to standard solid block augments for buildup of the tibial tray or femoral condyles and the use of stem extensions and with multiple implant systems [47–50].

Longer-term follow-up on the performance of porous tantalum cones has recently become available on larger cohorts of revision TKA patients [51, 52]. Kamath et al. reported on 66 tibial cones used as part of a revision TKA followed for a mean of 70 months. All had relatively major bone defects with 24 classified as type 3, 25 as type 2B, and 17 as type 2A defects according to the Anderson Orthopaedic Research Institute (AORI) bone defect classification system. Half of the

patients in the series had a history of prior infected arthroplasty and had undergone or were part of a two-stage exchange of components. Despite this, and an average of 3.4 prior knee surgeries and ranging as high as 20 prior operations, revision-free survivorship of the tibial cones was over 95% at the last follow-up. Clinical results were very good with statistically significant improvement in Knee Society scores from a mean of 55 to 80 points (range 28–100). Only three patients in this series had any evidence of lack of complete bony incorporation of the cone: one with partial radiolucencies on the tibial side, one with complete radiolucencies around the cone suggestive of fibrous fixation, and one revised for aseptic loosening [51].

More recently an array of new more anatomic large-sized cones and smaller cones for central metaphyseal fixation of smaller bone defect cases have become available, allowing expanded use of

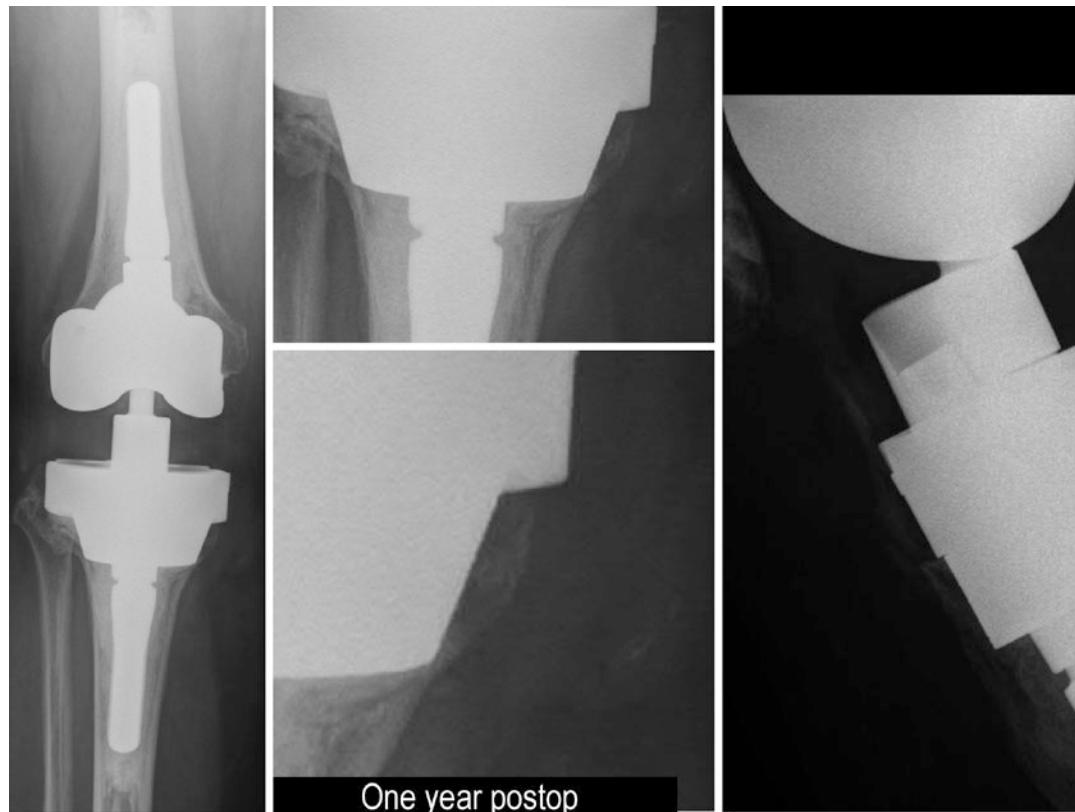


Fig. 13.12 Radiographs at 1 year post surgery with excellent fixation and no lucencies at the interfaces of bone and implant or cement. Note that bone graft material is still visible but appears less dense than previously

the hybrid fixation concept that has been validated by this experience, where both cement and cementless fixations are used on the same individual component. This provides a synergistic fixation effect, with the cement providing immediate fixation and aiding in achieving the goal of a completely motionless interface at the junction of the cone and host bone. Long-term bone ingrowth to the uncemented porous tantalum portions of the device provides the potential for durable long-term fixation and reduced mechanical loading of the companion cement bone interfaces of the same component, which should be protective of overall implant fixation over the longer term.

- An array of anatomic large-sized cones for severe tibial cavitory defects and smaller cones for central metaphyseal fixation of smaller tibial bone defect cases have become available.
- Long-term bone ingrowth to the uncemented porous tantalum tibial cones provides the potential for durable long-term fixation.

Option 3: Proximal Tibial Prosthesis

Russell E. Windsor and Danielle Y. Ponzio

Key Points

- Porous tantalum is an attractive option in the treatment of severe tibial bone defects due to the potential for bone ingrowth and provides structural support and fixation.

Case Presentation

History

A 60-year-old male was involved in a train accident in 1979 and sustained a pelvic fracture and left lower extremity open fracture of his distal



Fig. 13.13 Radiographic appearance at 6 years after surgery with excellent fixation well maintained, but graft material has completely resorbed. Good clinical result without knee pain reported



Fig. 13.14 Anteroposterior preoperative radiograph showing aseptic loosening, fracture of the revision tibial component, varus settling of the tibial implant, and a large uncontained region of medial proximal tibial bone loss

tibia and ligamentous injuries to his knee. He required a medial collateral ligament reconstruction, anterior cruciate ligament reconstruction, femoral artery anastomosis, and Z-plasty of his Achilles tendon. He underwent left total knee arthroplasty (TKA) for post-traumatic osteoarthritis in 1993 followed by tibial component revision in 1996 for aseptic loosening. He presented 16 years later with swelling, instability, and significant varus deformity with severe limitation of function.

Physical Examination

The patient ambulated with a short-legged, antalgic gait with a pronounced lateral thrust. There were healed medial, midline, and lateral incisions. A significant joint effusion was appreciated. The overall limb alignment was in 15° of varus at the knee. Varus and valgus stress testing revealed 3+ mediolateral laxity with pain. Range of motion was 0–90° with crepitus. Neurovascular status was intact, but there was no left ankle motion due to prior fusion.

Radiographs

Figures 13.14, 13.15, and 13.16 show anteroposterior (AP), lateral, and Merchant views of the left knee which demonstrate his prior revision TKA with a stemmed and augmented tibial construct and a posterior cruciate retaining implant system no longer available. There is a hardware present from prior ligament reconstruction. The radiographs demonstrate tibial loosening, mechanical failure of the tibial component, and varus settling of the implant with associated proximal tibial bone loss.

Surgical Approach

The indication for revision arthroplasty was aseptic tibial component loosening with fracture of its proximal portion due to metal fatigue and asymmetric loading. The tibial component was previously augmented with a medial metal wedge to address bone loss during the first revision in 1996. The progressive varus settling of the fractured tibial component caused severe



Fig. 13.15 Lateral preoperative radiograph showing aseptic loosening of the tibial component and staples from a previous anterior cruciate and medial collateral ligament reconstruction

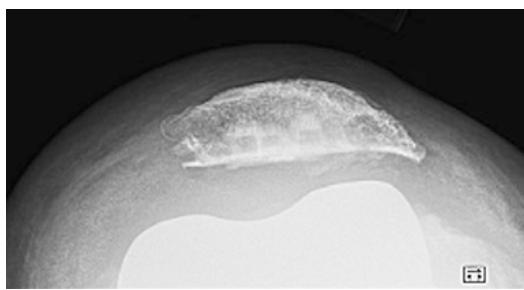


Fig. 13.16 Merchant preoperative radiograph showing a well-fixed patellar component

destruction of the proximal medial bone stock of the tibia.

As the prior revision TKA consisted of a posterior cruciate retaining implant system no longer available, complete femoral and tibial component revision to a contemporary, stemmed and constrained design was required. The previous ligamentous reconstruction was most likely no longer functional. The use of a constrained prosthesis was necessary to address not only medial collat-

eral ligament insufficiency but also secondary damage to the lateral collateral ligament due to prolonged lateral thrust during ambulation.

The operative challenges are to rebuild the medial bone loss and maintain the joint line. While the tibial component settled into varus causing medial bone deficiency, the preserved proximal lateral cortex serves as a reference for reconstruction of the joint line. The new implant should sit at the level of the proximal lateral cortex, and the medial side of the proximal tibia would require substantial augmentation to accommodate the severe bone loss. Options for bone loss augmentation include a larger medial metal wedge beneath the tibial baseplate, distal fixation with a stem with additional metal augmentation or structural bone allograft. Due to the patient's history of multiple operations, a challenge is achieving long-term fixation of the tibial component in the setting of sclerotic bone with little cancellous bone remaining for adequate cement penetration. Therefore, proximal augmentation with a large porous metaphyseal fixation cone was deemed necessary to provide a fixation point for cement.

This case incorporates metal augmentation with tantalum trabecular metal, along with a large medial angular wedge attached to the tibial component. Femoral component revision was routine. The intercondylar notch bone that was removed during femoral preparation for a posterior cruciate substituting implant was preserved and used as autologous bone graft on the tibia. Patellar component revision was unnecessary as it was well fixed.

A midline longitudinal incision was made along the previous incision for his primary and first revision operations. A thick, villous, gray synovitis was encountered which typically accompanies chronic aseptic loosening. Due to its aggressive physiologic activity, it is necessary to excise this synovium as completely as possible.

To aid exposure, the femoral component was removed first with a revision saw blade to disrupt the cement-prosthesis interface. Bone stock was preserved, and the intercondylar notch bone was saved as autograft for the tibial reconstruction.

The loose, broken tibial implant and stem were extracted without difficulty. Attention was turned toward complete removal of the fibrous membrane. A new bone surface was prepared along the more preserved lateral side of the tibia for additional cement fixation. The tibial intramedullary canal was reamed to accept a 14 mm × 100 mm stem extension.

The proximal tibia was prepared to accept a 30 mm × 15 mm medial tantalum trabecular metal cone. The exterior surface of the cone would be placed without cement so bone ingrowth can occur. After placement of the implant solidly into its broached surface, autologous bone graft from the femoral notch was placed along the outer margin to facilitate bone ingrowth.

The trabecular metal cone served as an anchor onto which the stemmed tibial component was cemented. Due to the uncontained large area of medial bone loss, a 22.5 mm medial metal half-wedge augment was attached beneath the tibial baseplate. Metal augmentation is preferred over

acrylic cement or structural allograft for this size defect. The medial metal augment sat on the proximal surface of the trabecular metal cone. Of note, the lateral aspect of the tibial baseplate rested at the level of the proximal lateral cortex to preserve the patient's original joint line.

Postoperative Result

At 4-year follow-up, the patient has a small area of nonprogressive radiolucency at the interface between the bone and the proximal lateral aspect of the tibial implant (Figs. 13.17 and 13.18). The interface surrounding the metaphyseal cone is intact. Clinically, range of motion is 0–110° with only mild swelling and pain. The patient has no further complaints of instability events, and examination reveals no laxity upon stress testing.

Clinical Results

Tibial aseptic loosening and instability are leading causes of TKA failure and often associated

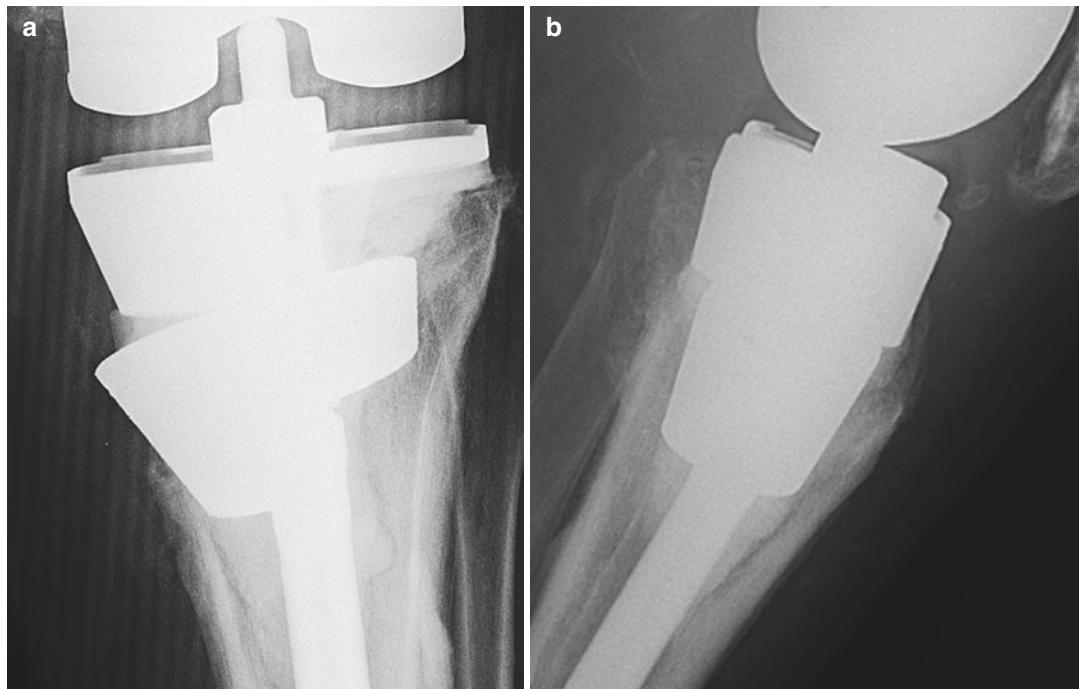
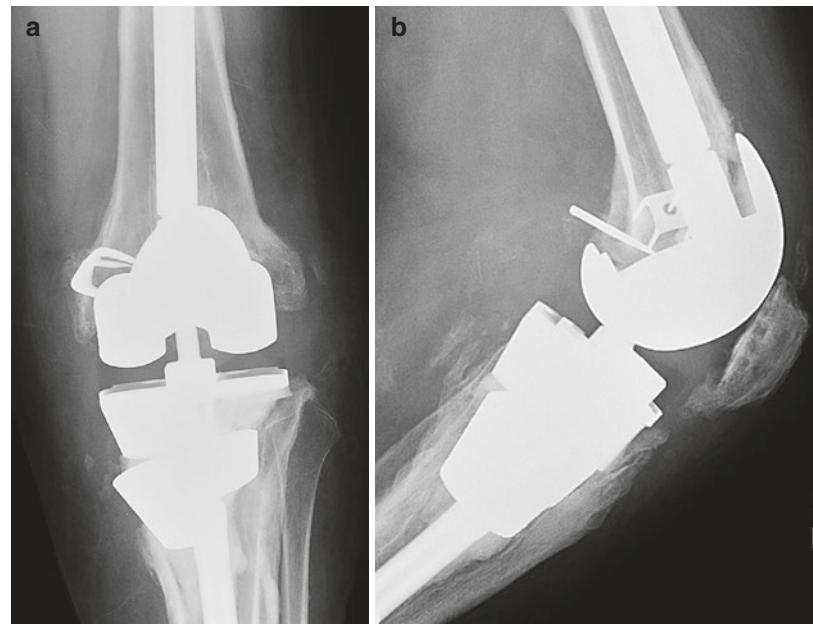


Fig. 13.17 Post-revision anteroposterior (a) and lateral (b) radiographs demonstrate the reconstruction of the proximal tibia with a combination of a prosthetic augment and a metaphyseal cone. The outer surface of the trabecu-

lar metal cone is implanted in direct contact with the host bone. The inner surface serves as an anchor for acrylic cement insertion

Fig. 13.18

Anteroposterior (a) and lateral (b) post-revision radiographs showing a proximal lateral, nonprogressive radiolucency at the cement mantle. There is no radiolucency surrounding the trabecular metal tibial metaphyseal cone



with bone loss [52]. Metaphyseal bone loss can compromise initial and long-term fixation of components during revision TKA, as demonstrated by this case with failure of the tibial revision construct necessitating re-revision. The goals of revision surgery are to preserve viable host bone, reconstruct bone deficiencies for implant fixation, restore the joint line, achieve proper patellar tracking, establish neutral alignment, and optimize ligamentous stability and flexion-extension balance [53–55]. The long-term goal is a well-fixed, stable knee joint that improves the patient's functional status and quality of life. Selection of the reconstructive technique(s) to manage bone deficiency is determined by surgeon experience and training, the integrity of the posterior cruciate and collateral ligaments, the location and magnitude of bone loss, and patient factors including the potential for additional revision, functional demand, and comorbidities [36, 53–56].

Major bone defects, classified as Anderson Orthopaedic Research Institute (AORI) types 2B and 3, have been reconstructed using impaction bone grafting with or without mesh augmentation, structural or bulk allografts, modular metal augmentations of prostheses, and tumor-type mega-prostheses [36, 53, 55, 57, 58]. Each option for

reconstruction of metaphyseal bone deficiencies during revision TKA has advantages, disadvantages, and outcomes such that the best technique is not clearly established [55]. Studies using structural allografts have reported complications of nonunion, delayed union, collapse, graft resorption, graft infection, and the possibility of disease transmission [36, 59] and a reoperation rate of 8–23% [12, 26, 48, 60, 61]. A possible solution in our case was to reconstitute the region of bone loss with augmentation to the implant which included a combination of a modular prosthetic metal augment beneath the medial tibial baseplate, which is generally indicated for reconstruction of uncontained segmental defects of between 5 and 20 mm in depth, and a metaphyseal cone, designed to fill large contained cavity and combined cavity-segmental metaphyseal defects [62]. The cone was placed in direct contact with the host bone to achieve peripheral osseous ingrowth and offer the potential for long-term structural support. The high porosity of tantalum and its scaffolding abilities for osteoblast activity enable bone ingrowth and make it a suitable material for these augment [36, 48, 49]. Upon osseointegration, the augment shares the intramedullary axial loading forces, effectively protecting the epiphyseal fixation and improving the rotational

stability of the construct. A variety of prosthetic devices can be cemented into the inner, central surface of the metaphyseal cone [36]. In this case, the medial tibial prosthetic augment rested upon the metaphyseal cone. Autograft obtained from the femoral notch cut was used around the circumference of the cone to ensure bony contact. The cone then served as a receptacle for the cement and the stemmed tibial component. Advantages to proximal tibial reconstruction using augmentation of the prosthesis include the ability to provide mechanical support for the tibial component, provide the potential for long-term biologic fixation, decrease the complexity of the reconstruction, enable immediate weight-bearing, and avoid the known complications associated with bone graft [55, 62]. Disadvantages include the expense, the lack of long-term clinical experience, the requirement to remove host bone for positioning of the implant in certain cases, and the possibility of difficult extraction if removal is required [55, 62].

Multiple studies have demonstrated favorable short-term outcomes using metaphyseal cones, though in limited numbers of patients [5, 46, 48, 49, 63–66]. Long and Scuderi described 16 patients treated with tibial metaphyseal cones and followed for 31 months with no revisions for aseptic loosening, and all patients showed radiographic evidence of osseointegration [5]. Meneghini et al. followed 15 patients over 2 years after revision TKA with tibial cones, all of which demonstrated radiographic osseointegration [46]. Lachiewicz et al. reviewed 27 patients with 33 tantalum cones (9 femoral, 24 tibial) followed for a mean of 3.3 years [48]. One knee with two cones was removed for infection. One cone did not osseointegrate. One knee was revised for femoral cone and component loosening. Kamath et al., including senior authors who are developers of the porous tantalum metaphyseal cone, were the first to report midterm results, at a mean of 5.8 years, of 66 tibial cones implanted [50]. One patient had progressive radiolucency about the tibial stem and cone. One patient had complete radiolucency about the tibial cone, concerning for fibrous ingrowth. Three cones were revised: one for infection, one for aseptic loosen-

ing, and one for periprosthetic fracture. Revision-free survival of the tibial metaphyseal cone was >95% at the time of the latest follow-up [50]. De Martino et al. reported on 18 knee revisions using tantalum cones which all were osseointegrated at a mean of 6 years [58].

Regardless of the technique utilized, in all cases, attention must be given to restoration of an anatomic joint line. This optimizes ligamentous stability and joint kinematics. The principle of restoring the joint line is highlighted in this case where during revision surgery the implant was shifted laterally to optimize contact with the structurally intact proximal lateral cortex which was used as a reference for the joint line and to assess the extent of augmentation needed. For cases with ligamentous insufficiency and moderate bone loss, a constrained condylar knee (CCK) design that supplements the collateral ligaments is appropriate [67]. In cases of massive bone deficiency with loss of collateral ligamentous support or gross flexion-extension mismatch, a hinged prosthesis is indicated [53].

Porous metal metaphyseal cones and sleeves represent the most recent advances in the treatment of metaphyseal bone loss during revision TKA [55]. These technologies offer biologic ingrowth fixation and a mechanically sound scaffold for revision components while avoiding the concerns associated with bone grafting [55]. Long-term clinical follow-up is needed.

Key Points

- Key off of the relatively intact proximal lateral cortex as a reference for the joint line which should be restored in the final construct.
- Aim to achieve circumferential bone contact with the trabecular metal metaphyseal cone and augment with autograft or allograft as needed.
- The inner aspect of the metaphyseal cone should serve as a receptacle for cement that is then compatible with the tibial baseplate and stem.
- Cement technique, using fully cemented stems versus a hybrid construct, is according to the surgeon's preference.

- The trabecular metal metaphyseal cone offers a fixation point for further buildup of the prosthesis as needed. In this case, a 20-mm medial augment was supported by the cone.

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Management of Severe Femoral Bone Loss

14

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Douglas A. Dennis, David G. Lewallen,
R. Michael Meneghini, and Kirsten Jansen

Introduction

Alfred J. Tria

Severe femoral bone loss can be the result of aseptic or septic loosening, periprosthetic fracture, or iatrogenic bone loss secondary to the implant removal. The preoperative evaluation should consider the degree of loss and prepare appropriately for the procedure [1]. The Anderson

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Orthopaedic Research Institute (AORI) classification has become a standard and is very helpful for the revision preparation (Fig. 14.1) [2]. The F1 defects can almost be ignored and require simple autografting or cement fill. The F2 defects are slightly more complicated with some associated cortical loss and require defect reconstruction and intramedullary stems. The F3 defects involve bone loss and soft tissue compromise and require defect reconstruction and ligamentous support from the prosthetic device itself. The case presentations to follow review these principles and illustrate the appropriate approaches.

Option 1: Femoral Bone Grafting for Severe Femoral Bone Loss

Richard W. Rutherford and Douglas A. Dennis

Case Presentation

History

A 79-year-old man underwent a primary cemented primary total knee arthroplasty (TKA) 16 years prior for advanced osteoarthritis. His TKA functioned well for many years until he developed painless swelling over a 6-month time period. The patient denied any significant trauma other than a minor twisting of his knee. Radiographs obtained in clinic demonstrated massive distal femoral

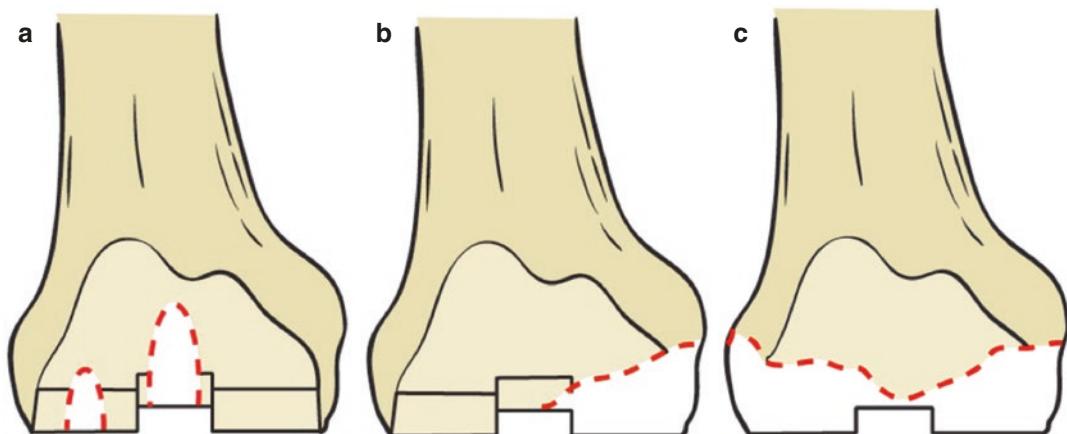


Fig. 14.1 The Anderson Orthopaedic Research Institute classification: (a) F1 defect with intramedullary bone loss without cortical compromise; (b) F2 defect with bone loss

and cortical involvement; (c) F3 defect with cortical bone loss and compromise of one or both collateral ligament complexes

osteolysis associated with polyethylene wear and suggested prior distal femoral stress fractures in various stages of healing. Revision TKA was recommended with the use of a structural femoral allograft to address the massive distal femoral osteolysis. Preoperative evaluation including obtaining an erythrocyte sedimentation rate, a C-reactive protein, and knee aspiration for cell count and cultures demonstrated no evidence of infection.

Physical Examination

Prior to surgical intervention, the patient had a well-healed left knee midline incision with a moderate effusion. Knee range of motion was 0–110° with mild laxity in the sagittal and coronal planes. No deficits were detected on neurovascular exam.

Radiographs and Advanced Imaging

Anteroposterior, lateral, and Merchant patellar radiographs of the left knee were obtained, demonstrating eccentric medial polyethylene wear and massive secondary osteolysis of the distal femur. The radiographs suggested implant fixation was maintained (Fig. 14.2). The posterior cruciate-retaining femoral component allows for better visualization of distal femoral osteolysis than cruciate-substituting designs. Oblique radiographs and CT scans of the knee can be useful in further evaluating the extent of osteolysis but were not felt to be necessary in this case.

Surgical Approach

Preoperative Considerations

After infection was ruled out, the first step in this case is to assess the size, location, and quality of the bone defect. The Anderson Orthopaedic Research Institute (AORI) bone loss classification system is a useful method to classify bone defects in TKA [3]. In a Type 1 defect, there is adequate metaphyseal bone with a near normal joint line. A Type 2a femoral defect has loss of cancellous bone in one condyle requiring augments or bone grafting with revision components and stems. A Type 2b defect involves extensive damage to both femoral condyles. A Type 3 femoral defect usually involves almost complete loss of metaphyseal bone with possible cortical loss resulting in damage to the collateral ligaments. Preoperative evaluation should be undertaken with the understanding that plain radiographs usually underestimate the severity of bone loss, especially when it concerns the femur [4]. This can occur due to a visual obstruction from a radio-opaque implant, bone loss that occurs iatrogenically during implant removal, as well as the intrinsic poor sensitivity of radiographs in quantifying bone loss. In the face of massive bone loss in revision TKA, the goals of reconstruction are to preserve host bone and avoid iatrogenic bone loss during implant removal, to restore bone

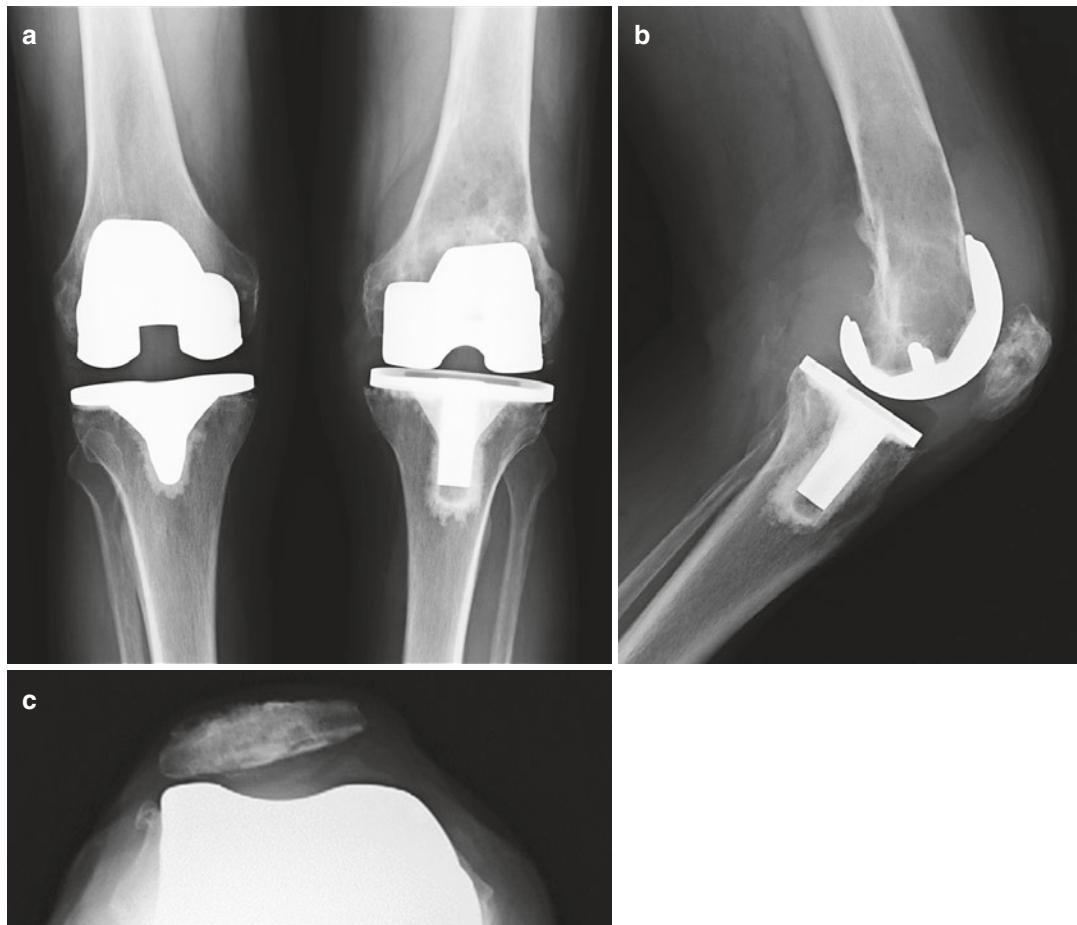


Fig. 14.2 (a) Anteroposterior (AP) radiograph demonstrating eccentric polyethylene wear and distal femoral osteolysis of a primary left total knee arthroplasty. (b) Lateral radiograph with osteolysis and concern for sub-

acute distal femoral stress fracture (posterior cortex). (c) Merchant patellar radiograph exhibiting a well-fixed patella and centralized extensor mechanism

stock with a structural allograft or prosthetic augmentation, to restore flexion and extension balance as well as the joint line, and to assure rigid implant fixation and knee stability.

The presence of infection is a contraindication for revision arthroplasty and it must be ruled out prior to consideration of managing severe femoral bone loss with metal or allograft. This typically involves laboratory testing (erythrocyte sedimentation rate [ESR] and C-reactive protein [CRP]) as well as aspiration for nucleated cell count and culture. Cell counts of 1700–2500 and above that are associated with greater than 60–65% PMN have been demonstrated to be highly suggestive of infection [5, 6]. Holding cul-

tures for a minimum of 14 days improves the likelihood of culturing a sessile or fastidious organism [7].

Treatment for bone loss in revision TKA is dependent upon the size and location of the defect and whether it is contained or uncontained [8]. For small defects, cement with or without screw reinforcement can be used. For contained defects, particulate bone grafting can be considered. For Type 2 defects of 5–15 mm, modular augmentation can be used. Bone graft or metaphyseal cones or sleeves are recommended for large Type 2 or Type 3 metaphyseal bone defects or defects with a depth greater than 15 mm. In larger osseous defects, structural autograft is usually not available, and

therefore allograft is more commonly used for structural bone grafting. The advantages of structural allograft are that it restores bone stock for both implant support and future TKA revision if needed, is customizable to the individual defect, is cost effective compared to trabecular metal cones and porous sleeves, and provides a more physiologic transfer of load. However, structural bone grafts are at risk of nonunion or malunion, late resorption and collapse, and disease transmission (<1 per 1,000,000 risk of HIV transmission [9]) and require skill to shape and match the allograft to the corresponding bone defect.

Preoperatively, proper allograft selection is critical. Sizing is important to avoid difficulties with later wound closure. Femoral head, distal femoral, or proximal tibial specimens are most commonly used. When possible, it is wise to select an allograft type that matches the host defect (i.e., distal femoral allograft for a host distal femoral defect). Placement of the allograft with the trabeculae oriented parallel to the axial loads that traverse the allograft enhances strength of the construct. Assessment of the soft tissue envelope and the status of the collateral ligaments should be performed as part of the preoperative examination. Early plastic surgery consultation is recommended if the skin and surrounding soft tissue envelope is compromised. A revision system with constraint should be available as cases with severe (Type 2 or 3) femoral bone loss can be at risk for collateral ligament insufficiency. Diaphyseal-engaging stems are usually necessary in conjunction with the use of a structural allograft to provide enhanced implant fixation and to off-load the allograft during osseous incorporation with the host. High-speed burrs are sometimes necessary to reshape the defect and allograft. Additional fixation devices such as screws and plates should be available. In this case, a fresh frozen distal femoral allograft was available, as were metaphyseal porous-coated sleeves in the event that the structural allograft was not necessary.

Operative Procedure

The procedure was performed utilizing the preexisting anterior midline skin incision and a medial parapatellar arthrotomy. Partial release of the

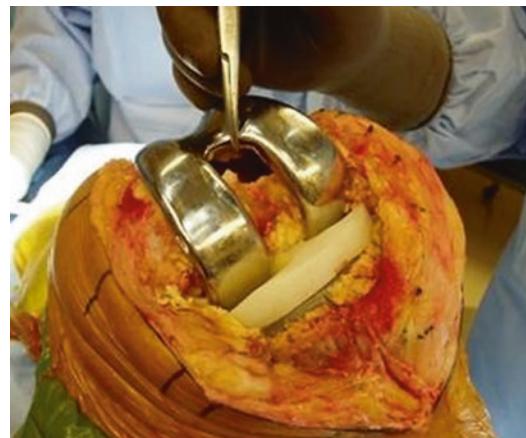


Fig. 14.3 Intraoperative photograph of the exposed total knee arthroplasty showing the osteolytic defect consistent with radiographic findings

deep medial collateral ligament was performed to allow visualization of the components. A proliferative synovitis was encountered, and an extensive synovectomy was performed which further facilitated implant exposure and reestablishment of the suprapatellar pouch and medial and lateral gutters. An extensile exposure such as a quadriceps snip or tibial tubercle osteotomy was not required. A 2 cm defect was visible in the intercondylar notch, which corresponded with the radiographic findings (Fig. 14.3).

The femoral component was then removed by interrupting the implant-cement interface using a thin oscillating saw blade and flexible osteotomes. There was an extremely thin shell of cortical bone, so removal of the component was done with great care to avoid fracture (Fig. 14.4). The size of the osteolytic defect was larger than the largest size of metaphyseal sleeve or cone, and the decision was made to proceed with a distal femoral allograft reconstruction. Due to the magnitude of posterior slope typical of a posterior cruciate-retaining implant and the associated ligamentous instability, use of a constrained implant was chosen, and therefore the tibial component was removed to allow for use of a tibial component with a metaphyseal sleeve and diaphyseal-engaging stem. The proximal tibia was then prepared to receive this tibial construct, and the trial tibial component was inserted.

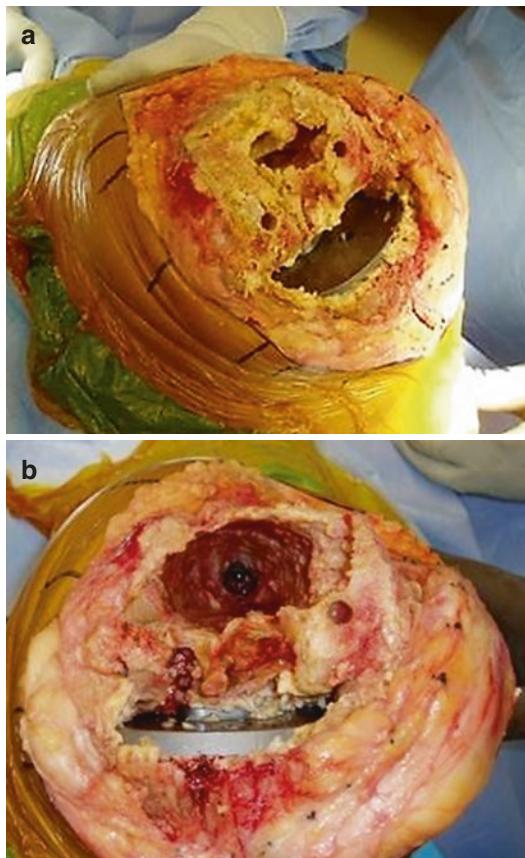


Fig. 14.4 Intraoperative photographs (a, b) following removal of the femoral component revealing massive osteolysis

Due to the relative cavitary nature of this massive osseous defect, an intussusception or invagination technique of the structural allograft was planned. The fresh frozen distal femoral allograft was first thawed in a warm antibiotic-containing solution. The standard femoral bone resections were performed at the back table using traditional femoral cutting guides (Fig. 14.5). The allograft was also prepared to receive a metaphyseal sleeve and stem to enhance the rigidity of fixation. Lastly, the allograft was shaped with a saw and high-speed burr to maximize allograft-host contact, provide inherent allograft stability, and assure that the allograft length would restore an acceptable joint line. The use of a technique which involves making a step cut in host bone and complimentary step cut in the allograft was not selected as it would remove more host bone,

and it was felt superior allograft-host fixation would be obtained with the invagination method.

The trial femoral allograft-prosthetic component was assembled and inserted, and the knee was reduced. The extension gap was assessed and balanced with appropriate soft tissue releases and choice of appropriate tibial polyethylene bearing thickness. A rotating platform constrained bearing was selected to both reduce fixation stresses and loads placed on the constraining cam-post mechanism. Flexion stability was maximized by adjusting the rotational position of allograft interlock with the host distal femur.

After assurance of satisfactory implant position and stability, trial components were removed. The knee was then irrigated copiously to prepare for cementation. The femoral component was cemented to the allograft on the back table (Fig. 14.6). The condylar surface of the tibial

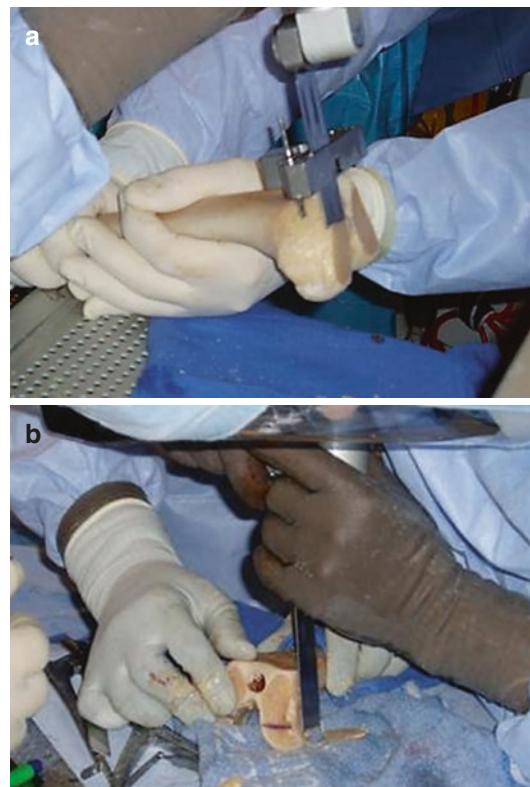


Fig. 14.5 Intraoperative photographs demonstrating preparation of the distal femoral allograft (a) and additional contouring of the allograft to maximize contact with the host distal femur (b)



Fig. 14.6 Intraoperative photographs (a, b) of the final allograft-prosthetic composite prior to implantation

component was cemented to the tibia, with the stem and sleeve being placed in a press-fit fashion. Then the distal femoral allograft-prosthesis composite was impacted into the host femur, taking great care to ensure proper rotation. Good rotational stability was achieved without micro-motion. The patient's patellar component exhibited some mild wear but was well fixed without osteolysis and was therefore retained. After the cement was cured, the tourniquet was released, hemostasis obtained, and a drain placed. The

wound was then closed and dressed in a traditional fashion.

The technical keys of structural allografting include developing a healthy, bleeding host recipient site, maximizing allograft-host and prosthesis-host contact, optimizing mechanical interlock between graft and host, restoring the anatomic joint line, and obtaining rigid implant fixation with no instability or malalignment. In this case, the selected distal femoral allograft was press fit into the host femur using an invagination technique following preparation of the host bony surfaces to maximize allograft contact and stability. Other techniques of preparation for the use of a structural allograft include hemispherical geometric shaping of both the host and allograft, which can be accomplished using male and female acetabular reamers. Having complementary surfaces with maximized bony contact enhances graft incorporation. In some cases of femoral allografting, temporary fixation with the use of bone clamps or K-wires prior to securing the graft permanently with an intramedullary stem or axial screws and plates will be required.

Postoperative Result

Postoperatively, the patient's weight bearing was limited to toe touch for the first 8 weeks with a hinged knee brace to lessen angular stresses on the allograft-host fixation interface with no restriction on range of motion. Immediate post-operative radiographs can be seen in Fig. 14.7. The patient was then permitted 30–40 pounds of weight bearing for an additional 2 months. The hinged knee brace was utilized for 3 months. At 1 year following the operative procedure, the patient was independently ambulatory without ambulatory aid with good stability and a knee range of motion of 0–118°. Radiographs at that time demonstrated no migration of the allograft or implant with the suggestion of incorporation with the host distal femur.

At 5 years postoperatively, the patient presented complaining of occasional peripatellar pain. His exam continued to demonstrate good stability with a range of motion was 5–125°. He exhibited tenderness over the lateral facet of the patella consistent with lateral facet syndrome

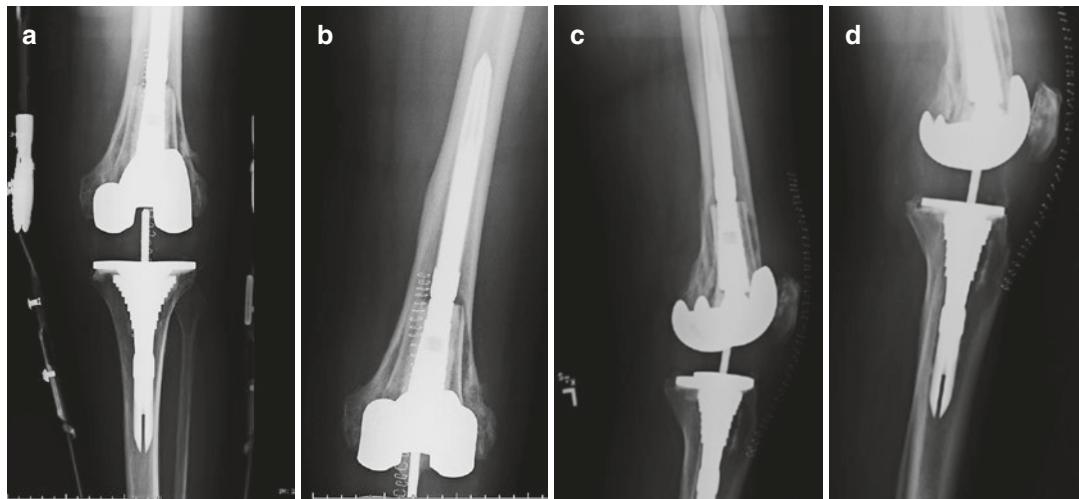


Fig. 14.7 Immediate postoperative radiographs (a–d) after revision total knee arthroplasty utilizing a distal femoral allograft implanted via an intussusception technique

which was not relieved with nonoperative measures. For this reason, a lateral patellar facetectomy was planned. Intraoperatively, the patellar component was found to be loose. The component was removed and not re-surfaced due to insufficient patellar bone stock which resulted in resolution of his patellar symptoms. Five-year postoperative radiographs continue to demonstrate good implant position and fixation with allograft-host union (Fig. 14.8).

Clinical Results

There are limited studies in the literature describing the medium- to long-term clinical results of the use of structural allografts in revision TKA. Chun et al. reported on a retrospective review of 27 patients with a median 107-month follow-up duration which demonstrated survival of all but one allograft, which was revised for infection [10]. Clatworthy reported results of 52 revision knee replacements with 66 structural grafts [11]. Thirteen of the knee replacements failed, with five failures due to allograft resorption, two from a lack of osseous integration, and four failures due to infection. A 72% survival was reported at 10 years in this analysis.

A recent systematic review of 17 studies by Beckman and colleagues demonstrated a revision rate of 10.2% in 805 grafts with an average

follow-up period of 70.8 months. The most commonly reported reasons for revision were aseptic loosening or fracture of the allograft followed by infection [12]. As previously stated, the disadvantages of using structural allografts include nonunion or malunion, late resorption, fracture, and disease transmission. Figure 14.9 demonstrates a case of late allograft resorption in a patient 23 years after revision TKA with a distal femoral allograft. In this patient, due to the magnitude of allograft resorption and the advanced age of the patient, this knee was salvaged with a distal femoral replacement prosthesis.

Tantalum cones and porous metaphyseal sleeves are alternatives to structural allograft use in revision TKA for massive bone loss [13]. Some proposed advantages include greater ease of implantation and fixation that does not depend upon allograft-host integration. It is hypothesized, in fact, that tantalum cones have better biocompatibility than structural allograft and will therefore be shown to have superior osteointegration [14]. This has been supported in the literature by one systematic review which demonstrated a decreased rate of aseptic loosening, a trend toward decreased revision rates, and no difference in infection rates between trabecular metal cones and structural allograft [12].

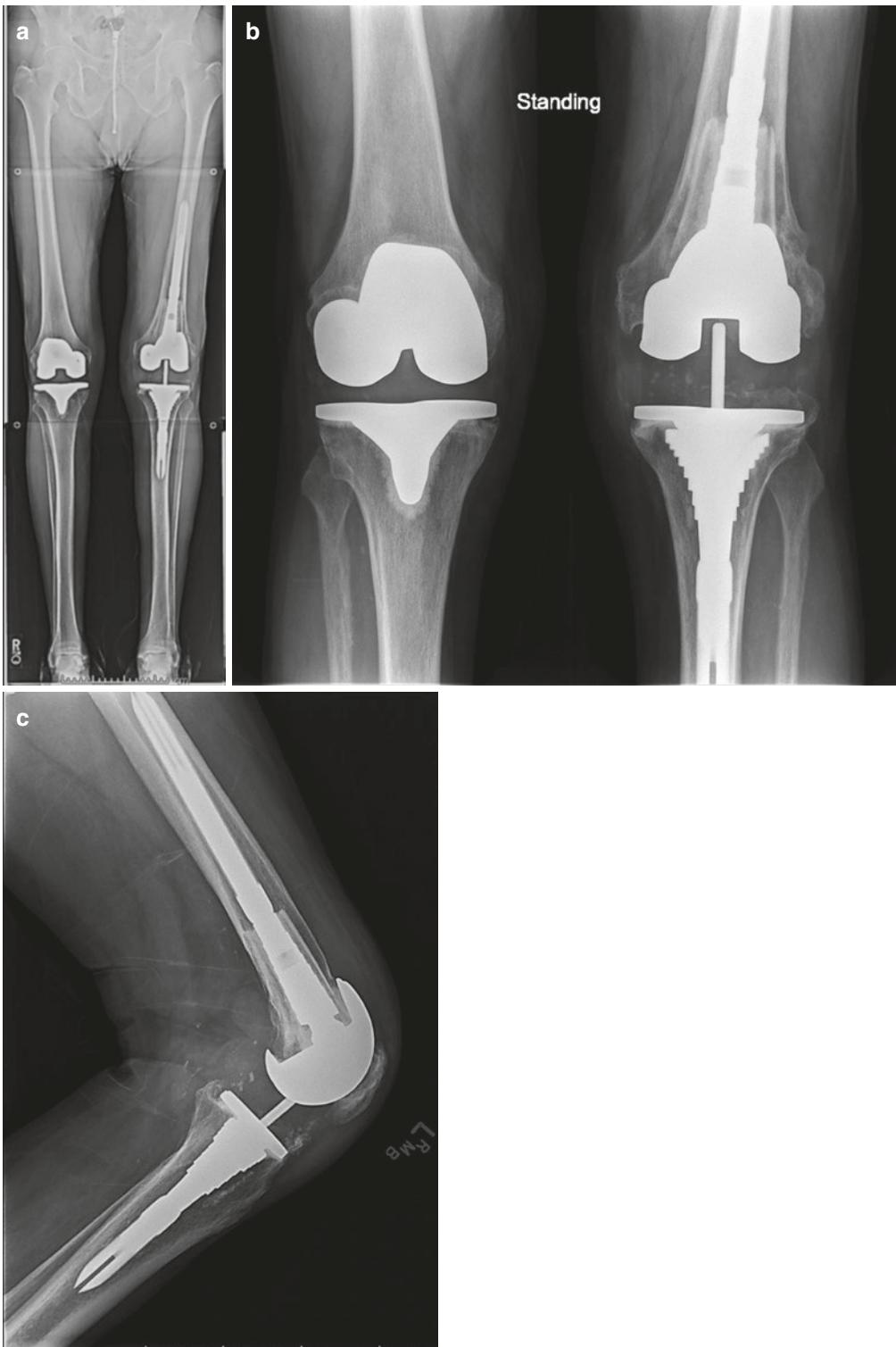


Fig. 14.8 Five-year postoperative radiographs (a–c) demonstrating satisfactory position and fixation of the implant-allograft composite



Fig. 14.9 Intraoperative photograph of a failed revision total knee arthroplasty with late (23-year) resorption of a distal femoral allograft

Despite the decrease in the utilization of structural femoral allograft due to the advent of newer devices such as sleeves and cones, structural bone grafting remains useful in younger patients with massive defects in whom restoration of bone stock for future revisions is desired.

Key Points

- Structural allografts are appropriate for management of massive defects in younger patients.
- Precise bone preparation of the host defect and allograft is imperative to maximize allograft-host contact and subsequent osseous integration.
- Rigid fixation is mandatory and usually requires the use of diaphyseal-engaging stems along with screws and plates in some cases.
- Cases requiring structural allografting often have associated ligament instability, and having implants with increased prosthetic constraint available is recommended.
- X-rays typically underestimate the magnitude of bone loss, especially in the femur.

Option 2: Femoral Augments and Cones

David G. Lewallen

Case Presentation

History

The patient is a 64-year-old male without major comorbidities who 10 years prior to presentation underwent a primary left total knee arthroplasty (TKA) because of progressive pain and knee symptoms from osteoarthritis.

Physical Examination

The initial TKA performed well but has been marked by gradually progressive pain over the past 2 years and markedly increased pain and swelling with instability over the past several months. Initial wound healing after the primary TKA was uneventful, and the patient has never had local or systemic signs to suggest infection involving the knee. Preoperative laboratory tests and aspiration of the knee were negative for signs of infection.

Radiographs and Advance Imaging

Presenting x-rays showed clear evidence of femoral component migration and loosening (Fig. 14.10), with significant osteolysis beneath the still well-fixed tibial component apparent on close-up fluoroscopic views (Fig. 14.11).

Surgical Approach

Surgery was recommended with a plan for revision of both the tibial and femoral components of the knee arthroplasty. Provision was made for possible increased constraint, with a varus-valgus constrained option available at surgery in the event this was needed due to compromise of the collateral ligaments. At surgery the femoral component was grossly loose, and the tibial component was well fixed but easily removed as fixation was tenuous. Following component removal the defects in both the femoral metaphysis and central portion of the tibia were assessed. The massive cavitary femoral bone deficiency involving both condyles noted by x-ray preoperatively and the anticipated tibial bone defect from the combined effects of tibial implant removal and extensive tibial osteolysis presented a reconstructive challenge on both sides of the joint (Fig. 14.12). Defect size and

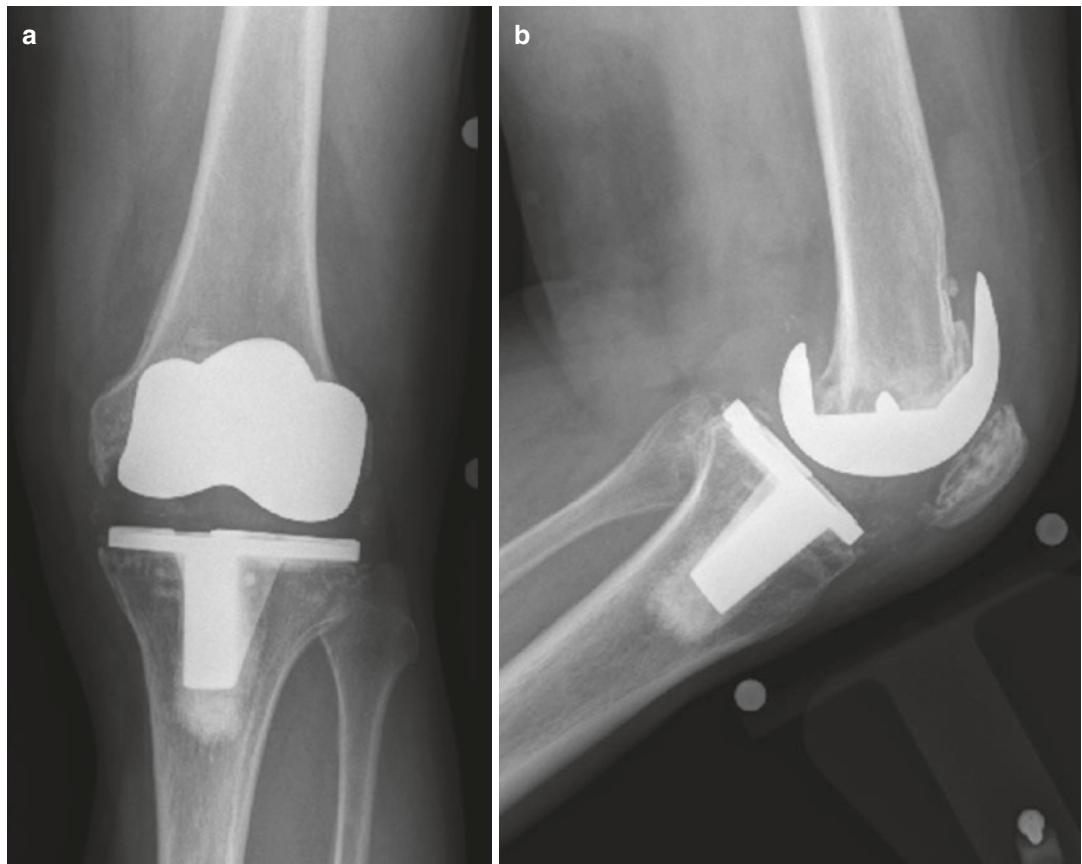


Fig. 14.10 Presenting anteroposterior and lateral radiographs of 64-year-old male with knee pain and instability symptoms. The tibial component appears secure, but there

is osteolysis noted adjacent to the undersurface of the tibial tray (a). The femoral component is radiographically loose and has migrated proximally (b)

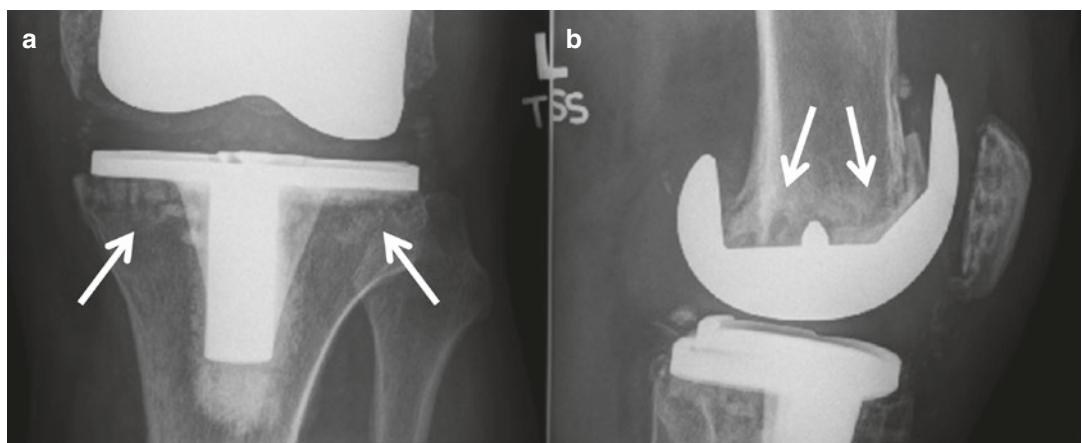


Fig. 14.11 Fluoroscopically controlled close-up radiographic views of the implant interfaces showing more clearly the tibial side osteolysis (a, arrows) and femoral radiolucencies (b, arrows)

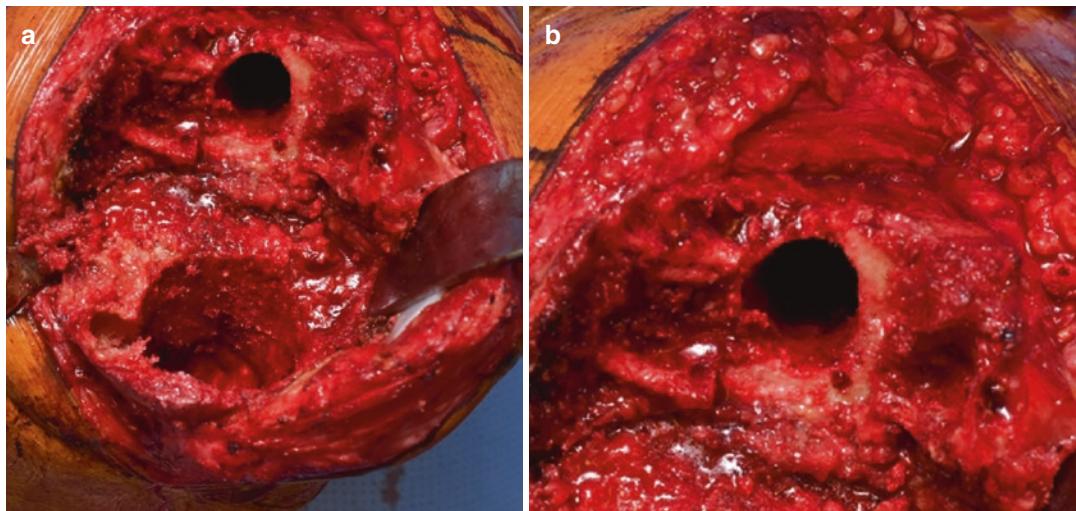


Fig. 14.12 Intraoperative view of the tibial side and femoral side bone defects before insertion of the porous tantalum cones. Note the large central defect in tibia (a) and major cavitation of the femoral condyles (b)

location appeared to lend itself to reconstruction with highly porous tantalum cones on both the tibial and femoral sides. On the tibial side, two tibial cones were used in combination in a “stacked” configuration with a small cone distally and a larger cone resting on it immediately proximal (Fig. 14.13). This helped reestablish a stable tibial platform for a stemmed revision tibial tray. Next, a large femoral cone was used to achieve fixation inside the medullary portion of the distal femur and also to provide critical mechanical support for a revision femoral component at the proper level. The cavitated femoral condyles were first sculpted with a high-speed burr using a plastic femoral cone trial as a guide, in order to achieve maximum possible contact between the cone and the host bone at the time of real cone impaction (Fig. 14.14). The large femoral cone provides not only axial support but rotational stability for the femoral component by anterior-posterior capture of the femoral flange and posterior condyles of the device. After reestablishing metaphyseal support on both the tibial and femoral sides of the joint, trial components were used to balance the knee in flexion-extension and in varus-valgus. The reconstructed tibial platform provides the start-

ing point or reference, allowing changes in trial femoral component size, and proximal to distal position to effect balancing with block augments used to fine-tune contact against the host bone and cone. After efforts to achieve optimal component sizing, positioning and soft tissue balance are complete, and a decision can be made on whether an increased level of constraint is required. In these specific cases, residual medial-lateral imbalance led to the use of constrained condylar components. At the time of real component implantation, a motion-free initial interface between the porous metal cone and host bone was provided by cementation of the undersurface of the real component and stem, first on the tibial side and then on the femoral side. With this combination of both cemented and cementless zones on the same device, a synergistic fixation effect between the cone and implant it supports is achieved. Gradual bone healing into the porous cone is protective of the cement-bone interfaces of the same implant to which the cone is secured. As bone grows in, the stresses transferred to the cone-bone interface off-load stresses in the remaining implant-cement-bone interfaces over the long term.

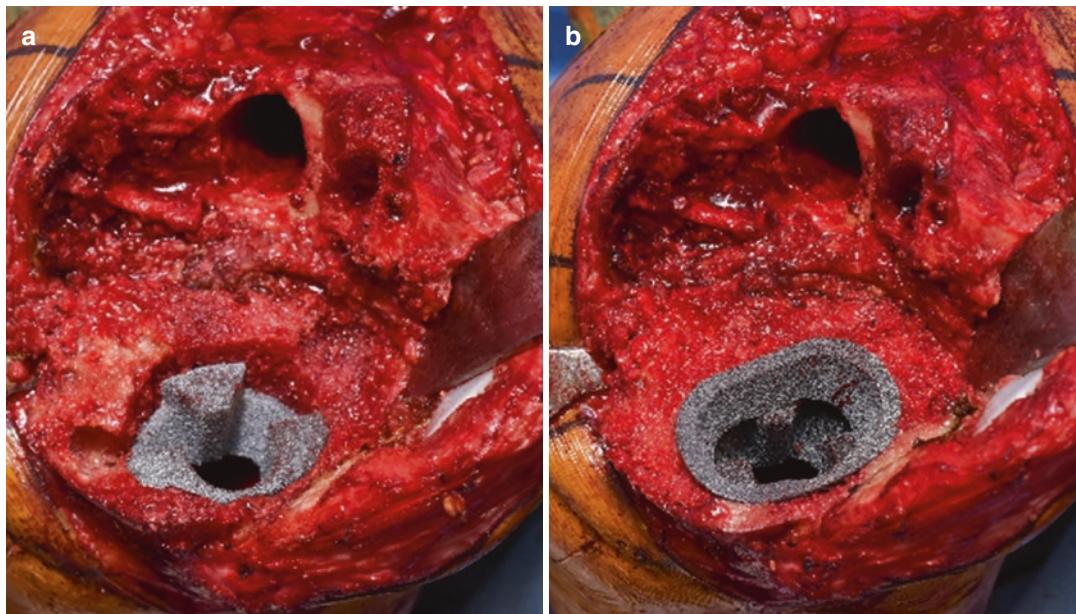


Fig. 14.13 Insertion of smaller central tibial cone distally at the junction of the diaphysis and metaphysis (**a**) and then stacking of a second larger metaphyseal cone

more proximal to best fill the large tibial cavity (**b**) and reestablish the tibial platform for support of the remainder of the reconstruction

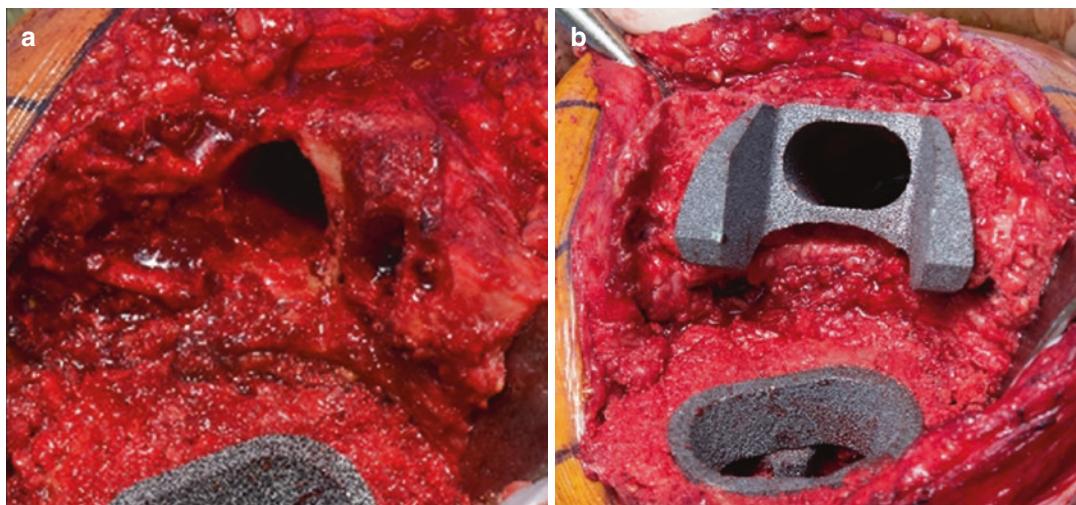


Fig. 14.14 Shaping of femoral defect with a burr (**a**) is done in iterative fashion going back and forth with burr and femoral cone trial to gradually remove bone to finally accommodate a selected “best fit” for the real femoral cone (**b**)

Postoperative Result

In this case postoperative radiographs revealed restoration of good axial alignment and initial fixation, and the knee was stable clinically (Fig. 14.15). The initial postoperative clinical course was marked by gradually increasing

motion and weight bearing, which was advanced as tolerated given the secure initial cement fixation achieved. Wound healing and recovery was uneventful, and on final follow-up, the patient reported satisfactory return to independent ambulation and no further surgery needed or other



Fig. 14.15 Postoperative x-rays showing cones in place, the knee well aligned, and secure implant fixation on both the anteroposterior (a) and lateral views (b) using short

cemented stems for initial fixation, pending bone ingrowth to the cones and resulting protective off-loading of stresses to the cement-bone interfaces

major adverse outcomes. More recently an expanded inventory of smaller diaphyseal cones has become available as an alternative to the larger sized cones used in this case. These diaphyseal cones can provide the same enhanced and synergistic cementless and cemented fixation in cases where there is central distal femoral bone deficiency but where the condyles are still largely intact, and standard larger cone use would require excessive host bone removal.

Clinical Results

The development of porous tantalum femoral cones, like the companion tibial cones, was prompted by earlier successes with porous tantalum acetabular augments used in revision hip sur-

gery [15]. Porous tantalum was used as an implant material for these revision implants because of reported improved and rapid bone ingrowth, favorable material properties, and structural strength sufficient to allow freestanding load-bearing devices [16, 17]. The acetabular augments and subsequent femoral and tibial cones were initially envisioned and subsequently used as a “prosthetic structural allograft” in order to avoid the occasional failures from graft resorption, expense, and technical challenges associated with structural allograft use. Once the usefulness of this concept was established for revision hip surgery, it rapidly led to the development of anatomically shaped alternatives for use in knee defects encountered in revision knee sur-

gery, where similar challenges with allograft use have been reported [18]. Because the anatomy of the proximal tibia and resulting tibial defects is simpler and more symmetrical, early tibial cone shapes became available first in 2002, followed soon after by the more complex right and left femoral cone shapes in 2003. Since that time increasingly anatomic versions of the cones have been made available, including the most recent small diaphyseal cones for the femur, which allow “hybrid” cementless plus cemented fixation of the femoral component in cases with less severe defects and still intact condyles but impaired bone quality and bony surfaces that might make standard cement only fixation to the distal femur unreliable over the long term.

Results of the initial porous tantalum femoral cones were equally encouraging to those seen with the slightly earlier released tibial cones, with very good clinical performance and excellent radiographic appearance without evidence of migration, loosening, or progressive lucent lines. This very good early implant performance was despite a negative bias, as the use of cones was reserved for the subset of worst revision cases with the largest and most challenging of bone defect problems, and commonly with a history of prior infection [19, 20]. Subsequent reports by other authors soon confirmed similar excellent results in the management of major femoral bone defects during revision knee arthroplasty [21–23].

Longer-term follow-up on the performance of porous tantalum cones has recently become available on larger cohorts of revision TKA patients [24, 25]. Potter et al. reported on 159 femoral cones used in 157 patients as part of a revision TKA followed for a mean of 60 months. All had relatively major bone defects with 80% classified as Type 2B and 20% Type 3 according to the Anderson Orthopaedic Research Institute (AORI) classification system [25]. Patients in this series had undergone a mean of four prior surgeries (range 1–23) of the knee, and nearly half of the patients in the series (75/157) had a history of prior infected arthroplasty and were being treated as part of a two-stage exchange of components. 23/159 required repeat revision, with infection the most common indication seen in 14, followed

by aseptic loosening in 6, and laxity in 3 cases. All six cases of aseptic loosening were in Type 3 femoral defects treated with a rotating hinge. This yielded a survivorship free of cone revision for aseptic loosening of over 96% at last follow-up and survival free of cone removal for any reason of 84%. Clinical results showed statistically significant improvement but variability in Knee Society scores from a mean of 47 preoperatively to 65 points post-surgery (range 6–94). All 134 unrevised patients showed clear evidence of osseointegration on follow-up x-rays.

These data support the potential value of the concept of combined “hybrid” cemented plus cementless fixation of an individual implant, as this technique appears to have clearly helped enhance the midterm durability of femoral fixation in the face of massive defects during revision knee arthroplasty. These midterm results with porous tantalum components have resulted in the broader adoption of this same philosophy of cementless metaphyseal support combined with partially cemented periarticular and stem fixation into a variety of porous titanium cone-like shapes and porous-coated metaphyseal sleeves for use with other knee systems. Additional data and longer-term follow-up will be needed to further validate this overall general reconstructive strategy and to determine the relative merits of the various specific materials and implant designs becoming available for use in bone defect management and enhanced fixation in revision knee arthroplasty.

Key Points

- Porous tantalum cones allow for bone ingrowth and provide a prosthetic structural allograft to support the femoral component.
- Small diaphyseal femoral cones allow for hybrid metaphyseal cementless fixation enhancing cemented periarticular and stem fixation.
- Larger femoral metaphyseal defects are managed with larger anatomically shaped tantalum cones that provide cementless metaphyseal fixation with osseointegration and a structural foundation for the revision components without the need for structural bone allograft.

Option 3: Distal Femoral Prosthesis

R. Michael Meneghini and Kirsten Jansen

Case Presentation

History

A 73-year-old woman with a history of anemia and osteoporosis presented with left knee pain and inability to bear weight secondary to a fall down stairs several days prior while vacationing out of state. Four months earlier, she underwent primary total knee arthroplasty (TKA) for osteoarthritis and expressed great satisfaction with her outcome.

Physical Examination

Her physical exam demonstrated a swollen and painful knee with valgus deformity and well healed prior surgical incision.

Radiographs and Advanced Imaging

Radiographs demonstrated a primary TKA with distal femoral periprosthetic fracture, characterized

by complete fracture and displacement of the lateral femoral condyle and valgus collapse (Fig. 14.16). Computed tomography (CT) showed severe comminuted fracture around the prosthesis; however, loosening of the femoral component was not clearly observed.

Surgical Approach

Other than mild anemia, routine laboratory investigations were unremarkable. Therefore, the patient's diagnosis was confirmed to be failed primary TKA secondary to distal femoral periprosthetic fracture. Due to the severe comminution and poor femoral bone stock, along with the patient's age, general low-demand activity level, and radiographic osteopenia, revision with additional constraint was planned.

Preoperative planning is critical in order to ensure proper leg-length restoration, which in a revision TKA for a distal femoral replacement with a hinge or proximal tibial replacement can affect the extensor mechanism tension and subsequent quadriceps muscle and knee extension strength. Restoration of the joint line and reproduction of the coronal plane anatomy ensure

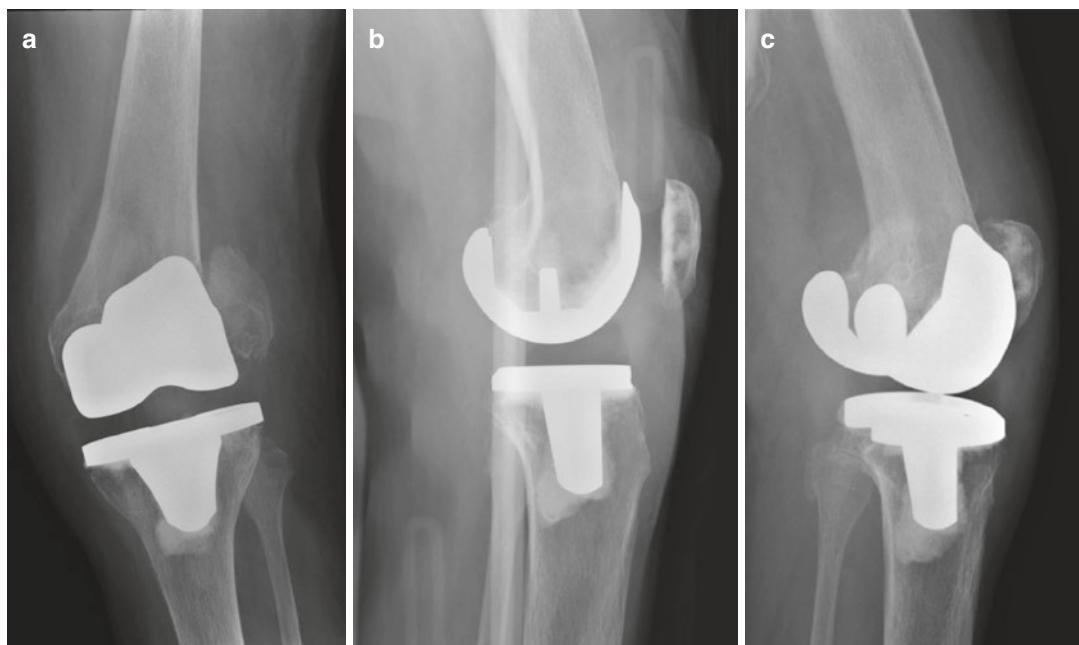


Fig. 14.16 Anteroposterior (AP) (a), lateral (b), and oblique (c) radiographs of failed primary TKA secondary to distal femoral periprosthetic fracture, characterized by

complete fracture and displacement of the lateral femoral condyle and valgus collapse

optimal extensor mechanism tension and optimize patellar function.

Depending on how proximally the incision is located, a sterile surgical tourniquet may be needed. An extended medial parapatellar arthrotomy is typically employed, and because a rotating hinge is used, the superficial MCL may be released from the proximal tibia to facilitate exposure, particularly if a proximal tibial replacement is anticipated. Familiarity with the periartricular neurovascular anatomy is required. The extensive dissection should be performed meticulously, avoiding the tendency to stray away from the bone surfaces.

Intraoperatively, the fracture was characterized by severe comminution and displacement of the lateral femoral condyle with fracture propagation transversely through the medial femoral condyle that was not seen on preoperative CT scan or x-ray. The tibial component was well fixed. Revision to a distal femoral replacement prosthesis was selected and felt to be most appropriate for the patient due to her fracture pattern, bone quality which was inadequate for internal fixation, and low-demand activity level. The distal femur was skeletonized carefully protecting all surrounding neurovascular structures. Prior to removal of the femoral component, a resection level in relation to the joint line was calculated from known implant options, and proper femoral rotation was marked on the femur. A transverse resection was completed perpendicular to the anatomic axis of the femur at the superior edge of the femoral component anterior phalange with all soft tissues protected. The tibial component was removed using conventional technique, preserving as much tibial bone as possible. The tibia and femur were prepared for cemented stem placement and trial components were placed. Various thicknesses of rotating hinge bearings were placed until gap balance and symmetry were reached. Femoral length, patellar tracking, and extensor mechanism tension were also confirmed. The trial components were removed and the final components cemented in place paying careful attention to recreating component rotation, which had been previously marked during



Fig. 14.17 Anteroposterior (AP) (a) and lateral (b) radiograph of revision total knee arthroplasty with a rotating hinge distal femoral replacement megaprosthesis. Due to the patient's lower-demand activity level, cemented stems were utilized for rapid mobilization and weight bearing

trialing with cautery (Fig. 14.17). After the final components are in place, closure is accomplished in the standard fashion along with meticulous attention to protection of the soft tissues and skin. Due to the large amount of dead space involved with these procedures, the authors prefer to use topical tranexamic acid prior to closure and leave an intra-articular drain until postoperative day number 2.

Postoperative Result

Full weight bearing with assistance was allowed immediately. At her 8-week follow-up, the patient had nearly resumed her previous level of activity. Range of motion was measured as full extension with flexion of 120°. There were no signs of infection around the knee and cultures obtained intraoperatively were negative.

Clinical Results

Undertaking prosthetic knee revision in cases of poor surrounding bone quality or significant bone loss is often a complicated task. In rare cases of severe femoral or tibial bone loss, salvage reconstruction with a megaprosthesis to replace the deficient bone may be optimal due to the inadequate native bone support or incompetent ligamentous attachments necessary for traditional revision TKA. This also applies to instances of periprosthetic fracture in which the short segment of distal femoral or proximal tibial bone stock is inadequate for internal fixation. Although initial designs were linked to early failures, presumably due to the increased bearing constraint transmitting forces to the prosthesis-bone interface, modern rotating hinge designs (see Fig. 14.17) have demonstrated improved outcomes and clinical results [26–34]. The use of a rotating hinge device for distal femoral replacement is indicated only for the most severe cases of bone loss in elderly patients and those with lower activity demands.

The need for a distal femoral replacement is determined by the proximal femoral extent of bone loss. If the bone loss encompasses the medial epicondyle, the medial collateral ligament (MCL) is likely to be incompetent, necessitating a greater level of varus-valgus constraint in the form of a rotating hinge bearing. Because of the space required for the hinge articulation and bearing, significant bone removal is required. This approach may be optimal in situations with catastrophic bone loss, as in cases of chronic infection, severe osteolysis, or severe osteopenia with distal periprosthetic femur fractures. For advanced-age or lower-demand patients, prosthetic replacement of the bone loss may be advantageous in order to facilitate mobilization, avoid prolonged periods of restricted weight bearing, and circumvent the unpredictable union rates associated with bulk allograft.

The clinical results of rotating hinge distal femoral replacements have been satisfactory for salvage of the most severe bone deficiencies and complex revision TKAs [26–34]. Springer and colleagues described 26 knees that were treated at

the Mayo Clinic with arthroplasty using a segmental, kinematic, modular rotating hinge total knee prosthesis for nonneoplastic limb salvage [30]. The indications included nonunion of a periprosthetic femur fracture, severe bone loss and ligamentous instability, nonunion of a supracondylar femur fracture, acute periprosthetic fracture, fracture of a previous hinge, and prior resection arthroplasty. The average age of the patients was 72.3 years and the average follow-up was 58.5 months. Most patients had improvements in functional scores and motion. Eight patients had complications; the most common was deep infection which occurred in five patients [30].

Barrack reported a series of 23 revision TKAs using a second-generation rotating hinge component [32]. Indications for surgery included MCL disruption, revision of a previous hinged component with massive bone loss, comminuted distal femur fracture or distal femoral nonunion in elderly patients, extensor mechanism disruption requiring reconstruction in an unstable knee, and ankylosis requiring femoral peel exposure with a moderate residual flexion-extension gap imbalance. At the 2- to 9-year follow-up, the clinical results, range of motion, and satisfaction scores were comparable with those of a standard condylar revision knee arthroplasty, despite the fact that the cases were more complex [32].

Berend and Lombardi reported the results of 39 knees in elderly patients, with an average age of 76 years, treated with a rotating hinge distal femoral replacement [29]. Surgical indications were revision with severe bone loss or ligamentous instability, failed non-modular hinge, nonunion of the distal femur, prior resection arthroplasty, periprosthetic fracture, acute femur fracture, and complex primary TKA. At the 24- to 109-month follow-up, there were five reoperations, no cases of aseptic loosening, and excellent pain relief and functional improvements [29].

Several studies have been published specifically addressing the use of rotating hinge distal femoral replacement for treatment of periprosthetic fractures with bone loss. Mortazavi described 22 knees with an average of 58.6-month follow-up [28]. Although there were ten

postoperative complications, five requiring additional surgery, Knee Society scores were promising [28]. Jassim evaluated outcomes of 11 elderly patients, with average age of 81 years, at 4- to 72-month follow-up and reported no cases of reoperation and acceptable functional outcomes [27]. Saidi compared three different methods for treating comminuted distal periprosthetic femur fractures in 23 patients, over the age of 70 [26]. Seven received allograft-prosthetic composites, nine standard revision TKAs with augments, and seven distal femoral replacements. Operative time and blood loss were significantly less with the revision TKA and distal femoral replacement cases. Hospital stay was less with distal femoral replacements, and functional scores were equal at 6-week and 6-month follow-ups [26]. In a recent study, Hart and coauthors compared ORIF and distal femoral replacement for comminuted distal femoral fractures in elderly patients 70 years or older [35]. The authors reported that one in four patients who underwent ORIF was wheelchair bound, while all patients who underwent a distal femoral replacement were ambulatory at 1-year follow-up [35]. All authors supported the use of distal femoral replacement in complex periprosthetic fractures with a loss of bone stock [35].

Studies show that the use of megaprostheses in the form of a distal femoral or proximal tibial replacement can be suitable in certain clinical situations, such as severe metaphyseal bone loss and comminuted or periprosthetic femur fractures in patients with lower activity demands. These procedures can yield satisfactory clinical results in properly selected patients.

Key Points

- Consider a distal femoral prosthetic replacement for:
 - Severe femoral bone loss.
 - Bone loss with incompetent ligamentous attachments.
 - Distal femoral fracture with inadequate bone for internal fixation of the distal fragment
- Allow for proper leg-length, femoral rotation, and extensor mechanism tension with the prosthetic replacement.

- Distal femoral replacement in the proper setting saves loss and operative time especially in the elderly patient.

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Fred D. Cushner, Stephen Petis, Michael Taunton,
Arlen Hanssen, Michael D. Ries, Kelly G. Vince,
and Michel Malo

Introduction

Fred D. Cushner

It is well known that patella resurfacing has its limits. Severe patella bone loss can occur in the primary knee where significant patella bone loss can make it difficult to perform a patella resurfacing. While the ultimate limit as to the smallest amount of residual bone will allow a patella resurfacing to be performed, it is commonly believed

that at least 12 mm is needed to avoid complications of resurfacing.

So in the setting of significant patella bone loss, several options do exist. The first is to perform a resection arthroplasty. If a patella bone stock is not sufficient, the osteophytes can be removed and the residual patella contoured with no prosthesis placed. This can also occur in the revision setting. Once the patella prosthesis and residual cement are removed, it is possible to have insufficient bone stock for resurfacing. Pagnano reviewed resection patella arthroplasty in the revision setting and found significant pain and quad weakness in the resected group. Parvizi found similar results with poor results found in significant unsurfaced patients.

Therefore, complications can be avoided if indeed a patella can be resurfaced. One option is in the patella prosthesis selection. Bourne and associates describe the use of a biconcave patella design. The boney bed is prepared and a prosthesis with two domed surfaces is cemented into place. According to their study, 97% survivorship was seen in these patients. Another option is to utilize a tantalum patella. Once again the boney residual bed is prepared and the tantalum side of the patella is sutured into place on top of the residual bone. Once in position, a polyethylene prosthesis can be cemented into place. The key with the use of this design is that residual bone must be in place. Ries describes his initial experience and found a high failure rate when this

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design was sutured into the soft tissue with no boney residual bed.

Vince describes a unique technique to dealing with significant patella bone loss, the gullwing osteotomy. Named after the classic Mercedes sports car design, a vertical split is made in the residual patella bone, and the “wings” of the patella are then allowed to raise up and conform to the trochlea design. Hartzband and associates describe their initial results in 12 patients and good results were noted.

One last option is the patella bone grafting procedure made popular by Hanssen. This technique utilizes a soft tissue envelope sutured around the residual patella bone in a circumferential fashion. Local soft tissue can be used or graft material is another option. Once the envelope is created, autologous bone chips are then placed and patella bulk is recreated. Hanssen describes his results with an average postoperative patella thickness of 22 mm achieved. Hanssen has gone back and resurfaced some of these patellae and was able to place a patella prosthesis once the bone grafting had healed.

Certainly the best treatment is prevention. So in a revision setting, if the patella is stable and of proper thickness, it should be retained if at all possible.

Option 1: Patellar Bone Grafting

Stephen Petis, Michael Taunton, and Arlen Hanssen

History

An 81-year-old male was referred to our clinic 2.5 years following an uncomplicated posterior stabilized left total knee arthroplasty (TKA) with a resurfaced patella. He complained of progressively worsening anterior knee pain, which was exacerbated by ascending and descending stairs. The pain started to gradually worsen approximately 1 year after the index procedure. He noticed worsening quadriceps weakness, which

manifested as knee instability. He was an avid cyclist and was finding it difficult to pedal, particularly with increasing knee flexion through each cycle. He denied any ipsilateral lumbar spine or hip discomfort. He did not disclose nighttime pain or constitutional symptoms. The patient had undergone a course of physical therapy with no improvement in his symptoms. He was taking oral analgesics in order to perform daily activities.

The differential diagnosis of anterior knee pain following TKA is extensive (Table 15.1). Revision surgery for patellofemoral complications was very common several decades ago [1]. This was largely due to mechanical failure and polyethylene wear of metal-backed patellar designs, as well as differences in femoral component trochlear design [2]. With contemporary surgical techniques and implant designs, revision surgery for patella-related complications has decreased [3, 4]. However, as part of the patient’s history, it is critical to review previous operative reports to determine the methods used to set component rotation and alignment, as well as techniques used for patellar preparation, as patellar maltracking, component loosening, and over-resection can contribute to bone loss following TKA [5–7]. Treating patellar bone loss during TKA revision surgery is relatively uncommon, and there remains a lack of consensus on management [8, 9].

Table 15.1 Differential diagnosis of anterior knee pain following total knee arthroplasty

Aseptic loosening of a resurfaced patella
Extensive bone loss and osteolysis of patellar component
Component malrotation and patellar maltracking
Periprosthetic patella fracture
Avascular necrosis of the patella
Wear of patellar polyethylene
Patellofemoral clunk syndrome
Overstuffing the patellofemoral joint
Lateral facet impingement
Patellofemoral arthritis with non-resurfaced patella
Quadriceps or patellar tendinitis
Patellofemoral instability/dislocation
Periprosthetic joint infection

Physical Examination

The patient had a well-healed midline incision free of any signs of infection. He stood with a neutral, mechanically aligned knee. He had an antalgic gait, particularly during the early phases of stance. He had pain to palpation along the lateral border of the patella. Pain was also elicited with patellofemoral compression testing. Active and passive knee range of motion was from 10° of extension to 115° of flexion. The patella did track slightly lateral of midline beyond 30° of knee flexion. The patient was able to perform a straight leg raise without difficulty. Quadriceps muscle strength was graded as 4/5 based on the Medical Research Council grading system. There was no evidence of coronal or sagittal plane instability. Hip range of motion was pain-free. His neurovascular examination was normal.

A detailed clinical exam can help determine deficiencies and abnormal mechanics caused by a failed patellar component. Point tenderness can suggest fragmentation secondary to avascular necrosis, periprosthetic fracture, aseptic loosening, or facet impingement from lateral tilt. Patellar maltracking is usually a consequence of malrotated components. Quadriceps weakness may be secondary to poor restoration of retropatellar offset. Overstuffing the patellofemoral joint can cause reduced flexion range of motion [10]. This can also lead to increased contact pressure, which may accelerate polyethylene wear and increase the risk of aseptic loosening [11].

Radiographs and Advanced Imaging

Plain radiographs of the knee revealed a radiolucent line around the cement-bone interface of the patellar component. There was excessive medialization of the patellar button and erosion of the lateral patellar facet. There was minimal patellar bone stock due to over-resection and osteolysis from component loosening. The femoral and tibial components were well-fixed (Fig. 15.1). Inflammatory biomarkers were not suggestive of infection.

Surgical Approach

The patient was in the supine position under general anesthesia. We examined the knee under anesthesia to confirm preoperative range of motion, as well as coronal and sagittal plane stability. A tourniquet was applied and inflated only for the duration of component cementation.

The previous surgical incision was used. A standard medial parapatellar arthrotomy was performed. The previous polyethylene patellar component was loose and easily extracted from the retropatellar surface. We noted that there was excessive medialization of the patellar component, such that one of the patellar lugs was not seated in the bone.

We critically assessed the position of the femoral and tibial components. There was evidence of internal rotation of both components (Fig. 15.2). On that basis, we elected to revise the entire total knee. We minimized our distal femoral resection to avoid elevating the joint line, thereby avoiding alterations in patellofemoral mechanics [12]. We added a posterolateral augment to the femoral component to ensure adequate external rotation. Patellar tracking was excellent with trial implants *in situ*.

Our attention turned to the patellar bone grafting. The retropatellar surface was debrided of retained cement, and sclerotic bone was burred to expose a bleeding bone bed. We measured the maximum thickness of the remaining patellar bone stock at 6 mm. The peripatellar and suprapatellar tissue was assessed for autologous tissue to create a flap to contain the patellar bone graft. This tissue was of poor quality, leading to a decision to use tensor fascia allograft to create our tissue flap. The allograft was secured to the surrounding peripatellar and retinacular tissue using several interrupted non-resorbable sutures (Fig. 15.3). A small window in the allograft tissue flap allowed for insertion and impaction of allograft cancellous bone chips (Figs. 15.4 and 15.5). We recommend restoring the patellar thickness to at least 20 mm, as this can improve patellofemoral contact pressures, reduce painful patellofemoral crepitus, optimize

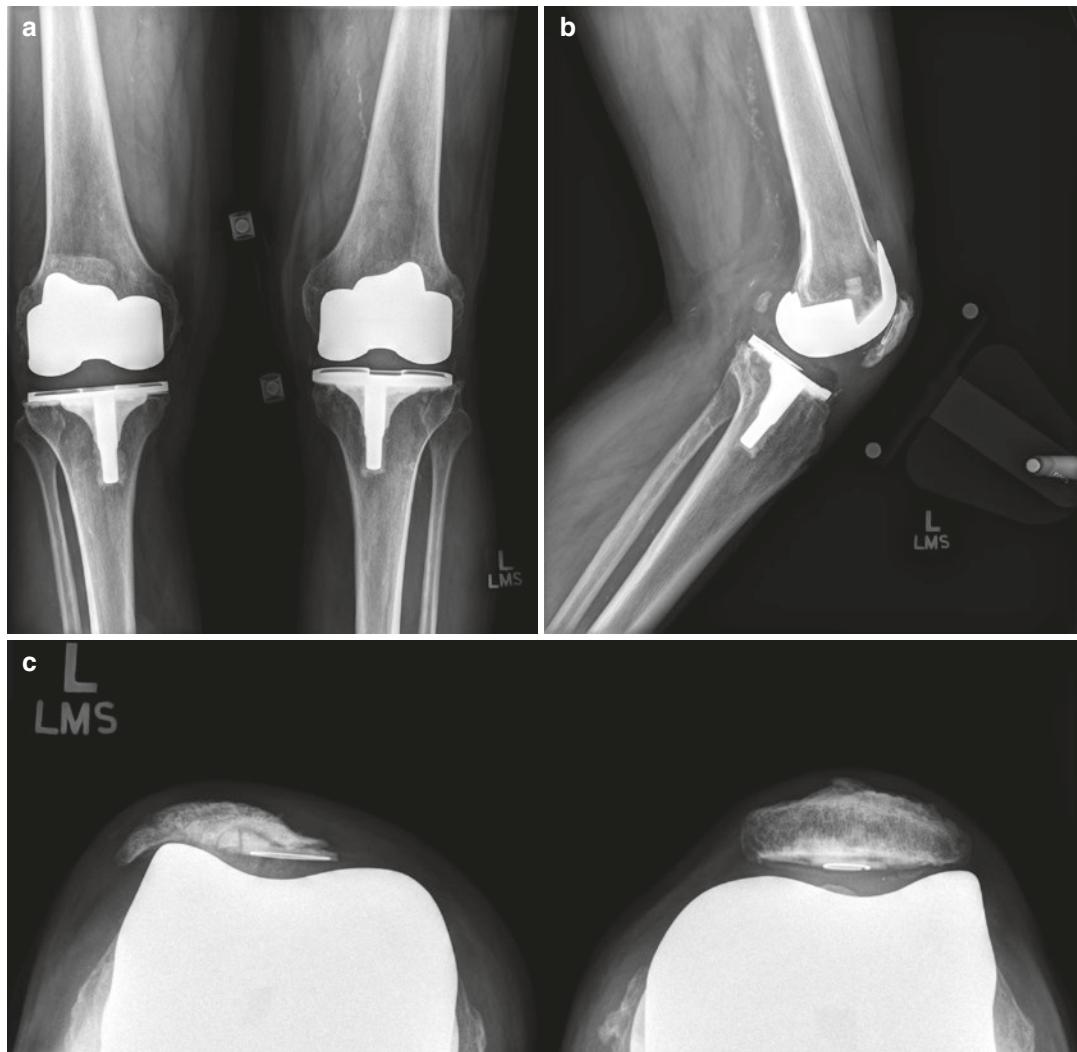


Fig. 15.1 Preoperative series of knee radiographs. (a) Anteroposterior (AP) radiograph demonstrating well-fitted femoral and tibial components. (b) Lateral radiograph demonstrating minimal residual patellar bone with

a radiolucency between the cement and bone interface. (c) Skyline radiograph with medialization of the patellar button, lateral facet erosion, and re-demonstration of the cement-bone radiolucency

the quadriceps lever arm, and account for patellar bone graft resorption that may occur over time [8, 13, 14].

The knee range of motion was reexamined to ensure appropriate patellofemoral tracking. Range of motion was from 0° of extension to 120° of flexion. The definitive implants were cemented, ensuring to match the rotation of the trial components. Postoperatively, the patient was permitted to weight-bearing as tolerated and perform range of motion as tolerated.

Postoperative Result

Postoperatively, radiographs demonstrated excellent reconstitution of retropatellar offset (Fig. 15.6). The patella was also seated centrally within the femoral trochlea. Knee range of motion improved to 0° of extension to 120° of flexion. The patella tracked nicely within the femoral trochlea throughout knee range of motion. The patient did not disclose any anterior knee pain at late follow-up.



Fig. 15.2 Intraoperative photograph showing internal rotation of the femoral component. Note the asymmetric position of the posterior-stabilizing post within the femoral box



Fig. 15.4 Intraoperative photograph showing insertion of cancellous bone graft through the medial window under the tensor fascia allograft



Fig. 15.5 Intraoperative photograph with the tissue flap secured after bone graft impaction with the final components inserted



Fig. 15.3 Intraoperative photograph of the tensor fascia allograft secured to the surrounding peripatellar soft tissue with multiple interrupted sutures. A medial window in the tissue flap remains for insertion of bone graft

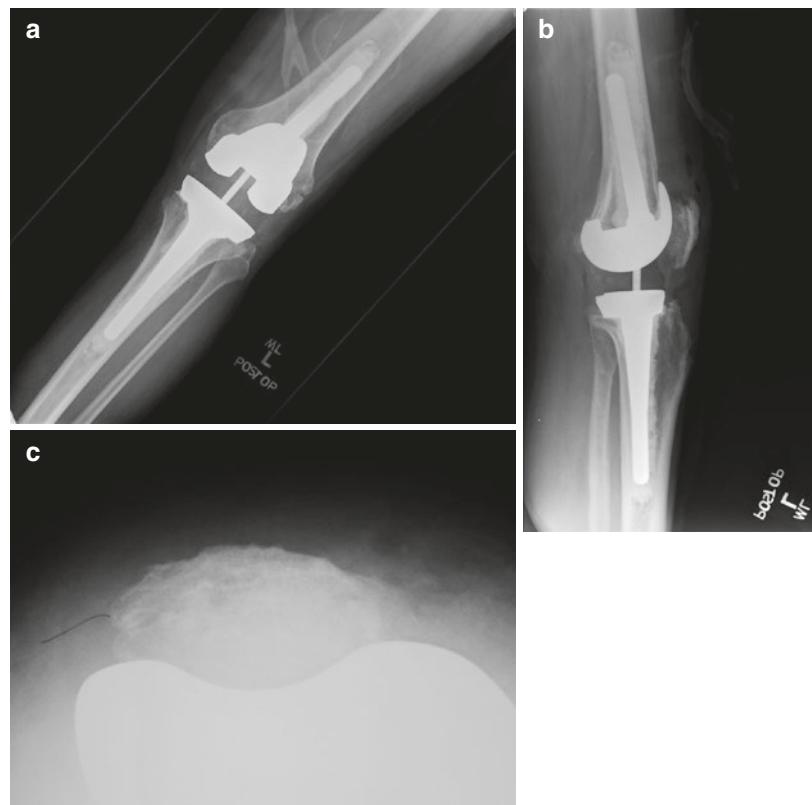
Clinical Results

Patellar bone loss following TKA is a relatively rare scenario, where few successful reconstruction or salvage options exist. Treatment options include retaining the current patellar component, total or

partial patellectomy, patelloplasty, allograft reconstruction, gullwing osteotomy, tantalum metal-backed reconstruction, and patellar bone grafting.

Hanssen outlined the surgical technique and clinical results of patellar bone grafting in nine patients following revision TKA. This technique is a variation of a historical procedure described by Cave and Rowe, where the infrapatellar fat pad was sewn and interposed between the patella and femoral trochlea as an interpositional arthroplasty [15]. The etiology for patellar bone grafting at the time of revision included four cases of aseptic loosening, four cases of polyethylene wear with a metal-backed patellar implant, and one malpositioned patellar button. The tissue flap used to contain the bone graft was harvested from peripatellar scar tissue (four knees), the suprapatellar pouch (two knees), or fascia lata

Fig. 15.6 Immediate postoperative knee radiographs. (a) Anteroposterior (AP) and (b) lateral and (c) skyline radiographs demonstrating revised femoral and tibial components, with reconstitution of patellar thickness



(four knees) from the lateral aspect of the knee joint. This tissue is carefully sewn to surrounding peripatellar and retinacular tissue, leaving a small flap to insert and impact bone graft, attempting to reconstitute retropatellar offset of at least 20 mm. Mean follow-up in this series was 36.7 months. Knee Society pain and function scores increased from 39 to 91 and 40 to 84 points, respectively. Knee range of motion improved from 6.7° to 1.1° of terminal extension and from 82.8° to 98.9° of flexion. The patellar bone graft will resorb with time, as patellar height decreased from 22 mm immediately postoperatively to 19 mm at the latest follow-up. This resorption may be a consequence of devascularization of the graft, heterogeneity in femoral trochlear designs and patellar contact, and malrotation of the components leading to patellar maltracking [8].

There have been few other series on the clinical and radiographic outcomes following patellar bone grafting for severe patellar bone loss. Buechel reported on five failed TKAs that had

patellar bone grafting for previous partial or complete patellectomies. In this series, the autograft bone was placed in a sling of subsynovial tissue from the patellar tendon. At late follow-up, four of the five knees reported good or excellent results. Radiographic bone resorption occurred in three of the five cases.

More recently, Boettner and Monsef reported good clinical results in three failed TKAs using Achilles tendon allograft to reinforce the extensor mechanism. The tendon allograft also served to contain the bone graft placed on the retropatellar surface. The principles of patellar preparation were comparable to that outlined by Hanssen. They reported an improvement in the Western Ontario and McMaster University knee scores from 53 to 88.5 with no complications at late follow-up [16].

Patellar bone grafting at the time of revision TKA is rare. Patellar component wear, loosening, and osteolysis secondary to component design, patellar maltracking, and technical errors can

lead to significant bone loss requiring revision. There are few reports on the success of patellar bone grafting. However, early clinical and radiographic results are encouraging.

Key Points

- The differential diagnosis for anterior knee pain is extensive. Narrowing the diagnosis requires careful history taking, a concise physical examination, and critical evaluation of perioperative imaging.
- Operative reports should be analyzed for technical errors and implant selection, which may predispose the patellar component to mechanical failure.
- Patellar bone grafting requires careful preparation of the remaining bone stock to optimize incorporation of the graft.
- Native soft tissue around the knee can be used to contain the patellar bone graft. If this tissue is of poor quality, allograft tissue augmentation is recommended.
- The femoral and tibial components should be revised if there is any evidence of patellar maltracking, as this may accelerate bone resorption and lateral subluxation of the patellofemoral joint.

Option 2: Patellar Augments

Michael D. Ries

Case Presentations

Case Report #1: Greater Than 50% Bone Coverage of the TM Implant

History

An active 72-year-old man developed bilateral anterior knee pain 12 years after prior bilateral TKA. After his TKAs, he was active and was able to hike steep inclines and mountains. However, over the past year, he experienced pain and catching sensations in both knees. The symptoms occurred during walking or getting up from

a seated position. He had not been able to hike on any incline for the past 6 months. The pain was relieved to some extent with ibuprofen, but did not allow him to carry out all routine functional activities on a daily basis. His goal was not only to resume routine activities but also to return to hiking mountains. He did not experience giving-way episodes or have any history of falling.

He presented with range of motion in both knees from 0° to 120°. A zero degree extensor lag was present bilaterally. However, he experienced pain during active knee extension. Palpable and audible crepitus was present in both knees during knee flexion. Tenderness was present anteriorly along the medial and lateral patellar soft tissues bilaterally, but there was no tibiofemoral tenderness. Mild mediolateral laxity was present in flexion, but both knees were stable in extension.

Radiographs and Advanced Imaging

AP (Fig. 15.7a) and lateral radiographs (Fig. 15.7b, c) demonstrated bilateral cruciate retaining TKAs with patellar component loosening and patellar bone loss. Patellar views (Fig. 15.7d) demonstrated considerable patellar fragmentation.

Surgical Approach

The patella is a sesamoid bone in which approximately one-third of the bone is removed during a primary TKA with patellar resurfacing. Most patellae have a thickness of approximately 21–26 mm (18–27 mm in females, 20–30 mm in males) [17]. A typical resurfacing patellar component is 9 mm thick. After making a transverse bone cut for patellar resurfacing, the thickness of the remaining patella is reduced to 12–17 mm to maintain a composite height of 21–26 mm (Fig. 15.8a, b).

Failure of a resurfaced patella may occur due to multiple causes including mechanical loosening, wear, infection, and other etiologies. If failure occurs, resulting in bone loss to the level of the patellar pegs, a relatively large cavitary bone defect can result with loss of cancellous bone (Fig. 15.8c, d). Re-revision with a cemented component may not be feasible. The Trabecular Metal (TM) patellar component (Zimmer,

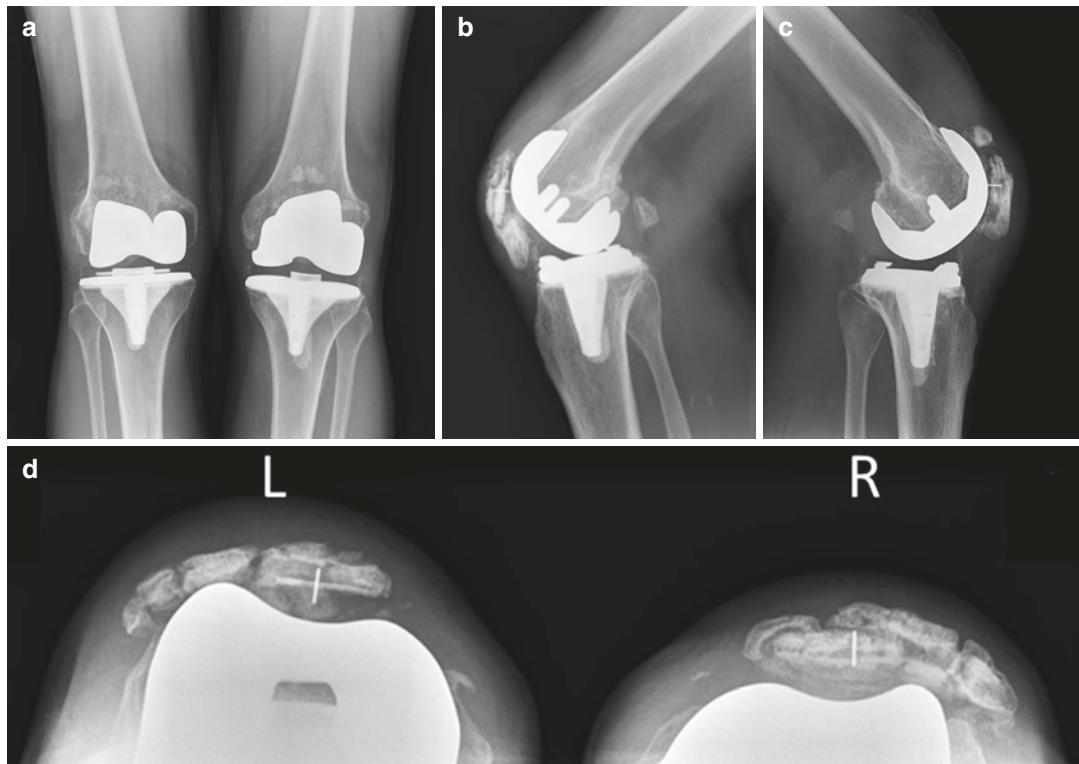


Fig. 15.7 (a) Anteroposterior (AP) radiograph of both knees demonstrates well-aligned CR TKAs. (b) Lateral view of the right knee demonstrates patellar component loosening and patella infera. (c) Lateral view of the left

knee demonstrates patellar component loosening and patella infera. (d) Patellar radiographs of the left (L) and right (R) knees demonstrate bilateral periprosthetic patellar fractures

Warsaw, IN, USA) provides a cementless fixation option for patellar revision associated with substantial patellar bone loss, based on the successful ingrowth capabilities of TM acetabular augments used in revision total hip arthroplasty and tibial and femoral TM cones used in revision total knee arthroplasty [18, 19]. Animal studies have also indicated that soft tissue can adhere directly to TM suggesting that tendon and muscle attachment directly to the TM surface may be possible [20].

The TM patellar component consists of a two-part tantalum patellar implant and UHMWPE bearing surface (Fig. 15.9). The curved cementless surface of the metal implant is fixed to the remaining native patella with sutures placed through drill holes around the periphery of the patella (Fig. 15.10a). The ultra-high-molecular-

weight polyethylene (UHMWPE) component is then cemented to the metal component (Fig. 15.10b).

The patient was treated with bilateral tibial insert exchange and patellar revision to TM patellar components. A medial parapatellar arthrotomy was used. At the time of surgery, both extensor mechanism soft tissue sleeves were in continuity despite the patellar fragmentation. The patellar components were loose and removed. Loose cement debris, devascularized patellar bone fragments, and synovium were debrided. The tibial inserts were exchanged and new cruciate retaining inserts 2 mm larger than the previously implanted inserts secured into the tibial baseplates.

The remaining patellar bone surfaces were prepared with conical reamers to provide a

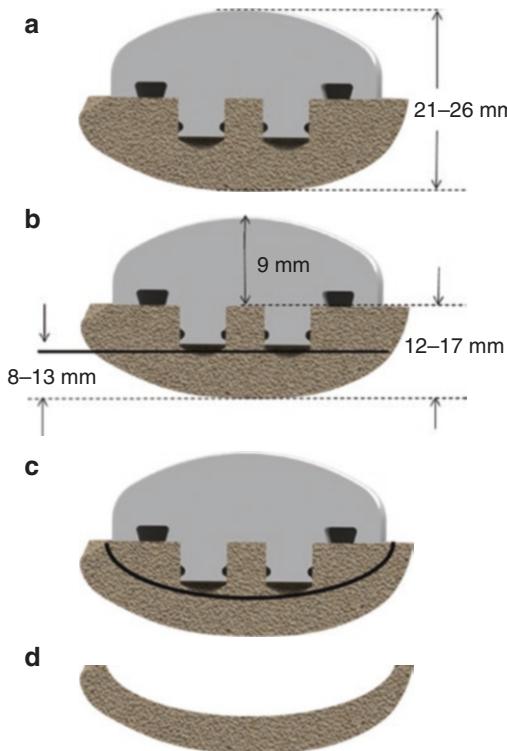


Fig. 15.8 (a) Transverse section after patellar resurfacing showing the location of the bone cut and patellar component. The composite thickness of the patella and resurfacing implant should equal the native anatomic patellar thickness, which is usually between 21 and 26 mm. (b) To achieve a composite thickness of 21–26 mm with a 9 mm thick patellar component, the thickness of the remaining patella should be 12–17 mm. For 3 mm deep pegs with 1 mm of cement, the patellar bone thickness under the pegs is approximately 8–13 mm. (c) Bone loss to the level below the pegs (black line) can result from infection, osteolysis, or loosening and cause a large cavitary defect. (d) Illustration of the remaining patellar bone stock after bone loss to a level below the pegs. Re-revision with a cemented component is usually not possible since the cancellous bone stock has been lost

smooth curved shape to fit the TM patellar components into (Fig. 15.11a–c). The TM patellar component is held in place with a towel clip and each of the peripheral holes drilled with a smooth K-wire. The TM metal component is then sutured into the extensor mechanism using #2 FiberWire sutures followed by cementing the UHMWPE implant onto the TM baseplates (Fig. 15.11d, e).



Fig. 15.9 The Trabecular Metal (TM) patellar component consists of a cementless TM baseplate and an ultra-high-molecular-weight polyethylene (UHMWPE) bearing surface

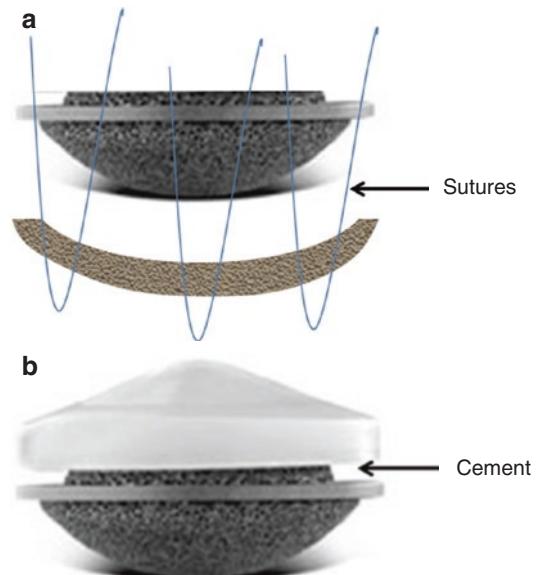


Fig. 15.10 (a) The interior of the patella is reamed to a smooth surface and the Trabecular Metal (TM) component fixed with sutures placed through drill holes in the periphery of the patella. Sutures are tied over the metal baseplate rather than the anterior surface of the patella to minimize soft tissue irritation from subcutaneous suture knots. (b) The ultra-high-molecular-weight polyethylene (UHMWPE) bearing surface is cemented onto the TM patellar baseplate

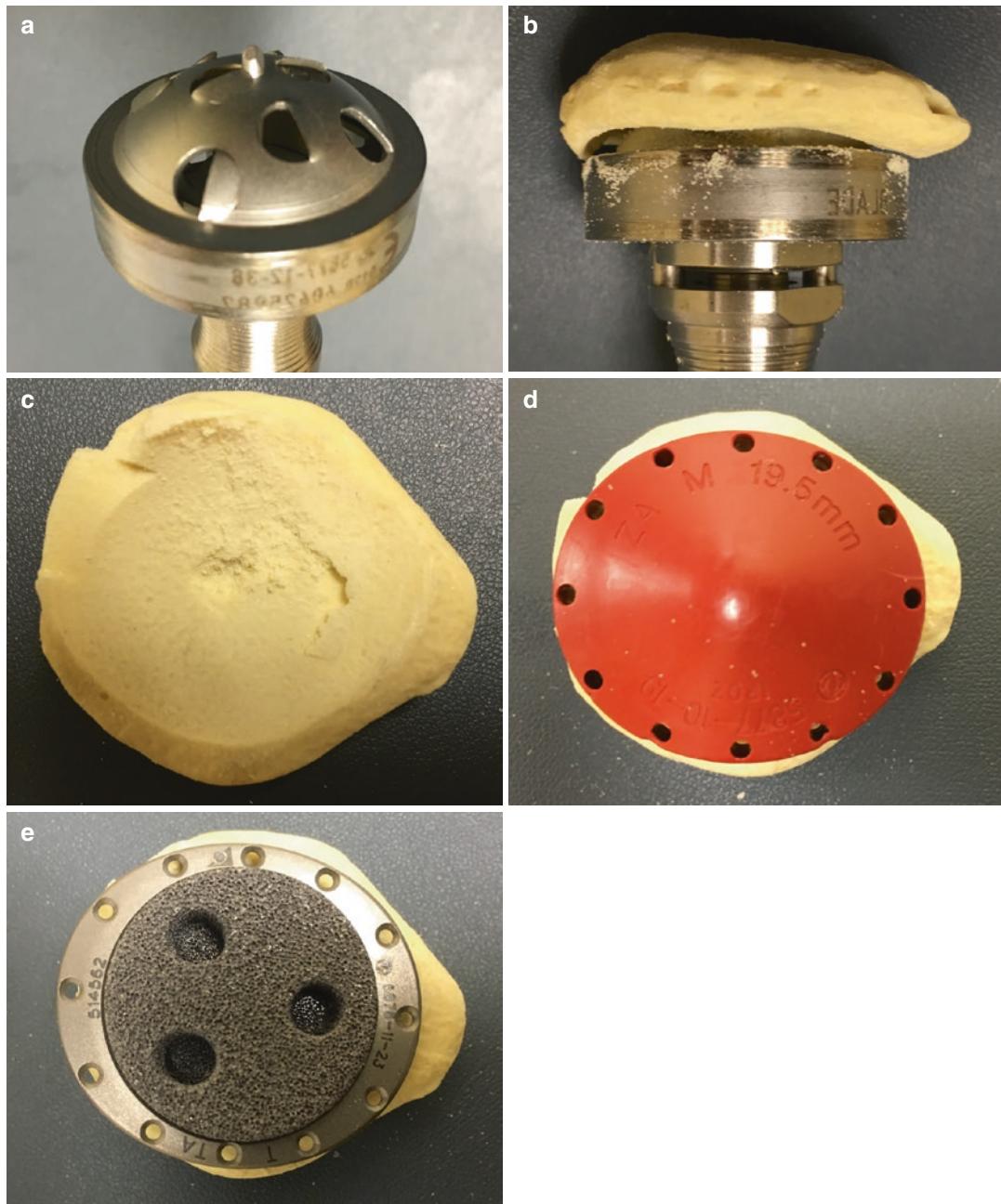


Fig. 15.11 (a) A conical-shaped cheese grater-type reamer, similar to acetabular reamers used in total hip arthroplasty, is used to prepare the interior of the remaining patellar bone. (b) The reamer (shown with a Sawbones patella) prepares a conical shape in the patella to fit with the Trabecular Metal (TM) patellar component. (c) A direct view into the reamed patella shows that the interior of the dome and periphery has been reserved providing complete bone coverage for the TM implant. The inferior pole of the patella (patellar nose) is shown to the right and

proximal pole to the left. (d) A patellar trial is fit into the remaining patella which shows the size and orientation of the implant and location of peripheral holes used for suture fixation of the implant. (e) The TM implant is fit into the reamed patellar host bone. Peripheral holes are drilled through the host patella and, then, sutures are placed through the TM implant and the patella for fixation. Sutures are tied over the TM implant rather than the anterior surface of the patella to minimize soft tissue irritation

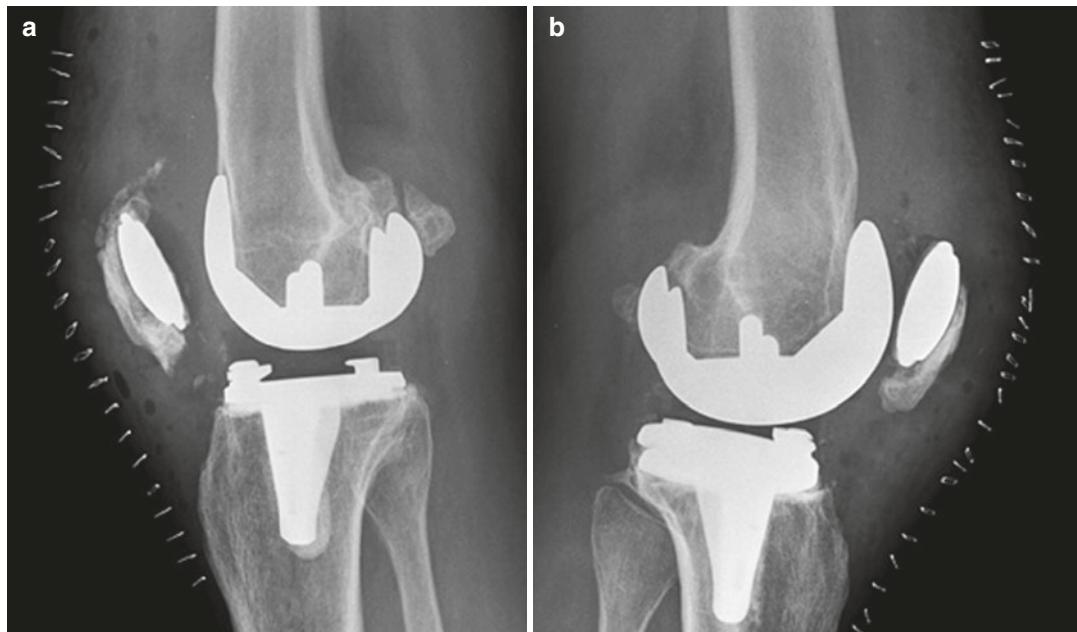


Fig. 15.12 (a) Lateral immediate postoperative radiograph of the right knee demonstrates bony coverage over nearly the entire surface of the Trabecular Metal (TM) patellar component. (b) Lateral immediate postoperative

radiograph of the left knee demonstrates bony coverage over approximately two-thirds of the TM patellar component

Postoperative Result

Postoperative radiographs demonstrated that nearly all of the TM patellar ingrowth surface of the right knee and approximately two-thirds of the surface of the left knee were covered with viable patellar host bone (Fig. 15.12). After surgery weight-bearing as tolerated activity was permitted and knee flexion was restricted to 90° in a hinged knee brace. Isometric quadriceps strengthening exercises were also permitted, but resistance strengthening avoided for 6 weeks. Six weeks after surgery, unrestricted activity and exercise were started.

Clinical Result

Six months after surgery, the patient was able to flex both knees 0–125° and had normal quadriceps strength. Nine months after surgery, he resumed mountain climbing (Fig. 15.13). Ten years after surgery, the patient has normal quadriceps strength, no knee pain, and 0–125° of motion in both knees. He no longer climbs mountains as a result of back and hip problems, but remains independent in all other activities. Radiographs demonstrate stable position of the TM patellar components (Fig. 15.14).



Fig. 15.13 Nine months after surgery, the patient climbed a 12,000 ft mountain without use of assistance devices

Case Report #2: Prior Patellectomy, No Patellar Bone Stock

History

A 52-year-old male developed posttraumatic arthritis of the right knee following multiple ligament reconstructions and patellectomy. He underwent primary TKA but experienced symptoms of

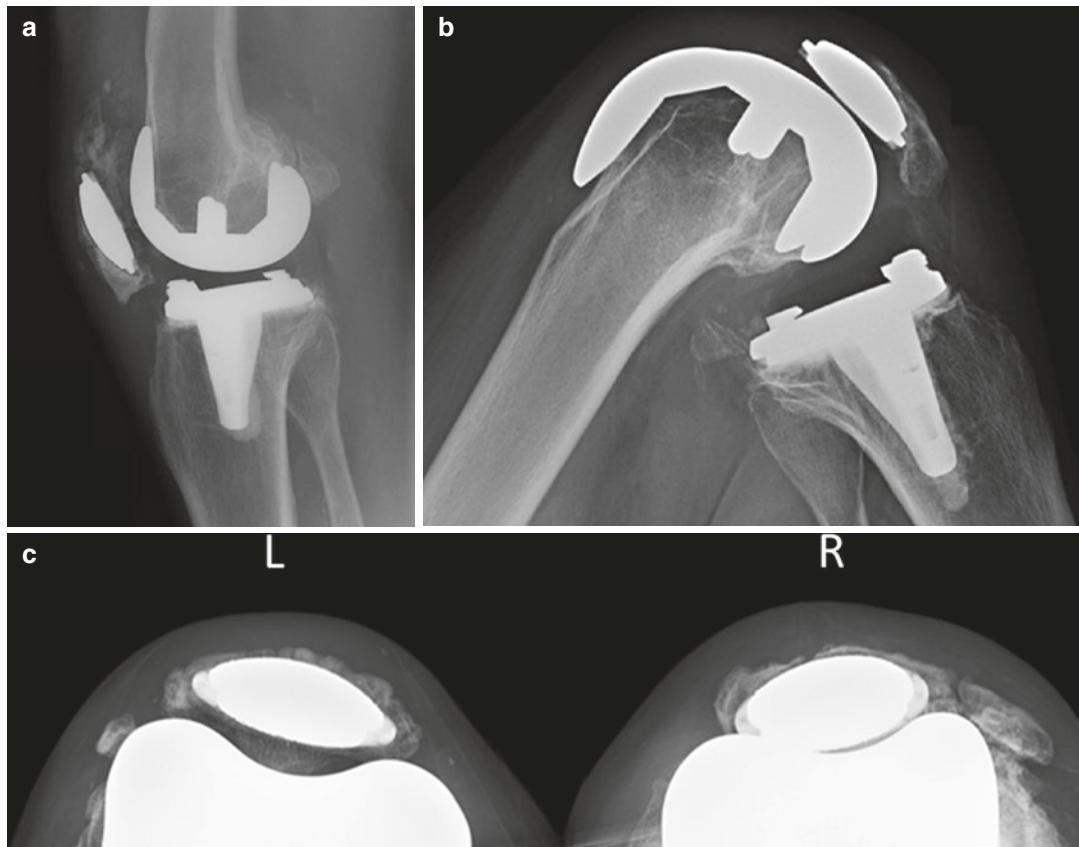


Fig. 15.14 (a) Lateral radiograph of the right knee 10 years after surgery demonstrates resorption of the bone over the proximal one-third of the Trabecular Metal (TM) surface but stable position of the patellar component. (b)

Ten-year postoperative lateral view of the left knee demonstrates preservation of bone stock over 50 percent of the TM surface. (c) Patellar views 10 years after surgery demonstrate a thin cover of the bone over both TM implants

giving way and falling which were attributed to flexion instability. He then was treated with revision to semi-constrained stemmed components. However, he complained of persistent anterior knee pain and giving-way episodes when descending stairs or inclines.

Multiple scars were present over the knee. Quadriceps strength was diminished in comparison to the contralateral knee, but the patient did not have an extensor lag. Active and passive knee motion was 0–110°. The knee was stable to varus and valgus stress testing in both flexion and extension.

Radiographs and Advanced Imaging

Radiographs demonstrated stemmed revision components in good position and a small patellar bone fragment (Fig. 15.15a, b).

Surgical Approach

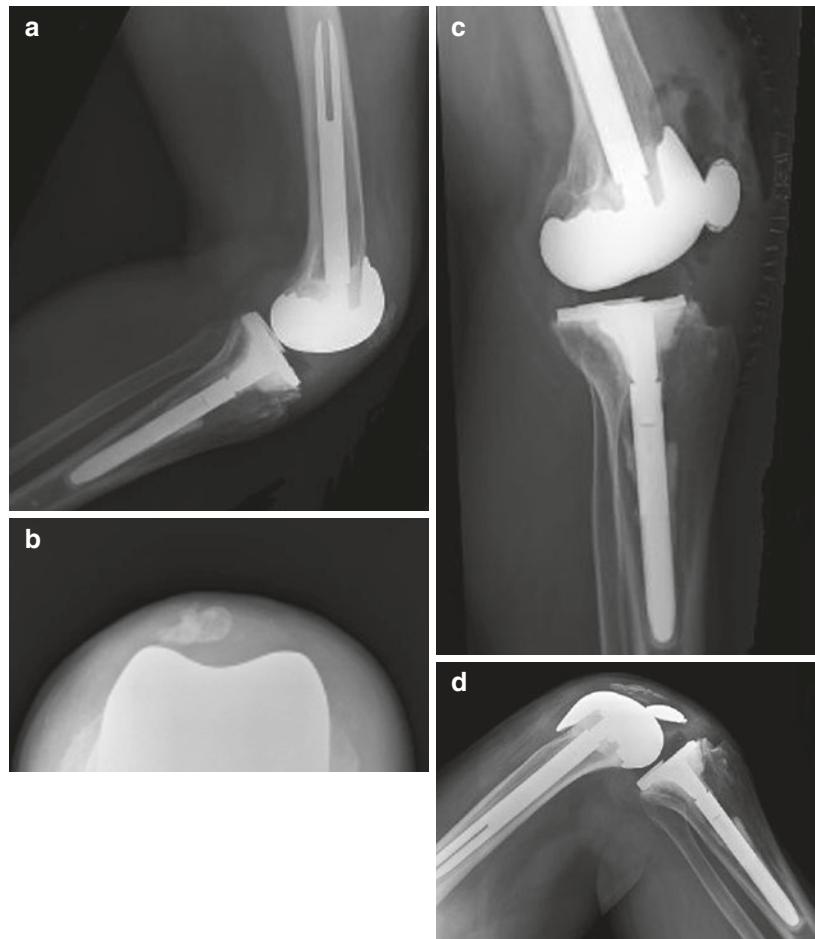
He was treated with TM patellar reconstruction by suturing the TM baseplate directly into the quadriceps tendon (Fig. 15.15c).

Postoperative Result

Six months after surgery, he experienced increased anterior knee pain and giving-way episodes. Radiographs demonstrated inferior migration and displacement of the TM component (Fig. 15.15d). He was treated with removal of the TM component and tubing the extensor mechanism. Two years after surgery, he has moderate anterior knee pain which limits his activity and no longer complains of giving-way episodes. Knee motion is 0–110°, and he has no extensor lag.

Fig. 15.15 (a)

Anteroposterior (AP) radiograph demonstrates well-fixed stemmed revision components with the absence of the patella. (b) Patellar radiograph demonstrates a small patellar bone remnant. (c) Lateral radiograph immediately after Trabecular Metal (TM) patellar reconstruction with the implant sutured directly into the extensor mechanism soft tissue sleeve shows relatively anatomic positioning of the implant. (d) Lateral radiograph 6 months after surgery shows complete displacement and inferior migration of the TM implant



Clinical Results

Nassar and Poggie reported on 11 patients with TM patellar reconstruction during revision TKA [21]. Preoperative knee function and pain scores were 24 and 20, respectively, and average knee motion was 62°. At an average follow-up of 32 months, knee pain and function scores had improved to 69 and 53, respectively, average knee motion was 103°, and no implants had loosened.

Tiganai et al. reported on ten patients (three primary and seven revision TKAs) with TM patellar reconstruction [22]. Nine patients had marked patellar deficiency, and one had a prior patellectomy. Patients were followed up for an average of 45 months. The component in the patient with prior patellectomy failed, but there was no displacement of the implant when at least 50% of the TM implant was covered by host bone.

Nelson et al. reported on 20 consecutive patients treated with trabecular metal patellar reconstruction during revision TKA [9]. Results were good or excellent in 17 patients. Three patients developed polar patellar fractures, but none of the TM components displaced at an average follow-up of 23 months. The authors later reported minimum 5-year results with this technique in 23 patients [23]. Knee Society scores for pain and function averaged 82.7 and 33.3, respectively, at most recent follow-up (average 7.7 years). Four patients underwent revision surgery. Failures were associated with avascular residual bone and fixation of components directly to the extensor mechanism.

Ries et al. reported on 16 patients (18 knees) treated with TM patellar reconstruction and separated the patients into two groups based on the

amount of residual patellar bone stock [24]. Group 1 (seven knees) had prior patellectomy and no patellar bone stock. Group 2 (11 knees) had greater than 50% bone coverage of the TM implant. All seven (100%) of the patellar components in group 1 loosened within 1 year. Two of these developed necrosis of the extensor mechanism leading to extensor mechanism discontinuity. One component in group 2 became infected and loosened, while the remaining ten (91%) were stable at 12-month follow-up.

Kwong and Desai reported on seven patients with prior patellectomy who underwent TM patellar reconstruction [25]. In three patients, implant loosening occurred within 15 months. Two patients remained symptomatic despite solid fixation. One patient developed wound complications, and the procedure was abandoned in one patient as wound closure was not possible. The authors recommended that this procedure be avoided in patients with prior patellectomy. However, Nanjayan and Wilton reported a successful case of TM patellar reconstruction after prior patellectomy in which the rim of the component was sutured into a soft tissue pocket in the quadriceps tendon with a deep purse ring suture layer technique in addition to sutures securing the TM metal component to the quadriceps tendon [26]. The authors attributed their favorable clinical result to the quality and stability of soft tissue attachment to tantalum using a technique to interpose the tantalum rim into the quadriceps tendon.

Summary

Successful TM reconstruction of the patella after failure of a prior patellar resurfacing can restore favorable quadriceps strength and knee function. Most studies report relatively small case series with early to mid-term follow-up and emphasize the importance of adequate viable host bone coverage of the TM implant. Better results are generally achieved when over 50% of the TM implant is covered by host bone, and poor results occur when there has been a prior patellectomy and the implant is sutured directly into soft tissue.

Although animal studies have demonstrated the ability of soft tissue to adhere directly to TM, the clinical experience with TM patellar recon-

struction after prior patellectomy has generally been unfavorable. There may be a number of reasons for this including the stability of the host soft tissue-TM interface with a TM implant secured using suture fixation, compromised vascularity of the extensor mechanism soft tissue sleeve, and variable force transmission to the patellar fixation surface during knee range of motion and activities in vivo after surgery.

Key Points

- Greater than 50% of the TM ingrowth surface should be covered by viable host patellar bone. If the component is sutured directly to soft tissue (prior patellectomy), there is a high risk of failure.
- Ream the host bone to a smooth cavitary shape.
- Size the appropriate TM implant with trails. Position the implant adjacent to the center of the femoral component trochlear flange just above the joint line.
- Hold the TM implant to the reamed patella surface with a towel clip or clamp. Drill peripheral holes for suture fixation. Place #2 FiberWire sutures through each pair of adjacent drill holes, and tie knots over TM implant.
- Cement UHMWPE implant to TM component. Use a small amount of cement to avoid penetration of cement through the TM implant to the cementless TM/patellar bone interface.

Option 3: Gullwing Patellar Osteotomy for Osteolytic Deformity

Kelly G. Vince and Michel Malo

Case Presentation

History

A 67-year-old male had a revision total knee arthroplasty (TKA) with primary style uncemented components 6 years previously for aseptic loosening. Pain increased gradually after this revision and was accompanied by large effusions.

Physical Examination

The patient had an antalgic gait with a 5° arc of varus-valgus pseudo-laxity related to loosening. The large effusion and pain limited the flexion to 90°. There was full active extension without a lag. All motion was painful. The patella is tracked in the midline.

Radiographs and Advanced Imaging

The x-rays illustrated osteolysis and extensive radiolucencies indicative of recurrent aseptic loosening. The patella was midline with a loose prosthesis and extensive osteolysis (Fig. 15.16). Aspiration of the synovial fluid yielded a low white cell count and negative cultures, eliminating prosthetic joint infection [27].

Surgical Approach

There was extensive bone loss around the loose patellar prosthesis. Once the patellar component was removed, only the anterior cortical shell remained, and this articulated on the lateral femoral condyle, as it did not fit between the femoral condyles. Accordingly, at the second revision, a patellar osteotomy was performed from superior to inferior (in the sagittal plane). The medial and lateral edges of the patella were raised anteriorly, while the medial edge of the lateral fragment and the lateral edge of the medial fragment were pushed posteriorly (Fig. 15.17).

The second revision, which included the gullwing osteotomy, was performed with a tibial-first technique, followed by stabilizing the

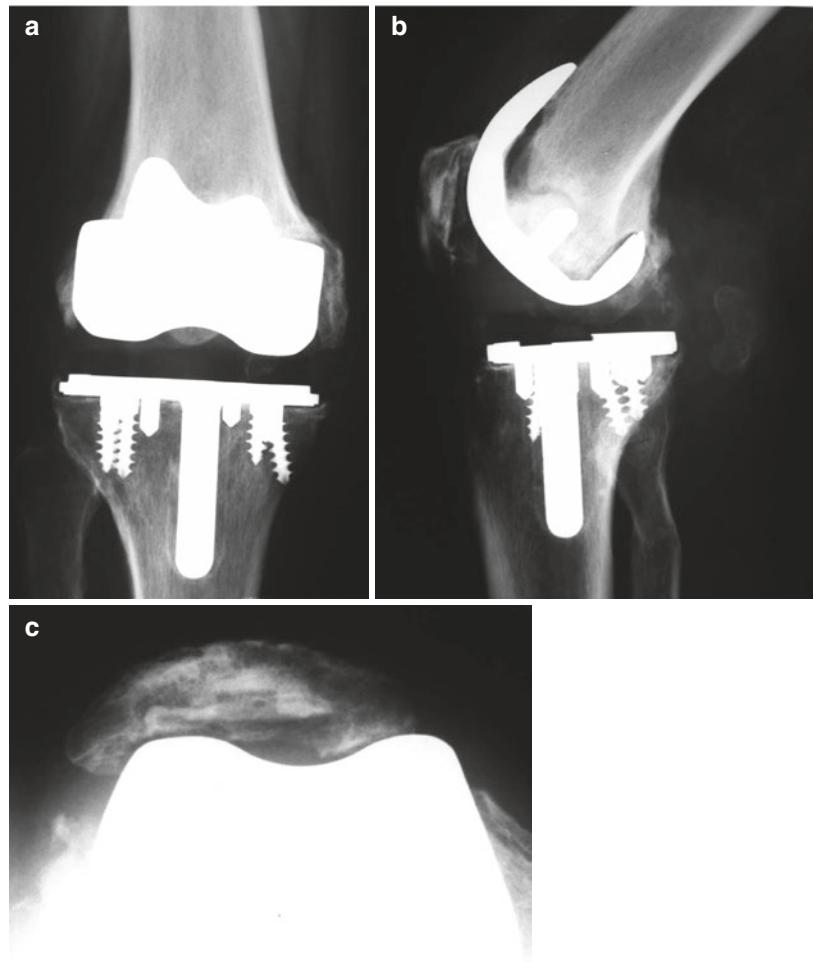


Fig. 15.16 (a) Anteroposterior radiograph of failed revision total knee arthroplasty that had been performed for aseptic loosening with uncemented primary components. (b) Lateral view of failed revision showing aseptic loosening and extensive osteolysis in the femur. (c) Merchant patellofemoral radiograph showing resurfaced patella that is loose (circumferential radiolucency) with only the scaphoid-shaped anterior cortex as the residual bone. Once the prosthesis is removed, this bone will not fit well between the femoral condyles.

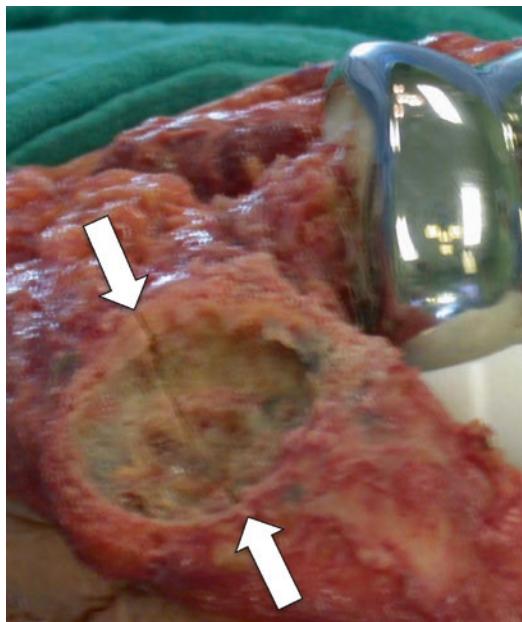


Fig. 15.17 Intraoperative photo of articular side of everted patella at second revision surgery. Arrows indicate the superior and inferior ends of the “gullwing” osteotomy

flexion gap and then matching this with the extension gap [28].

Surgical Technique: Decision-Making

A decision on patellar disposition is required at revision arthroplasty, usually after the tibial and femoral components have been implanted [29]. An intact (unworn), well-positioned, and well-fixed patellar component that is compatible with the revision femoral component should be left in place. A loose, worn, or incorrectly positioned component should be removed. Once removed, a new prosthesis should be implanted if the residual bone foundation is adequate for reliable fixation. The general goal of resurfacing in this situation is to restore the patellar lever arm and joint congruence.

When only a shell of anterior cortex remains, conventional polyethylene implants are likely to loosen rapidly, as they are designed for cement fixation against a flat, cancellous bone surface. Biconvex polyethylene patella implants were used at one time [30, 31]. They have the advantage of “fitting” into the defect, but the remaining

sclerotic surface is still a poor fixation interface for bone cement in the revision arthroplasty. A good prosthetic solution would be a modular trabecular metal implant, with a convex porous metal surface against the residual bone, and an opposing flat surface that a conventional dome-shaped polyethylene button can be cemented into. The thickness and lever arm of the patella may be restored despite extensive bone loss, with these prostheses, if there is still a boney shell for ingrowth [9, 21]. The trabecular metal implants fare poorly in the presence of a patellectomy [23, 24]. Bone grafting inside of a pouch is another method of restoring patellar thickness [8]. These options, including the gullwing osteotomy, have been clearly demonstrated in print and surgical videos by Ritschi and colleagues [32, 33].

Osteotomy

With the knee fully extended and the extensor mechanism everted, the residual articular surface of the patella faces the surgeon. An oscillating saw, oriented proximal to distal, is used to divide the patella into medial and lateral halves. Each “wing” of the osteotomy can be “cracked” anteriorly so that the osteotomy itself lies in the trochlear groove and the wings articulate against the respective femoral condyles. Some small pieces of bone autograft may be inserted up through the osteotomy, onto the anterior cortex, where they will be held under the soft tissues on the anterior surface of the patella (Fig. 15.18). The arthrotomy, usually medial, can be closed with conventional technique.

Postoperative Management

As the extensor mechanism remains intact from origin to insertion, standard rehabilitation for a revision knee arthroplasty is appropriate. The osteotomy will have changed the shape of the residual patella so that it fits between the two femoral condyles. This will not solve maltracking problems resulting from internal rotation positioning of either the tibial or femoral components [34]. Nor will it address maltracking that persists from scar formed during extended periods of maltracking or dislocation. At its best, the osteotomized patella will track congruently on

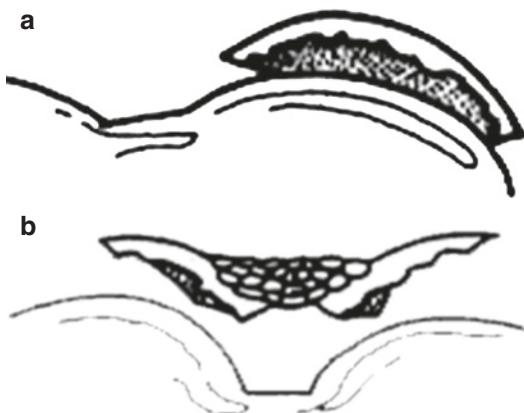


Fig. 15.18 (a) Schematic view of an osteolytic patella with component removed, from the perspective of a patellofemoral radiograph, like a Merchant view. Although the rotational position of components favors central tracking, the peculiar concave shape of the patella tends to “hug” the lateral femoral condyle. (b) Same perspective but now the patella has been divided into medial and lateral parts by a vertical osteotomy. Small pieces of bone graft may be placed up through the osteotomy onto the anterior surface of the patella

the distal femur, with a lever arm slightly superior to a patellectomy.

Postoperative Result

As the collateral ligaments were intact, the arthroplasty demonstrated mediolateral stability without the need for a constrained implant. At follow-up, the knee extended fully without a lag and flexed to 110° (Figs. 15.19, 15.20, and 15.21).

Clinical Results

Revision surgery may be required for several modes of knee arthroplasty failure [35, 36], but prosthetic joint infection and aseptic loosening are the two most common [37]. Both are associated with extensive bone loss. In the former, aggressive debridement may have been necessary to eradicate infection, and in the latter, osteolysis destroys substantial amounts of bone, including the articular side of the patella. If the patella had ever been resurfaced, only the outer cortical shell may remain. The thin flat patella or, worse, the “bowl” or “scaphoid” (boat-like) shape of this residual bone cannot articulate congruently between the femoral condyles but often “hugs”

the lateral femoral condylar, where the shapes match (see Fig. 15.18). This risks lateral maltracking, even in cases where the rotational positions of the femoral and tibial components are ideal, and the Q angle otherwise favors central tracking.

The so-called “gullwing” osteotomy is a simple procedure that changes the flat or concave shape of an osteolytic patella so that it fits between the femoral condyles during flexion and extension. The residual patellar bone is split from proximal to distal, maintaining continuity of the extensor. The residual facets are both “cracked up” anteriorly, such that the osteotomy recreates the crest of the former patellar articular surface. The name of the osteotomy comes from the resultant shape of the patella on a Merchant patellofemoral radiograph [38], resembling either a child’s drawing of a flying gull or the famed “top-hinged” driver and passenger doors, opening upward, of the classic gullwing Mercedes-Benz automobile of the 1950s [39].

The procedure was introduced prior to the advent of reliable trabecular metal bone ingrowth patellar augments [24] and techniques for osseous autograft reconstruction of osteolytic defects [8]. Both of those procedures have the advantage of reconstituting the lever arm of the patella and enhancing extensor power [40]. The gullwing osteotomy, by contrast, requires little time and no additional expense.

This procedure is not intended to correct maltracking that results from the common causes of patellar dislocation in TKA [34], notably internal rotation of the tibial and/or femoral components [41], or valgus alignment that increases the Q angle [42]. Indeed, the original manuscript describing the gullwing osteotomy [43] was rejected from several journals by reviewers who assumed that the procedure claimed to correct maltracking primarily. Patellar tracking problems should be treated by correcting the underlying cause. The gullwing osteotomy is simply an elemental maneuver to match the shapes of an osteolytic patella with the intercondylar groove of an arthroplasty.

There are no reports of revisions that involve a patella that has never been resurfaced.



Fig. 15.19 (a) Anteroposterior and (b) lateral radiographs at 4 months after second revision knee arthroplasty with non-constrained components. Lateral radiograph shows patella at desired height after “three-stage revision

total knee arthroplasty”. (c) Merchant radiograph showing consolidation of gullwing osteotomy at 4 months. The medial and lateral facets conform to the trochlear groove

Presumably, these knees would function well as the patella thickness and the extensor lever arm remain intact. When a patellar component is removed and left unrevised at revision knee arthroplasty, the clinical scores are generally lower than when the patella has been resurfaced [44]. Patients usually report that they cannot return to their pre-revision activities of daily living [45]. The problem is not usually pain as much as loss of function. Whether the compro-

mised results accrue directly from the thin patella cannot be deduced from the published series [29].

The gullwing osteotomy alters the concave shape of an osteolytic patella and eliminates the tendency of this shell to articulate where it fits easily, on the lateral condyle. The original report included one primary and three revision knee arthroplasties [43]. All patients were older, with an average age of 80 years (range 75–82).

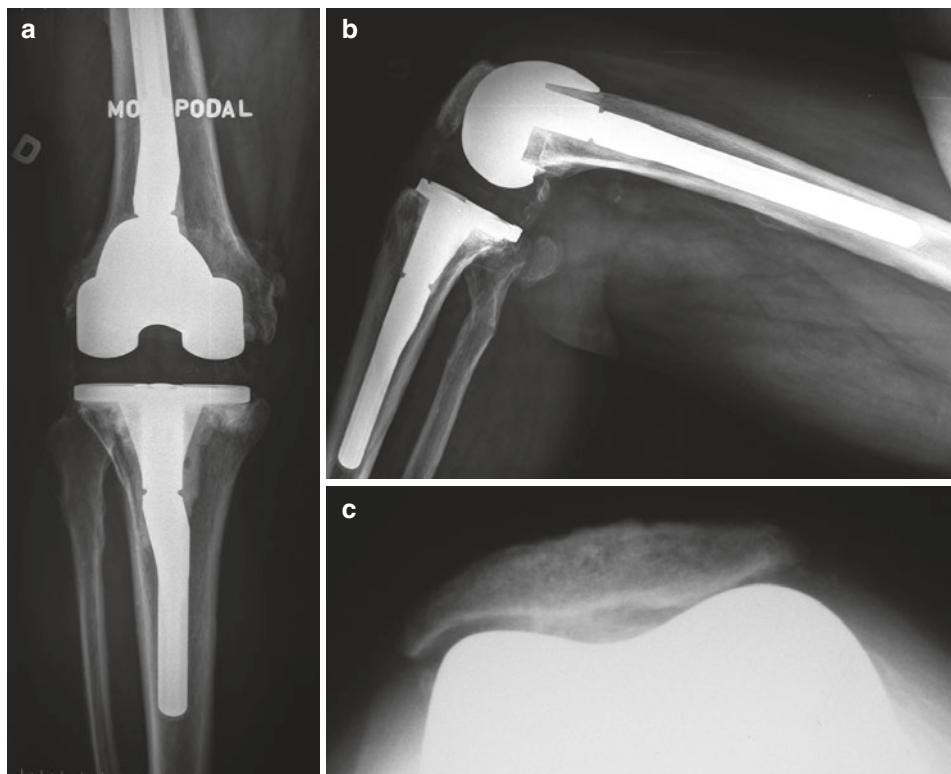


Fig. 15.20 (a) Anteroposterior, (b) lateral, and (c) Merchant radiograph 2.4 years after second revision. Patella height and integrity maintained on lateral view

with increased conformity of the centrally tracking patella apparent on the Merchant radiograph

Revisions were performed for aseptic loosening with osteolysis or at two-stage reimplantation for periprosthetic infection. The four osteotomies consolidated, and all patients remained ambulatory. One had a 10° extensor lag. The patient who underwent bilateral primary arthroplasties with a gullwing osteotomy on one side regained 115° of flexion but with bilateral flexion contractures of 15° and no lag. The overall functional results were typical of revision knee arthroplasty in the elderly, presumably with slightly superior extensor power and comfort because of a centrally tracking, osteotomized patella.

The first independent series of 12 cases was published in 2010. Radiographs demonstrated central tracking of the patella with healing of the osteotomy in all cases. The investigators accurately describe the gullwing osteotomy as a “viable method of patellar salvage reserved for the

most advanced cases of patellar bone stock compromise” [46].

The authors of a second independent series, presented at the 2015 annual meeting of the American Academy of Orthopedic Surgeons, reported that there were no aseptic re-revisions for patellofemoral complications, that 87% of patellae were tracking within the groove, and that radiographic healing occurred in the majority of the osteotomies [47].

Recent alternatives to the gullwing osteotomy include a technique to enhance fixation by attaching surgical wires around the pegs of the patellar component and then passing them from posterior to anterior through the residual shell of patella and tying them on the anterior aspect of the patella [48, 49]. The cases where this technique is recommended—patellar bone less than 8 mm thick—would not otherwise achieve solid cement



Fig. 15.21 (a) Anteroposterior, (b) lateral, and (c) Merchant radiographs at 8 years post-op. Patella highly congruent in trochlear groove

fixation of a conventional polyethylene prosthesis into the residual shell. If, however, these wires actively resist significant stress, especially bending moments, we would expect them to fatigue and fail, with resultant loosening. The representative cases provided in the [48, 49] are of concern, as most show knee recurvatum, a form of instability that suggests the extensor mechanism is weak and that the patient walks by locking the knee in hyperextension. Many of the illustrated

cases have significant patella infera, a situation where the resurfaced patella would not necessarily be expected to function advantageously.

Key Points

1. The gullwing patellar osteotomy is a simple and cost-effective procedure to shape a severe osteolytic shell of patella, where only the anterior cortex remains.

2. It is not intended to treat patellar maltracking due to internal rotation of tibial and or femoral components.
3. It does not restore patellar thickness and lever arm. Either extensor allograft or trabecular metal patellar prosthesis secured to some residual patellar bone would be required.

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Management of Patella Tendon Rupture

16

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Introduction

Giles R. Scuderi

Rupture of the patella tendon during or following total knee arthroplasty (TKA) can be an extremely challenging complication to manage. The following case reports will describe several surgical options for the management of patella tendon ruptures, but it is important to identify those patients who are at greater risk for rupture of the patella tendon. Those patients at higher risk tend

to be obese, have limited preoperative range of motion, have had prior surgery, or have a metabolic condition or connective tissue disorder that may compromise the patella tendon.

Tibial tubercle avulsion is the most common intraoperative injury to the patella tendon during TKA. This is an intraoperative complication that should be avoided than treated, and care should be taken to protect the patella tendon insertion on the tibial tubercle during TKA. Three specific steps to avoid this complication include: (1) Protect the patellar tendon at the insertion site by extending the medial arthrotomy distally and peel the patellar tendon along the medial tibial tubercle in order to avoid a transverse tear of the patellar tendon [1]; (2) extend the medial arthrotomy proximally and perform a quadriceps snip for a more extensile exposure, relieving tension on the patella tendon [2]; and (3) perform a tibial tubercle osteotomy if the prior procedure still does not afford adequate exposure and there is a risk of avulsion of the patella tendon [3].

The timing and location of the injury may have an impact on the chosen surgical management. Several surgical techniques have been described but none has yet to be considered the gold standard. Reconstruction options include direct repair, repair with autogenous graft [4], various allografts [5], and synthetic grafts [6]. Complete acute tears may be managed with direct repair, usually with autogenous graft augmentation, such as the semitendinosus tendon. Bone avulsion of the patella

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tendon from the inferior pole of the patella may be directly repaired to a bone trough at the site of the avulsion. Patella tendon avulsion from the tibial tubercle is a challenging repair since it is difficult to get secure fixation of the patella tendon into the tibial tubercle. In this scenario, the surgeon must choose between repair with autogenous augmentation and a reconstructive procedure with allograft or synthetic graft. The postoperative rehabilitation for all these procedures requires an extended period of immobilization with the knee locked in full extension, followed by gradual resumption of motion in a controlled dial flexion brace.

Late rupture of the patella tendon that may lead to chronic dysfunction of the extensor mechanism is a rare but devastating complication. Since the local tissue is compromised, the patella retracted proximally, and the patella tendon is atrophic and poor quality, a reconstruction of the patella tendon is necessary. The available options include Achilles tendon allograft, complete extensor mechanism allograft, and synthetic grafts. The chosen technique is dependent upon surgical experience and the quality of the local tissue. Clinical results with reconstruction of chronic ruptures of the patella tendon are variable and not always rewarding due to residual quadriceps weakness and extensor lag. The following case reports will review the surgical techniques available for the reconstruction of chronic ruptures of the patella tendon.

Option 1: Management of Patellar Tendon Rupture—Extensor Mechanism Allograft

Nicholas B. Frisch and Richard A. Berger

Case Presentation

History

A 54-year-old male presented to our office for a second opinion after a long history of left knee problems. He underwent a left total knee arthroplasty (TKA) 5 years earlier for degenerative arthritis at an outside hospital. He sustained a

fracture of his left patella 2 years later during a motor vehicle accident requiring partial patellectomy with revision of the patellar component. He developed lateral subluxation of the patella with anterior knee pain and swelling. He subsequently underwent a patellar component resection with medial retinacular reefing for this lateral subluxation. His lateral subluxation worsened the recurrent anterior pain. Finally, this progressed to recurrent instability from his patella dislocation for which he was treated in a brace by his primary surgeon who recommended revision total knee arthroplasty.

Physical Examination

On physical examination, the patient was 6'4" tall and weighed 215 pounds. He had physiologic valgus alignment of the knees in stance and an antalgic gait favoring his left side. Examination supine revealed full, painless passive range of motion of the left hip. There was a well-healed medial-based curved incision from a prior medial meniscectomy and a lateral midline incision over the left knee from the last few surgeries. Examination of the knee revealed a 30° extensor lag with full passive range of motion. He had 125° flexion. The patella tracked laterally, with passive motion. The patella was dislocating with resisted extension. There was no instability to varus/valgus stress at 0° and 30° of flexion. He had no anterior/posterior instability. He had a large effusion in the left knee. There were palpable pedal pulses and no sensory or motor deficits.

In cases of extensor mechanism failure, a proper physical examination is critical. Prior incisions over the knee must be inspected. Usually the more lateral incision is preferred due to the perfusion which comes from the medial side. The difference between the active and passive extension (extensor lag) must be measured as well as resisted extension which simulates climbing stairs and rising from a chair. A flexion contracture, inability to passively extend the knee, must be separated from an extensor lag. The tracking of the extensor mechanism during range of motion should be examined. A poorly tracking extensor mechanism is usually a result

of component malrotation and may be the cause of the extensor mechanism failure.

Radiographs and Advanced Diagnostics

Radiographs are evaluated for component alignment and fixation. Patellar position, tracking, and presence of heterotopic ossification are also evaluated. If there is any concern about malrotation of the components, an axial CT scan of the femo-

ral and tibial components should be obtained to evaluate for component internal rotation [7].

In review of this patient, plain radiographs revealed a well-fixed cemented TKA. The patella was sclerotic, and there was no evidence of a patellar component, suggesting that the remnant of the patella which is present is osteonecrotic. Furthermore, the skyline view shows that the patella is subluxed laterally (Fig. 16.1). CT scans were also reviewed and demonstrated that the

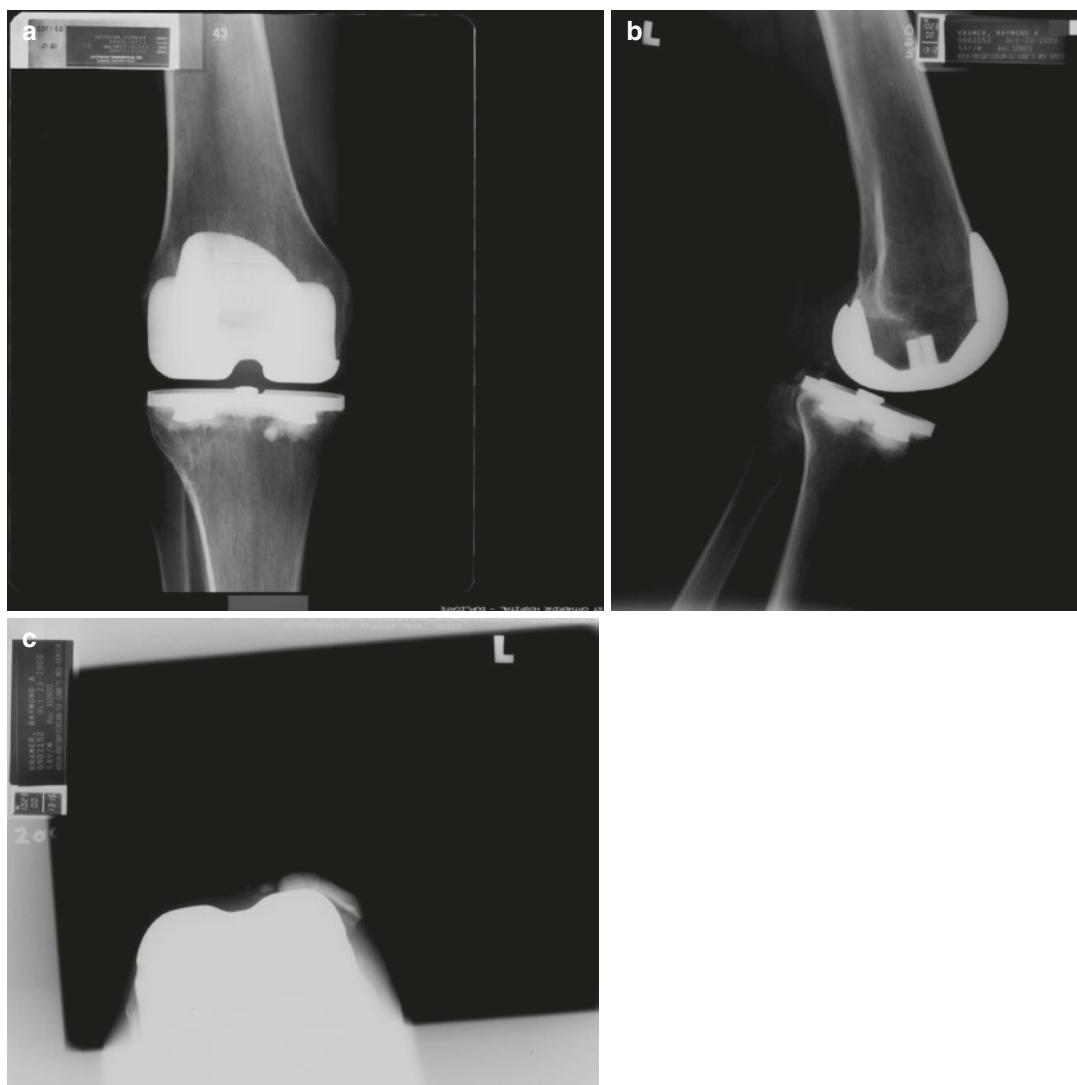


Fig. 16.1 Plain radiographs of the knee, including (a) anteroposterior, (b) lateral, (c) and skyline views, revealed a well-fixed cemented total knee arthroplasty. The patella was sclerotic, and there was no evidence of a patellar

component, suggesting that the remnant of the patella which is present is osteonecrotic. The skyline view shows that the patella is subluxed laterally

femoral component as well as the tibial component was excessively internally rotated.

It is critical to evaluate the patient for infection. Investigation starts with an ESR and CRP. If these values are elevated, a knee aspiration is mandatory. In this case infection was not present.

Surgical Approach

Allograft Extensor Mechanism

Extensor mechanism allografts are hard to obtain and advanced planning is needed. We order a specimen consisting of a quadriceps tendon (at least 5 cm), patella, patella tendon, and tibial bone or a large portion of the proximal tibia (Fig. 16.2). It is critical that the appropriate sided graft be ordered since a graft from the contralateral side will result in patellar maltracking and early failure. The allograft must be fresh frozen and non-irradiated. Freeze-dried allografts may be weakened leading to complications and failure [8, 9]. The authors have found that the best specimens are whole knee allografts, which allow us to fashion the extensor mechanism allograft as we see fit in the operating room.

Exposure of the Knee

The patient is positioned supine on the operating table with a non-sterile pneumatic tourniquet around the thigh. The leg is prepped and draped. The pneumatic tourniquet is inflated with the knee in flexion. For short legs, a sterile tourniquet is used so that it may be removed to obtain proximal access.



Fig. 16.2 Extensor mechanism allograft specimen consisting of a quadriceps tendon (at least 5 cm), patella, patella tendon, and tibial bone or large portion of the proximal tibia

Previous incisions are noted, and if possible, a midline skin incision is used. If multiple incisions are present, we use the most lateral incision closest to the midline in order to preserve the blood supply to the skin. This is important, as these are often multiple operated knees and wound healing may be compromised.

After choosing the appropriate incision, dissection is continued, keeping skin and subcutaneous flaps as thick as possible, and expose the retinaculum and extensor mechanism. A midline incision is performed through the remaining extensor mechanism (quadriceps tendon, patella, and patellar tendon including over the tibial tubercle), creating medial and lateral flaps of the entire extensor and exposing the joint. It is recommended that appropriate cultures and a cell count be done at this point. The midline incision is started proximally into the host quadriceps, maintaining a medial and lateral sleeve of tissue for later closure. The incision is carried over the patella, if present. The native patella, if present, it is osteotomized longitudinally, in line with the midline soft tissue retinacular incision (Fig. 16.3). This allows the patellar bone to be shelled out and removed, preserving the soft tissue continuity with the medial and lateral flaps (Fig. 16.4). Finally, the midline incision is then carried through the patellar tendon and over the host tib-



Fig. 16.3 The midline incision is carried over the patella, and if present, the native patella is osteotomized longitudinally, in line with the midline soft tissue retinacular incision

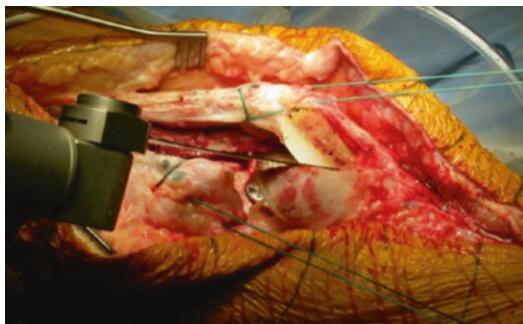


Fig. 16.4 After osteotomy, the native patellar bone is shelled out and removed, preserving the soft tissue continuity with the medial and lateral flaps



Fig. 16.5 The midline incision is then carried through the patellar tendon and over the host tibial tubercle, elevating the patella tendon from the tubercle both medially and laterally to expose the tibial tubercle, opening up like a book

ial tubercle, elevating the patella tendon from the tubercle both medially and laterally to expose the tibial tubercle, opening up like a book (Fig. 16.5).

TKA Component Revision

We have successfully performed extensor mechanism allografts with cruciate retaining, posterior stabilized, condylar constrained, and constrained hinge knee designs. Regardless of the implant, any malrotation of the femoral and tibial components must be adequately addressed as many extensor mechanism disruptions are the direct result of component malrotation. Similarly, flexion and extension gaps must be assessed and balanced properly. If necessary, revision of the components is performed at this time. In the event that stemmed components are to be introduced, the wires through the tibial bone can be placed posterior to the stem prior to tibial component insertion in order to provide additional fixa-

tion. The final polyethylene liner is inserted prior to performing the extensor mechanism allograft reconstruction.

Allograft Preparation

When preparing the extensor mechanism allograft, begin by cutting the allograft tibial tubercle on either side of the patellar tendon. Next, cut the allograft tibial tubercle 1 cm proximal to the insertion of the patellar tendon and distally at the end of the patellar tendon. The result is an allograft tibial tubercle that is roughly 6–8 cm long and 1.5–2 cm wide. Trim the depth of the allograft tibial tubercle to 1.5 cm proximally, tapering down to 1 cm distally (Fig. 16.6).

Now prepare the dovetail on the proximal aspect of the allograft tibial tubercle. The dovetail locks the allograft tibial tubercle into the native tibial trough and resists proximal graft escape. In addition, the dovetail allows a press fit of the allograft tibial tubercle into the native tibia. The dovetail is marked into the allograft tibial tubercle by drawing an angle of 45°, starting at the insertion of the patellar tendon onto the allograft tibial tubercle and going proximal as the bevel goes posterior. After marking, the bevel is cut with a thin saw blade (Fig. 16.7). The longitudinal length of the bevel is approximately 15–20 mm (Fig. 16.8).

Upon completion of allograft tibial tubercle, attention is turned to the proximal end of the allograft. Two, #5 nonabsorbable sutures are placed along the medial and lateral aspect of the allograft quadriceps tendon using a Krackow locking stitch. The proximal ends of the suture will exit proximally and will be used to tension the allograft tightly once appropriately secured distally in the host tibia.

Proximal Tibia Trough Preparation

Using a marking pen, the host proximal tibial trough is marked out to perfectly match the allograft tibial tubercle, which has already been prepared. The proximal-distal location of the trough is critical to determine where the patella will articulate with the trochlear. With the leg in full extension, the allograft patella is placed at the top of the trochlea so that it fully articulates, and



Fig. 16.6 Begin by cutting the allograft tibial tubercle on either side of the patellar tendon. Next, cut the allograft tibial tubercle 1 cm proximal to the insertion of the patellar tendon and distally at the end of the patellar tendon



Fig. 16.7 Prepare the dovetail on the proximal aspect of the allograft tibial tubercle. The dovetail is marked into the allograft tibial tubercle by drawing an angle of 45°, starting at the insertion of the patellar tendon onto the allograft tibial tubercle and going proximal as the bevel goes posterior. After marking, the bevel is cut with a thin saw blade



Fig. 16.8 The longitudinal length of the bevel is approximately 15–20 mm

the location of the junction of the allograft tibial tubercle and allograft patellar tendon is marked on the native tibial tubercle.



Fig. 16.9 The rectangular tibial trough is then cut into the host tibial tubercle such that the allograft tibial tubercle remains 1 mm wider than the host trough to ensure a press fit

The rectangular tibial trough is then cut into the host tibial tubercle such that the allograft tibial tubercle remains 1 mm wider than the host trough to ensure a press fit. Great care is taken to make sure that the medial and lateral walls of the host tibial tubercle remain intact for stability of the allograft tibial tubercle. Proximally, the host bone is beveled, to accept a press fit of the dove-tailed allograft tibial tubercle (Fig. 16.9).

The final preparation of the trough is to pass two or three 18 gauge stainless steel wires through drill holes in the tibia from medial to lateral. These wires pass deep to the tibial trough and can be placed around a stemmed tibial component for additional fixation as noted above. At this point, the allograft tibial tubercle is press fit into the trough. First the dovetail of the allograft tibial tubercle is inserted in the bevel of the host tibial tubercle. The allograft extensor mechanism is gently press fit in with a bone tamp or punch, with an up and in displacement of the allograft tibial tubercle to lock the dovetail of the allograft tibial tubercle in place. Once the allograft tibial tubercle is fully seated proximally, the distal aspect is seated, removing any excess allograft tibial tubercle that extends past the distal end of the trough with a saw or motorized burr (Fig. 16.10).

The allograft tibial tubercle is held in place with the two or three wires. The wires are tightened on the lateral aspect of the host tibial tubercle so that they are under the muscle of the calf and not directly under the skin (Fig. 16.11).



Fig. 16.10 Once the allograft tibial tubercle is fully seated proximally, the distal aspect is seated, removing any excess allograft tibial tubercle that extends past the distal end of the trough with a saw or motorized burr

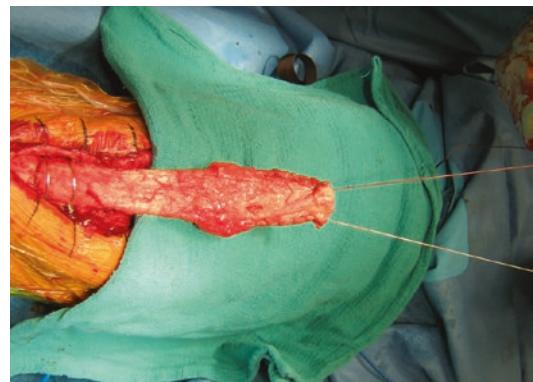


Fig. 16.12 A single retention suture is placed in the host distal quadriceps medially and laterally which allows the host quadriceps to be pulled distally. With the knee in full extension, the two sutures in the allograft quadriceps are pulled proximally as the host quadriceps is pulled distally

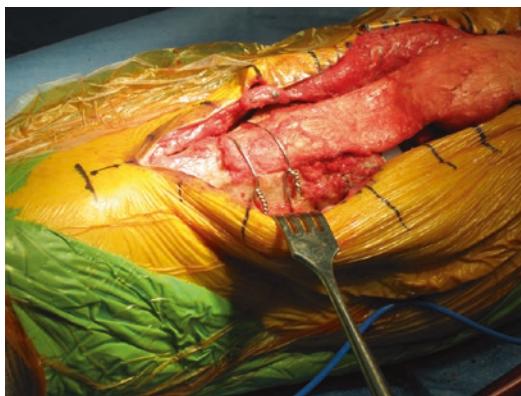


Fig. 16.11 The allograft tibial tubercle is held in place with the two or three wires. The wires are tightened on the lateral aspect of the host tibial tubercle so that they are under the muscle of the calf and not directly under the skin

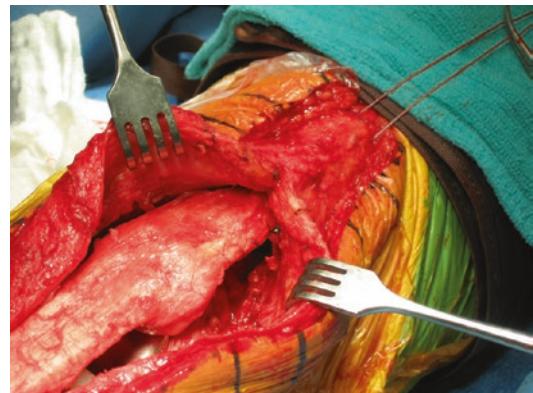


Fig. 16.13 The sutures in the allograft quadriceps are pulled from distal to proximal, out and up through the more proximal host quadriceps. The two ends of the allograft quadriceps sutures are tied together to hold it in place

Alternatively, a cancellous screw with washer may be added for additional fixation, taking care not to overtighten the screw and fracture the allograft tibial tubercle.

Host Distal Quadriceps Preparation, Tensioning, and Closure

A single retention suture is placed in the host distal quadriceps medially and laterally which allows the host quadriceps to be pulled distally. With the knee in full extension, the two sutures in the allograft quadriceps are pulled proximally as the host quadriceps is pulled distally (Fig. 16.12). The sutures in the allograft quadriceps are pulled from distal to proximal, out and up through the more proximal host quadriceps. The two ends of the allograft quadriceps sutures are tied together to hold it in place (Fig. 16.13). With this tension

maintained, the allograft quadriceps is sutured beneath the host quadriceps with #2 nonabsorbable suture, in a vest-over-pants fashion (Fig. 16.14). Maintain constant distal tension on the host quadriceps in order to maximize tension with the knee in the extended position.

Once the proximal aspect of the allograft is secured, the repair is continued along the medial and lateral sides trying to leave enough of the host retinaculum so that it may be brought over top of the allograft to completely cover it. After the allograft is fully sutured in place down to the



Fig. 16.14 With this tension maintained, the allograft quadriceps is sutured beneath the host quadriceps with #2 nonabsorbable suture, in a vest-over-pants fashion



Fig. 16.15 The repair is continued along the medial and lateral sides trying to leave enough of the host retinaculum so that it may be brought over top of the allograft to completely cover it. After the allograft is fully sutured in place down to the patellar tendon, the host quadriceps is closed over the top of the allograft with sutures

patellar tendon, the host quadriceps is closed over the top of the allograft with sutures (Fig. 16.15).

We do not routinely flex the knee to test our repair. In the event that the repair is to be tested, the knee should not flex beyond 30° due to the tightness of the allograft. At this point the subcutaneous tissues are closed in a routine fashion and the skin is closed with staples or a nonabsorbable suture.

Postoperative Protocol, Rehabilitation, and Results

The knee is placed in full extension in a brace in the operating room. Wound healing is a major

concern in these patients and it is important to use a brace that allows for complete immobilization of the knee in full extension but permits access to the wound postoperatively.

Patients are maintained in full extension for 8 weeks after surgery. During this period, we allow weight bearing as tolerated, but we do not allow any flexion. We encourage isometric static quadriceps contractions. After 8 weeks, active flexion is permitted with supervised physical therapy. Initially, the patient only achieves about 30–40°, but this slowing improves with time. We allow active extension in the brace to begin at 8 weeks too. During this time, the patients continue weight bearing with the brace locked in full extension. At 12 weeks, we remove the brace allowing further active flexion as tolerated and ambulation without the brace.

This patient followed the aforementioned protocol and has done well postoperatively. At his 3.5-year follow-up visit, he did have some residual swelling but had near full active extension to –10° and flexion to 120°. At 10-year follow-up, he had 7° extensor lag but full extension with passive range of motion and 120° flexion. Radiographs demonstrated well-fixed stemmed tibial and femoral components with intact extensor mechanism allograft. Alignment was maintained and there was no evidence of component loosening. Of note there was evidence of some resorption of the patella on radiographs (Fig. 16.16). There has been some controversy over whether or not to resurface the patella during this procedure. While historically we have not performed a patellar resurfacing, with improved long-term survival of the graft as in this patient, increased patellar resorption may suggest that resurfacing could prove to be beneficial.

Clinical Results

Extensor mechanism disruption is arguably the most devastating complication of total knee arthroplasty. Multiple techniques for repair or reconstruction of a deficient extensor mechanism have been described in association with total knee arthroplasty, but few have been able to reliably restore the extensor mechanism [10]. While direct repair in native knees usually yield good



Fig. 16.16 Radiographs including (a) anteroposterior, (b) lateral, and (c) skyline views demonstrated well-fixed stemmed tibial and femoral components with intact extensor mechanism allograft. Alignment was maintained, and

there was no evidence of component loosening. Of note there was evidence of some resorption of the patella on radiographs

results, the same technique following a total knee arthroplasty resulted in high failure rates [11]. Emerson et al. have reported on the use of an extensor mechanism allograft in TKA with reported good short-term results; however persistent extensor lag developed over time [8, 9]. Nazarian and Booth modified the original technique and recommended that allograft be tightly tensioned in full extension, yielding encouraging short- and midterm results [5]. We have reported

a comparison study which demonstrated tightly tensioning in full extension yielded excellent results and an average postoperative extensor lag of 4.3°, while not tightly tensioning the allograft resulted in a 100% failure rate [12].

Key Points

- The appropriate allograft for an extensor mechanism reconstruction can be very difficult

to obtain. It is important to contact the tissue bank several weeks prior to the surgical date and verify that the appropriate side has been ordered. It is also helpful for the allograft to be a similar size to the patient. The allograft must be a fresh frozen, non-irradiated allograft specimen consisting of a quadriceps tendon, patella, patella tendon, and tibial bone. It must have at least 3–5 cm of quadriceps tendon attached to the patella.

- It is imperative that full thickness flaps are created during the surgical exposure and that a midline incision, which utilizes the most lateral previous approach, is chosen. Wound healing is the primary concern with this surgical procedure as patients have usually had many prior surgical procedures. The skin of these patients is already tenuous, and the bulk of both allograft tissue and prosthetic component places more tension on the skin.
- Revise existing components if needed. Both the tibial and femoral components need to be assessed critically for malrotated or instability. If present, these problems were like a contributing factor in the extensor mechanism disruption, and failure to address suboptimal component positioning, rotation, or instability may result in premature graft failure.
- The allograft tibial tubercle bone block must be prepared and press fit into the native tibial trough to provide intrinsic stability to the graft. Failure to provide this mechanical stability may result in graft migration or failure of bone union.
- The proximal-distal location of the trough is critical to determine where the patella will articulate with the trochlear. With the leg in full extension, the allograft patella is placed at the top of the trochlea so that it fully articulates, and the location of the junction of the allograft tibial tubercle and allograft patellar tendon is marked on the native tibial tubercle.
- The allograft must be sutured into place as tight as possible with the knee in fully extended. While the extensor mechanism may appear overly tight, it is not. Failure to provide maximal tension on the graft will result in subsequent extensor lag.

- The host medial and lateral retinacular flaps are sewn over the allograft as much as possible in order to cover the allograft. Leaving the allograft under the skin usually results in a persistent subcutaneous skin reaction.

Option 2: Management of Extensor Mechanism Deficiency Using Knitted Polypropylene Graft

James A. Browne and Mark E. Mildren

Case Presentation

Case History

A 65-year-old male presented to our clinic with increasing pain and disability in his left knee 12 years following primary total knee arthroplasty by an outside surgeon. The patient had experienced a quadriceps tendon rupture, 4 years prior to presentation, and underwent primary repair without augmentation again by an outside surgeon, which failed almost immediately following this procedure. Upon presentation to our clinic, the patient was found to have complete extensor mechanism deficit as well as component loosening and active periprosthetic infection. He could not ambulate without a walker and failed an attempt at bracing. Given the failure of conservative management, he underwent two-stage revision, with the first procedure being static antibiotic spacer placement and patellectomy for a frankly necrotic patella in an attempt to eradicate his chronic infection. He represented after normalization of his inflammatory markers for the second-stage procedure.

Physical Examination

The patient was well nourished with a body mass index (BMI) of 34. He had been maintained in a cast given his static spacer. The knee showed a well-healed linear scar on the anterior aspect, without surrounding warmth or erythema. The knee was in anatomic alignment and, however, had no motion due to the static spacer. Ankle

plantar and dorsiflexion were all 5/5 strength. Distal sensation to the extremity was intact.

To rule out infection, blood work including erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were drawn as well as the knee aspirated and sent for cell count and culture. The lab work and aspirate were without signs of infection.

Radiographs and Advanced Imaging

Standing anteroposterior and true lateral views were obtained of the knee. These were consistent with static spacer placement with bone loss on the distal femur and proximal tibia.

Surgical Approach

After tourniquet placement, the supine patient is prepped and draped in the fashion typical for total knee arthroplasty. A standard midline incision utilizing the previous incision is made with typical dissection to the extensor mechanism as in revision knee arthroplasty, being cognizant to retain full thickness flaps on both the medial and lateral sides (Fig. 16.17). Both vastus medialis and vastus lateralis are mobilized to allow for excursion. This can be aided with placing a heavy tag stitch in each. In our patient, antibiotic cement needed to be removed prior to reimplantation (Fig. 16.18).

The knee is first prepared for revision knee arthroplasty components using standard techniques. Trial components are placed to confirm appropriate implant size and position as well as collateral ligament tension and stability. We



Fig. 16.17 Exposure of the antibiotic spacer with creation of full thickness medial and lateral tissue flaps

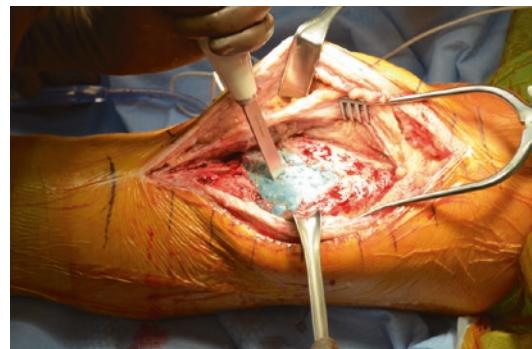


Fig. 16.18 Removal of the static antibiotic spacer



Fig. 16.19 The mesh is rolled over on itself to create a tubular structure approximately eight layers thick

recommend the use of a varus/valgus constrained prosthesis or hinge in the setting of extensor mechanism deficiency. Once satisfied with trial implants, attention is turned to preparing the knee for the extensor mechanism reconstruction. The synthetic mesh graft (Marlex mesh, CR Bard, Murray Hill NJ, USA) is prepared on the back table by rolling a single 25 × 35.5 cm sheet over on itself multiple times (Fig. 16.19), causing it to form the shape of a tube approximately eight to ten layers thick and 2–2.5 cm wide. This is then secured in place with a running #5 Ethibond or other heavy non-absorbable sutures (Fig. 16.20).

The synthetic mesh graft is always secured to the tibia in an intramedullary position. The exact technique to prepare the tibia depends upon whether or not the tibial component is being revised. In this case, a burr is used to create a trough on the anteromedial aspect of the tibia for

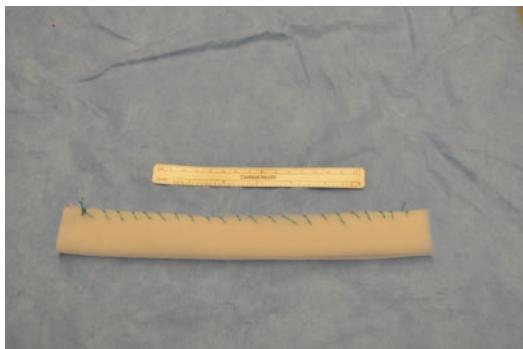


Fig. 16.20 The mesh is sutured in a running fashion with a heavy nonabsorbable suture



Fig. 16.21 Creation of an anteromedial trough in the tibia using a burr for placement of the mesh. The trials components are in place but can be removed to help facilitate this process

the graft to exit (Fig. 16.21). The graft is placed anterior to the tibial trial and exits the intramedullary canal in an anteromedial direction (Fig. 16.22). Care must be taken to ensure that several centimeters of the graft can be inserted into the canal to ensure adequate fixation. The graft is inserted prior to cementation of the tibial implant. The tibial prosthesis is then cemented into place using methyl methacrylate with the mesh adjacent to the tibial stem (Fig. 16.23). A periosteal elevator or freer can be used to be certain the graft remains in the canal and securely surrounded by cement. We choose a tibial stem that is at least 4–6 cm distal to the graft fixation to ensure tibial component fixation.

If the tibial prosthesis is to be retained, a burr is used to open up the anteromedial cortex of the tibia in a trough-like fashion. This trough is distal



Fig. 16.22 The mesh is inserted anterior to the tibial stem in an intramedullary position during tibial cementation, exiting out through the previously created trough. Care must be taken to ensure that several centimeters of graft are cemented into the canal



Fig. 16.23 The mesh exiting underneath the tibial baseplate

to the tibial tray, but proximal to the tibial tubercle, optimally placed slightly medial to the anterior tibial crest. Methyl methacrylate is used for fixation, with an additional screw and washer often placed for augmentation if there is adequate room for the screw in the metaphysis. The screw must be directed either medially or laterally to avoid the tibial keel/stem.

Once the methyl methacrylate has polymerized and the final implants are in place, a sleeve of scar or retinaculum is used as an interposition between tibial baseplate and the mesh to avoid abrasion of the graft on the polyethylene. This is accomplished by taking a sleeve of lateral tissue, passing it deep to the mesh and anterior to the tibial baseplate so that it lies between the graft and the polyethylene (Fig. 16.24). The tissue is



Fig. 16.24 A flap of lateral scar tissue or retinaculum is advanced to lie between the mesh and the polyethylene tibial insert, preventing abrasion of the graft



Fig. 16.26 A scalpel is used to create a rent in the lateral retinaculum to allow passage of the mesh from deep to superficial



Fig. 16.25 This tissue flap is sutured to the deep surface of the mesh

then sutured to the undersurface of the mesh using nonabsorbable sutures (Fig. 16.25). The mesh graft is then advanced from deep to superficial through a rent in the lateral patellar tendon scar or retinaculum (Figs. 16.26 and 16.27). Again, the vastus medialis and lateralis are extensively mobilized with blunt dissection to release adhesions. The knee is brought into extension, and the quadriceps muscles are pulled distally to restore patellar height (if the patella is present). The mesh is then brought proximally and laid superficially to the vastus lateralis so that the medial edge of the mesh lines up with the medial edge of the lateralis (Fig. 16.28). The mesh is secured to the lateral retinaculum, vastus lateralis, and remaining quadriceps tendon using multiple #5 nonabsorbable sutures with the graft and lateral quadriceps under tension (Fig. 16.29).

With the knee in extension, the vastus medialis is then further mobilized to allow its



Fig. 16.27 The mesh is passed from deep to superficial through the created rent



Fig. 16.28 With the lateralis mobilized and advanced, the mesh is laid so that it up with the lateral aspect of the quadriceps tendon and vastus lateralis. This is then secured in place under tension with multiple heavy nonabsorbable sutures

advancement over top of the graft in a lateral and distal direction (Fig. 16.30). This allows for a closure in a “pants-over-vest” fashion,



Fig. 16.29 Multiple nonabsorbable sutures are used to secure the mesh graft to the lateral retinaculum, vastus lateralis, and lateral split of the quadriceps tendon. Redundant mesh may be removed proximally



Fig. 16.31 The mesh is successfully covered in a “pants-over-vest” fashion so that no mesh is uncovered by soft tissue



Fig. 16.30 The vastus medialis is sufficiently mobilized laterally and distally to cover the lateral edge of the mesh. This is brought over top of the mesh and is secured with multiple heavy sutures

sandwiching the mesh between the deeper vastus lateralis and the now more superficial medialis, completely covering the mesh with host tissue. The medialis is secured to the mesh-lateralis construct with more #5 nonabsorbable sutures. This should be done in a manner so that no mesh is visible and completely covered by soft tissue (Fig. 16.31).

It is important to emphasize that this reconstruction is accomplished with the knee in extension and extensive mobilization distally of the quadriceps, especially the medialis, is required. It is also important to note that both the quadriceps and graft are secured under tension [13]. The repair should not be tested by bringing the knee into flexion following final suture placement.

Drains are placed deep to the reconstruction and the wound is closed in a layered fashion. Following wound closure, the patient is placed in a long leg splint and transitioned to a long leg cylinder cast prior to leaving the hospital.

Patients are immobilized in a long leg cast for 12 weeks and are allowed to be touchdown weight bearing during this time. We then gradually transition the patient to full weight bearing following cast removal using a hinged knee brace. They undergo a gentle increase in knee flexion over time. We progressively increase range of motion over the following 3 months: 0–30° during the first month, 0–60° the second month, and 0–90° during the third month [14].

Postoperative Result

Our patient experienced a rather uneventful recovery, with sutures removed 3 weeks postoperatively. He was transitioned out of the cast at 12 weeks following surgery. He was kept toe-touch weight bearing until cast removal, at which time he was transitioned to a hinged knee brace and made full weight bearing. The brace was continued for an additional 3 months following cast removal, with progressive knee flexion and strengthening with physical therapy. He obtained 90° of knee flexion at approximately 6 months post mesh reconstruction. Although he had a 10° extensor lag, he had a functional extensor mechanism and could ambulate with a cane. He had minimal pain and no signs of recurrent infection.

Clinical Results

As expected with this type of specialized procedure, no large trials exist confirming its results postoperatively. Browne and Hanssen produced the largest follow-up in patients with a mesh reconstruction for isolated patellar tendon disruption following total knee arthroplasty [15, 16]. Mean Knee Society pain and function both improved significantly. Excluding complications, the mean extensor lag for patients measured 2.8°. Of note, the ambulatory status of the patients fared extremely well with 10 of 12 patients being able to use stairs. Furthermore, the cost of the mesh is approximately one tenth of that compared to Achilles tendon allograft. The results of extensor mechanism reconstruction can be expected to be worse in those patients with periprosthetic joint infection when compared to those with aseptic failure.

Key Points

- Patients should be counseled that this is a procedure that necessitates extensive and protracted recovery period including 3 months in a cast following surgery.
- Infection must be ruled out in a patient with extensor mechanism disruption prior to undertaking a reconstruction.
- During the surgical approach, the quadriceps musculature must be extensively mobilized and advanced to secure the mesh graft under tension.
- The mesh must be fully covered in a “pants-over-vest” fashion, with the mesh laying between the medialis and the lateralis, so as to avoid irritation of the subcutaneous tissues and prevent wound complications
- The knee should *not* be taken through a range of motion following the mesh placement.

Option 3: Structural Proximal Tibia and Patellar Tendon for Chronic Rupture

Andrea BaldiniVincenzo Franceschini, and Michele D'Amato

Case Presentation

History and Physical Examination

The patient is a 60-year-old male with a BMI of 31. At the age of 54, he sustained an open tibial plateau fracture on the right knee with an associated external popliteal sciatic nerve palsy. The fracture was treated with an external fixator, but 6 months later, he underwent a total knee arthroplasty (TKA) because of malunion. Six months after surgery, the patient developed a sinus tract on the operated knee which was treated with antibiotic therapy with temporary relief of symptoms. After 3 years of intermittent antibiotic suppression therapy, he finally underwent a two-stage revision procedure with a static spacer followed by a semi-constrained stemmed TKA (Fig. 16.32).

When the patient came at our observation, the knee was swollen, painful, and with an evident sinus tract with purulent discharge on the antero-medial aspect of the proximal tibia. The knee had a range of motion from 0° to 100° and an extension lag of 20° with a palpable gap at the patellar tendon



Fig. 16.32 Radiographs of the patient at the moment he was referred to our service. It showed mobilization of the constrained implant

level. The knee was also unstable anteroposteriorly and at varus valgus stress, despite the semi-constrained articulation. Aspiration was positive to *Enterococcus faecalis* ampicillin-resistant.

At this time an antibiotic-loaded articulated cemented spacer was attempted but the fistula immediately recurred. Intraoperative culture at the time of the spacer was positive for *Klebsiella pneumoniae*. The spacer was explanted, and a resection arthroplasty was performed due to the high aggressiveness of the infection. Antibiotic therapy with meropenem and colistin was introduced. After 5 months the joint aspiration was negative for bacteria, but the cell count was still high. A cemented static spacer added with 10 g of vancomycin and 80 mg of gentamycin was performed. During this procedure the incompetent patellar tendon was reinforced with a synthetic hernia mesh (Prolene, Ethicon, Somerville NJ, USA) fixed on the tibia with the technique described by Hanssen et al. [15], as an attempt to solve the extensor mechanism insufficiency and to avoid another complex surgical step in the final procedure.

The patient has been casted for 2 months, and during the following months, he developed a progressive extension lag of approximately 40°, suggesting that the hernia mesh repair was not

completely efficient. The knee was dry, the skin was well healed, and all the clinical signs and the lab exams were negative for infection. A revision total knee arthroplasty with a hinged implant (Rotating Hinge Knee, RHK, Zimmer Biomet, Warsaw IN, USA) and with the use of a segmental proximal tibial graft inclusive of extensor mechanism was then planned.

Radiographs and Advanced Imaging

The preoperative x-rays are shown in Fig. 16.33. The anteroposterior and lateral x-ray views of the static spacer show a massive bone loss of the proximal tibia and patella lysis. The external fixator femoral pin, utilized as reinforcement of the static spacer, has been broken. The two screws that were used to fix the hernia mesh to the tibia are also evident.

Surgical Approach

Surgical exposure was performed extending the previous incision proximally and distally. The capsule, which was sutured in the previous surgery with the augmentation of a hernia mesh, was found intact. However, the patellar tendon was clearly still not competent. As a complete extensor mechanism graft was planned, a central

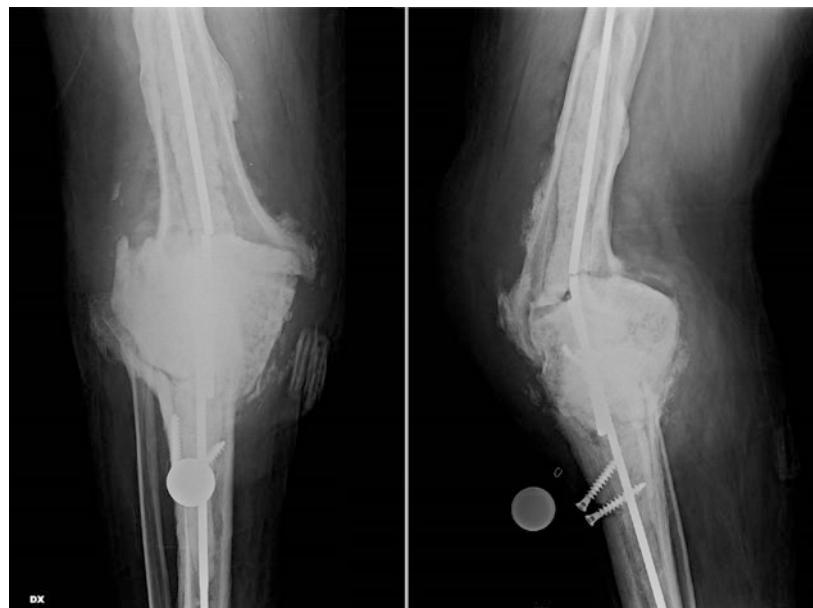


Fig. 16.33 Preoperative x-rays of the patient showing the rupture of the cemented static spacer and the two screws that were used to fix the hernia mesh

median arthrotomy was performed and the remnants of the patella were subperiosteally enucleated. The lateral and medial femoral gutters were cleared as well as all the adhesions in the suprapatellar pouch and on the rectus femoris in order to obtain sufficient exposure to the joint. Careful attention was paid in the removal of the broken cement spacer to avoid any additional bone loss on the tibial and femoral side. Gentle manipulation of flexion was performed after the spacer removal to gain some flexibility.

Bone loss according to Anderson Orthopaedic Research Institute (AORI) classification was 2B on the femur and 3 on the tibia. As a hinged implant was planned, the distal femur was reshaped and reduced in M-L size with a medial and lateral epicondylectomy in order to reduce the soft tissue tension and to help joint capsule closure.

The femoral side was prepared for a hybrid fixation: a cementless fixation with trabecular metal (TM) augments and cones was chosen for zones of sclerotic bone, while a cemented fixation was used in presence of medullary bone. According to that, epiphyseal fixation was enhanced with cementless TM augments (10 mm distal augments, 10 mm posteromedial and posterolateral augments) and a TM cone (size small 30 mm) was placed in the metaphysis. The definitive femoral component was then cemented on the epiphyseal and metaphyseal area, while a diaphyseal filling 17×130 mm stem was used.

The femoral distal joint line has been built up taking into account both the joint space in extension referring to the remnants of the lateral tibia and to the tension of the residual part of the extensor mechanism in flexion. Attention has been paid not to distalize the joint line more than 45 mm from the adductor tubercle as a hinged implant with an anti-recurvatum locking mechanism was used.

The tibial bone defect extended more widely on the medial side than the lateral one measuring 7 cm in depth from the tip of the fibula (Fig. 16.34). The stepped shape was then refined to the bone defect with the use of a saw blade in order to increase the stability of the graft/host bone construct (Fig. 16.35). The same shape was

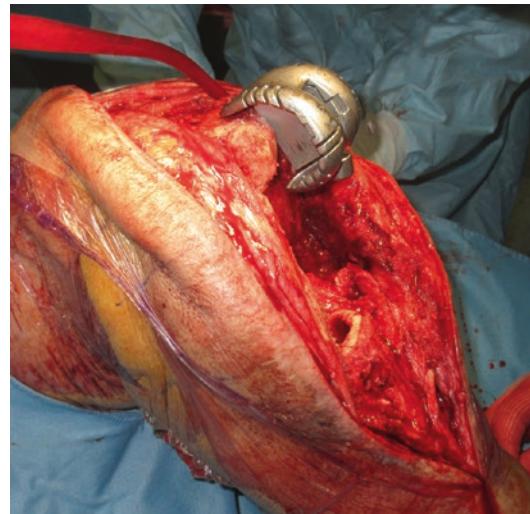


Fig. 16.34 Reconstruction of flexion and extension gaps was challenging as the tibial bone defect was severe measuring 7 cm in depth from the tip of the fibula



Fig. 16.35 The tibial bone defect was modeled to acquire a stepped shape in order to increase the stability of the graft. The defect extended more widely on the medial than the lateral side

reproduced over the graft. The graft was then positioned on the tibia, and the residual space in extension was checked under traction. The graft was modeled using intramedullary instrumentation to receive an RHK tibial component with a TM femoral cone (size small 30 mm off-label use) (Figs. 16.36 and 16.37). The TM cone was used an intramedullary temporary fixation device with its distal half portion inserted in the graft and its proximal half portion inserted in the host bone of the patient. Fixation in this zone would also provide long-term fixation of the tibia against subsidence and rotational forces in case of allograft resorption.

Tibial fixation was obtained with a hybrid technique. The proximal part of the tibial component was cemented to the proximal portion of the graft, and a diaphyseal filling 15 × 130 mm cementless stem was used to obtain fixation in the host tibial diaphysis. After the cement was hardened, a 14 mm hinged polyethylene liner was inserted.

Once the tibiofemoral joint was restored, the extensor mechanism insufficiency was then addressed by proximally suturing the quadriceps



Fig. 16.37 The tibial graft was remodeled to obtain the same size and shape of the native tibial bone defect



Fig. 16.36 The use of intramedullary instrumentation represents an easy and stable technique to remodel the tibial graft

tendon of the tibial graft with the remnants of the host quadriceps. Both the graft and the host quadriceps remnants were tightly tensioned in full extension with nonabsorbable #5 Krackow sutures, and the overlapping portions of autologous and graft tissues were sutured with nonabsorbable #5 and #2 sutures (Ethibond, Ethicon, Somerville NJ, USA), covering the graft as much as possible with the autologous tissue (Fig. 16.38). The correct patella height was chosen so that the proximal pole of the patella would have rested immediately proximal to the tip of the trochlea in full extension. A thorough washout and a meticulous wound closure were performed. After surgery the patient was placed into a long **leg plaster cast** in order to avoid any tension on the quadriceps tendon before its healing. The postoperative x-rays are shown in Fig. 16.39.

Postoperative Result

The plaster cast was maintained in full extension for 2 months, with partial weight bearing allowed from the second postoperative week after the wound has been healed. After 2 months the plaster cast was removed and physiotherapy began

allowing a slow progression of flexion (0–40° and then 15° every week). An extension brace was utilized for additional 2 months while walking. At 6



Fig. 16.38 The extensor apparatus was proximally sutured to the host quadriceps remnants while being tightly tensioned in full extension

months postoperatively, the patient did not show any recurrent sign of infection, was able to walk with one can for three blocks, and had 5° of extension lag and 90° of maximum flexion. The patient had no pain under weight-bearing activities and at rest. He still had to manage stairs with rail and one cane. His final level of satisfaction was high particularly because the authors proposed him an arthrodesis as the most valid salvage procedure alternative. The patient did not accept arthrodesis at that stage, and he was informed about the possible risks, including above-the-knee amputation. At 3-month follow-up, he stopped oral antibiotics (ciprofloxacin and amoxicillin) with a normal C-reactive protein (CRP) value. Close follow-up to detect a possible infection recurrence was undertaken and continued up to the midterm.

Discussion

Severe tibial bone loss represents a technical challenge for surgeons performing revision knee arthroplasty. AORI type 3 tibial defects are characterized by extensive loss of metaphyseal bone with possible damage to the collateral ligaments and, as in our case, of the extensor mechanism (EM) [17]. The remaining metaphyseal bone is usually sclerotic or fragile and do not provide an adequate surface for cement fixation.



Fig. 16.39 (a, b) Postoperative x-rays of the patient

Surgical options for large uncontained type 3 tibial defects include reconstruction with structural allograft, metaphyseal sleeves or cones, and megaprosthesis.

According to Dorr et al., structural allograft reconstruction is indicated in the presence of tibial defects involving >50% of the osseous support of either tibial plateau [18]. However, in the current case, the choice of a segmental proximal tibial allograft for reconstructing the metaphysis was inevitable as the EM was insufficient and there was no tibial bone available to fix a tendon graft or even a full EM allograft alone. In addition to that, the synthetic hernia mesh that was used in the previous surgery to reinforce the patellar tendon failed as demonstrated by the significant extension lag (40°) experienced by the patient. For these reasons, a segmental proximal tibial allograft that included the EM was performed.

Advantages of structural allograft reconstruction include the ability to create any shape or size of construct according to the bone defect, excellent support of the revision implant, and the biologic potential for bone stock restoration. Disadvantages include a minimal risk of disease transmission and risks of allograft nonunion, malunion, collapse, or resorption. This reconstructive approach requires careful preoperative preparation and a meticulous operative technique in order to (1) match the specimen with the host defect size; (2) develop a healthy, bleeding host recipient site; (3) maximize surface contact between the allograft and the host bone; (4) optimize mechanical interlock between graft and host; and (5) guarantee strong implant fixation without instability or malalignment.

In the current case, the interlock between graft and host was obtained by using a TM cone that was also useful to enhance long-term fixation of the tibia against subsidence and rotational forces. Tibial fixation was performed according to hybrid technique with cemented proximal portion in the graft and cementless fluted stem in the tibial diaphysis. The use of stem extension is critical to offload the structural allograft during incorporation.

Although it is difficult to compare the results of published series as they differ in type of graft fixation, length and type of stem fixation, and

constraint of the implant, several studies have reported the long-term outcomes of structural allografts with an average 74% graft survivorship at 10 years [19–21].

Engh et al. in a series of 46 knees with an AORI type 3 defect reported an 87% good-to-excellent outcome at a mean follow-up of 4.2 years. They noted only four failed allografts, two of which were secondary to infection. No allograft collapse or aseptic loosening was observed at a mean of 7.9 years [17].

However, Clatworthy et al. reported a less favorable allograft survival rate of 72% at 10 years in a series of 52 revision procedures for patients with large, uncontained osseous defects treated with structural allografts. They reported 11 failures because of infection (four), graft resorption (five), and allograft nonunion (two) [20].

Bauman et al. reviewed 70 revision TKA cases treated with structural allograft reconstruction and followed for a minimum of 5 years. Eight failures related to the allograft were found, and a revision-free survival rate of 75.9% at 10 years was reported [19].

Finally, a recent systematic review involving 551 structural allografts with a mean follow-up of 5.9 years described a 6.5% rate of graft failure, a 3.4% rate of aseptic loosening, and a 5.5% rate of infection [22].

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Alfred J. Tria, Jason M. Jennings, Raymond H. Kim,
Aldo M. Riesgo, and William L. Griffin

Introduction

Alfred J. Tria

Periprosthetic femur fractures are the most common fracture that leads to total knee arthroplasties [1]. The evaluation of the injury must first consider whether the fracture is displaced or not. The undisplaced fracture can be treated nonoperatively with various external supportive devices. The displaced fracture will require operative intervention in order to allow ambulation and subsequent range of motion activities. If the fracture is displaced, the femoral component must be eval-

uated for stability. If the component has enough underlying bone attached to it, fixation with component preservation may be possible. The fixation can involve either intramedullary rod fixation or an external plate technique. If the femoral component is completely loose from any underlying bone, replacement is the only alternative. The area of debate concerns the value of internal fixation versus replacement when there is that clinical choice [2]. Internal fixation preserves the original implant but exposes the patient to a longer period of recovery and possible nonunion [3]. Total replacement is much more invasive but may be more predictable [4]. There are no large series that compare these two techniques. The case presentations here will review the options and clarify the results that are available at the present time.

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Option 1: Management of Periprosthetic Femur Fracture—Open Reduction Internal Fixation (ORIF)

Jason M. Jennings and Raymond H. Kim

Case Presentation

History

A 72-year-old female presented 10 months after an uncomplicated left total knee arthroplasty

with a distal femoral periprosthetic fracture. The patient reported a ground level fall off of her motorized scooter which caused her to land directly onto her left knee. There were no other associated injuries.

Physical Examination

Examination of the patient's left lower extremity revealed superficial abrasions over her anterior knee from a fall. Her motor function was grossly intact distally; however, sensation was markedly decreased throughout the foot secondary to pre-existing neuropathy. She had 2+ dorsalis pedis and posterior tibial pulses, and her foot was well perfused. Her previous anterior midline incision was well healed. Her thigh and lower leg compartments were soft and compressible. The remainder of the physical examination was deferred secondary to her fracture; however, previous clinical notes revealed her preinjury range of motion was 3–115° with central patellar tracking and no signs of instability.

Radiographs and Advanced Imaging

Two views of the distal femur were obtained which demonstrated a distal femur periprosthetic fracture without signs of implant loosening (Figs. 17.1 and 17.2). Advanced imaging was not performed for this case; however, if there is uncertainty regarding extension of the fracture into the implant, the authors have a low threshold to obtain a computed tomography (CT) scan.

Surgical Approach

The patient is placed in a supine position on a radiolucent table with a bump under the ipsilateral extremity. A lateral-based incision is utilized distally to allow exposure over the distal femoral condyle for placement of the distal femoral locking plate through a minimally invasive approach. Direct visualization of the fracture is not required. The iliotibial band is split, and the vastus lateralis is elevated with an emphasis on minimal soft tissue disruption. The implant is inspected to assure there are no signs of loosening which should confirm what has been observed with preoperative radiographs and advanced imaging such as a CT scan if indicated. An appropriate size distal femoral locking plate is selected and placed from



Fig. 17.1 Attempted anteroposterior (AP) view of the distal femur demonstrating a distal



Fig. 17.2 Lateral view demonstrating the distal femur fracture without signs of implant loosening

distal to proximal in a submuscular fashion to avoid extensive soft tissue stripping until the most distal portion of the plate is oriented properly on the lateral condyle. The aiming arm, which allows for the proximal insertion of screws

percutaneously, may be placed at this time or after fracture reduction. We have found it advantageous in larger patients to attach the aiming arm after insertion of the plate to avoid impinging the lateral soft tissues during insertion. Fluoroscopic imaging may be indicated to determine the length of the plate and to assure that it is resting distal enough on the femur. The plate is then provisionally fixed with 1–2 Kirschner wires distally. The fracture is then indirectly reduced with a combination of traction and an appropriate coronal stress. Sagittal alignment is typically influenced by the deforming force of the gastrocnemius causing a posterior moment on the distal fragment. This deformity is typically controlled with a bump or a radiolucent triangle under the distal fragment creating an anterior-directed force for appropriate reduction. The anesthesiologist should be instructed to perform complete muscle relaxation while performing these maneuvers to allow ease of reduction. Appropriate length and rotation is confirmed with fluoroscopic imaging. Proximal fixation is then secured with provisional Kirschner wire fixation. Fluoroscopic imaging once again confirms on the anteroposterior and lateral views appropriate placement of the distal femoral locking plate. Minor corrections in the coronal and sagittal planes are still possible prior to placing the cortical and locking screws. Locking screws are then incorporated distally, followed by four (or more pending the fracture pattern) proximal cortical screws in a percutaneous fashion allowing for appropriate bridging of the distal femoral fracture (Figs. 17.3 and 17.4).

Postoperative Results

This patient's weight-bearing was limited to toe touch for the first 12 weeks with a hinged knee brace. Her knee brace was locked in extension for the first 2 weeks, and we then increased her range of motion from 0° to 80° with an increase in range of motion 20° weekly as she was able to tolerate. In general weight-bearing status is dictated on fracture reduction and bone quality. Many patients may begin range of motion sooner than this patient, and some patients may begin progressive weight-bearing as early as 6–8 weeks.



Fig. 17.3 Anteroposterior (AP) intraoperative view demonstrating placement of the distal femoral locking plate with restoration of length and coronal alignment

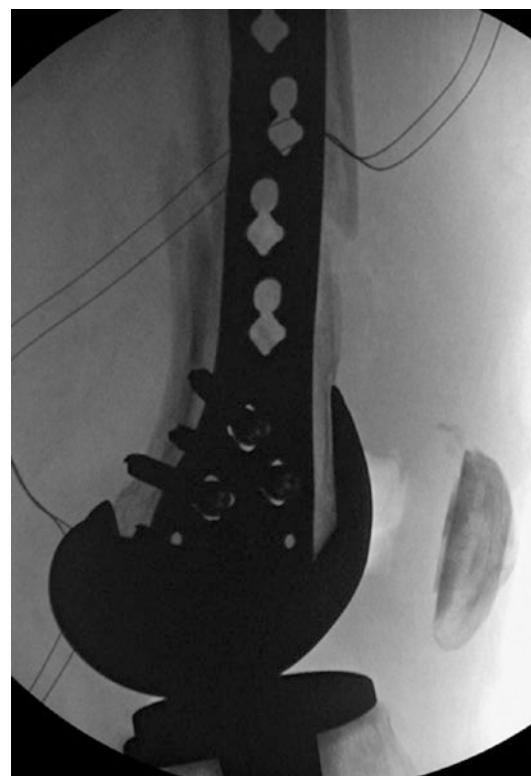


Fig. 17.4 Lateral intraoperative view demonstrating relative restoration of sagittal alignment

The patient's range of motion at last follow-up was 0–115° without pain, and she had returned to her previous preinjury function with her activities of daily living without limitations. Follow-up radiographs show healing of her distal femoral fracture with abundant callus formation at 3 and 6 months postoperatively (Figs. 17.5 and 17.6).

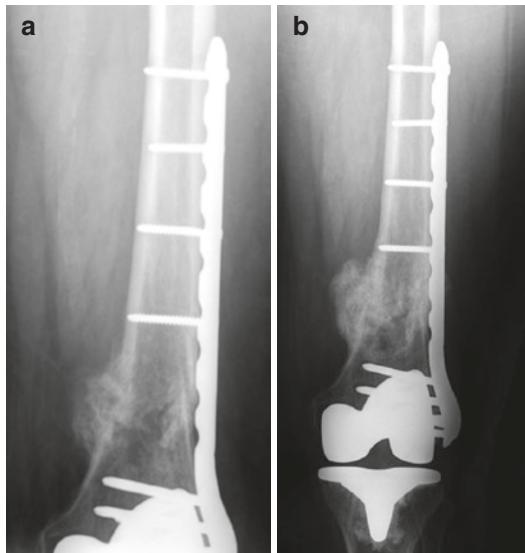


Fig. 17.5 Anteroposterior (AP) postoperative radiographs showing distal femoral fracture at (a) 3 months and (b) 6 months with abundant callus formation

Clinical Results

The incidence of periprosthetic fractures after TKA is approximately 2.5% [5]. Supracondylar periprosthetic fracture management is dictated based on fracture location and whether the implant is loose or stable. Previous classification systems have been described [6–9] (Table 17.1). Fractures around a stable femoral component are typically treated with intramedullary nailing or distal femoral locking plates. For the purpose of this discussion, we will focus on the stable total knee implant with an associated periprosthetic distal femoral fracture.

Intramedullary nailing fixation is advantageous because it limits soft tissue disruption and biomechanically may be superior to locking plating [10]. Some evidence suggest modern intramedullary nail fixation may result in less nonunions/delayed unions [11]. However, most reports consider these rates to be similar between these two types (plate vs. nail) of fixation [12, 13]. Intramedullary nailing cannot be performed in many patients secondary to fracture location and bone stock as well as access issues to the intercondylar notch, particularly in a posterior stabilized design.

The use of an indirect reduction technique with current locking plates as described in the above

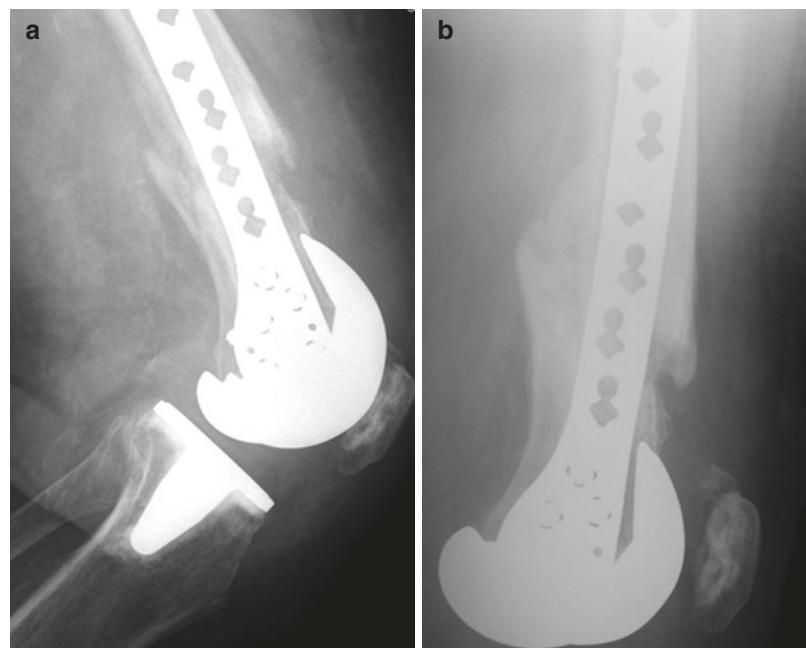


Fig. 17.6 Lateral postoperative radiographs showing distal femoral fracture at (a) 3 months and (b) 6 months with abundant callus formation

Table 17.1 Supracondylar periprosthetic fractures: classification system

Study	Type/group	Description
Neer et al. [8]	Type I	Nondisplaced (<5 mm displacement and/or <5° angulation)
	Type II	Displaced >1 cm
	Type IIa	With lateral femoral shaft displacement
	Type IIb	With medial femoral shaft displacement
	Type III	Displaced and comminuted
DiGioia and Rubash [7]	Group I	Extra-articular, nondisplaced (<5 mm displacement and <5° angulation)
	Group II	Extra-articular, displaced (>5 mm displacement or >5° angulation)
	Group III	Severely displaced (loss of cortical contact) or angulated (>10°); may have intercondylar or T-shaped component
Chen et al. [6]	Type I	Nondisplaced (Neer type I)
	Type II	Displaced and/or comminuted (Neer types II and III)
Lewis and Rorabeck [9]	Type I	Nondisplaced fracture; prosthesis intact
	Type II	Displaced fracture; prosthesis intact
	Type III	Displaced or nondisplaced fracture; prosthesis loose or failing

case is applicable to most patients and prosthetic designs. Locking plates afford the advantage of limited soft tissue stripping over conventional plating in addition to superior biomechanical properties [14]. Locking plate fixation reduces the incidence of overall complications, nonunion, malunion, loss of reduction, and additional surgeries compared with traditional non-locking plate fixation [15]. Multiple studies have reported reasonable union rates with locked plating for distal femoral periprosthetic fractures [16–19]. Similar to intramedullary nail fixation, locking plates promote early mobilization which may promote clinical healing [19, 20]. Locking compression plates have also been shown to be an effective form of management of distal femoral fractures around long stem TKAs [21].

Most studies show no significant differences in nonunion, revision rates, or clinical outcomes when comparing intramedullary nail vs. locking plate fixation of distal femoral periprosthetic fractures [22, 23]. Ristevski et al. [13] showed no significant differences with regard to nonunion rates or rate of secondary surgical procedures in a recent systematic review. There was a significantly higher malunion rate with intramedullary nailing when compared with locked plating; however, the significance of this finding is unknown. Similarly, Li et al. [12] in their meta-analysis found no differences in 6-month union rate, union time, or complication rates between the two methods of fixation. In contrast to the above findings, others have reported a potential greater union rate [24] and decrease complication rate [24, 25] with locked plates in certain fracture types. Whereas others have reported intramedullary nail fixation being superior in terms of nonunion and complication rates [11]. One study defined the risk factors specific for failure after locking plate fixation which included open fracture, diabetes, smoking, increased body mass index, and shorter plate length; however, they concluded most factors are out of the surgeon's control [26]. Given the paucity of evidence directly comparing intramedullary nailing and locked plating techniques for periprosthetic fractures of the distal femur, further research is warranted in this area. Regardless of the device chosen, secure distal fragment fixation must be achieved for predictable healing.

Despite significant advances in surgical technique (nail vs. locking plate) and regardless of the fracture type or implant design, the treatment of periprosthetic femur fractures above a TKA remains a challenge. The overall complications in this patient population remain high, including mortality [11, 18, 27, 28], and many patients will continue to experience persistent disability [17, 28–30].

A distal femoral replacement megaprosthesis may be warranted in low-demand patients with a loose implant and/or poor bone stock (Figs. 17.7 and 17.8). Recent data suggest that in certain fracture types, a distal femoral replacement may lead to better functional outcomes at 1 year [30]. Lastly, a salvage technique combining intramedullary



Fig. 17.7 Anteroposterior (AP) view of a distal femoral fracture with significant comminution and loss of bone stock

nailing augmented with bone cement has been described in patients where a standard retrograde nail or plating alone is inadequate in severely osteoporotic bone [31]. This may be reasonable in this patient population; however, the authors of this chapter are unable to comment on this technique since we have not utilized this in this patient population.

Key Points

- Implant stability and bone stock will determine the method of fixation.
- A CT scan may be helpful preoperatively to determine the fracture pattern and implant stability.



Fig. 17.8 Lateral view of a distal femoral fracture with significant comminution and loss of bone stock

- Most fractures can be treated with internal fixation (locking plate vs. intramedullary nail) utilizing the basic principles of fracture management.
- Minimally invasive techniques have increased union rates and decreased overall complications compared with traditional plating methods.
- Despite these surgical advances, nonunion remains a concern regardless of fixation type, and the overall complication rate in this patient population remains high, including mortality.
- In general, primary distal femoral replacement is reserved for low-demand patients with a loose implant and/or poor bone stock.

Option 2: Distal Femoral Replacement

Aldo M. Riesgo and William L. Griffin

Case Presentation

History

The patient is a 74-year-old female who presented with right knee pain and deformity after a fall from a standing height. She is 12 years status post total knee arthroplasty (TKA) for significant osteoarthritis with valgus deformity performed at an outside institution. At her baseline, she was quite pleased with her clinical result and did not use an assistive device to ambulate. After her fall, the patient was brought to an outside emergency department. She was transferred to our medical center for definitive surgical care.

Physical Examination

Height 5'5", weight 187 lb., body mass index 31.1 kg/m². She is nonambulatory currently due to pain from her fall. Her extremity examination reveals significant varus deformity and shortening. Her skin is intact with mild ecchymosis in the thigh with a well-healed midline anterior knee incision. Range of motion testing was deferred, but prior examinations revealed 0–115°. No palpable defect of the extensor mechanism is noted at time of injury. Examination of the leg reveals no other abnormalities. Palpable pulses are noted. Motor and sensory examination is unremarkable.

Radiographs and Advanced Imaging

The primary total knee required a tibial intramedullary stem and a lateral augment for the valgus deformity (Fig. 17.9). The injury films showed a comminuted periprosthetic distal femoral fracture with minimal bone remaining on the femoral component (Fig. 17.10).

Surgical Approach

The patient was positioned supine with a standard total knee setup. The prior surgical incision was identified, and full-thickness flaps were made down to the extensor mechanism. In this case, a standard medial parapatellar approach was used leaving a 1 mm cuff of medial quadriceps tendon proximally. The arthrotomy was extended distally to the level of the tibial tubercle. If extension of the arthrotomy is necessary or

the exposure is particularly difficult, our preference is to begin with a quadriceps snip. Quadriceps turndowns or tibial tubercle osteotomies are usually unnecessary in this setting of periprosthetic fracture since removal of the distal femur creates significant space.

Recreation of the medial and lateral gutters is performed. All hypertrophic scar is debrided systematically to the depth of the normal supracondylar fat and underside of the vastus. The superior lateral geniculate vascular bundle is identified, and a partial lateral release is performed with preservation of the bundle. This allows for improved access to the lateral gutter. The patellar component is inspected for signs of loosening. In this case, it was not revised.

If possible, bony landmarks should be used to try and assess anatomic rotation of the distal femur. Longitudinal traction can be used to help determine appropriate rotation that is then scored on to the remaining distal femur as a guide for implantation. The linea aspera can also be identified and



Fig. 17.9 Anteroposterior and lateral views of the right knee prior to trauma. Well-fixed hybrid total knee arthroplasty (Vanguard SSK Revision Knee System, Zimmer Biomet, Warsaw IN, USA) with stemmed tibial component. Lateral hemiplateau augment used due to lateral tibial bone loss from severe valgus osteoarthritis. Note the presence of osteolysis behind the femoral component and underneath the tibial baseplate

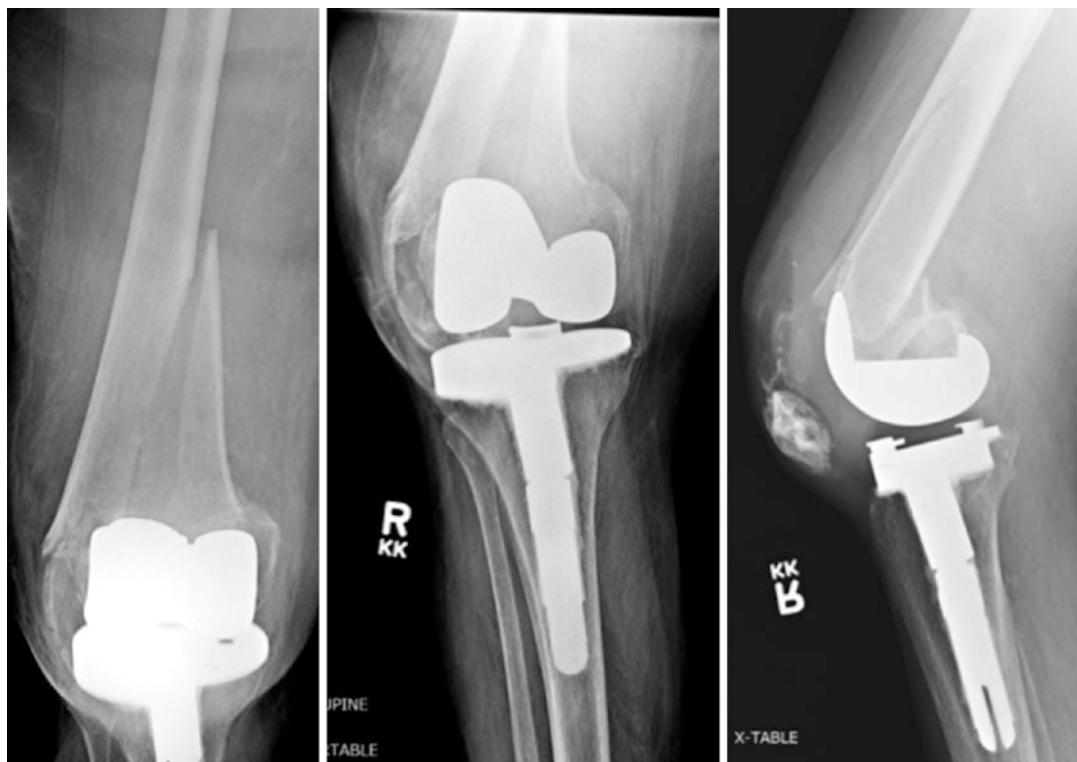


Fig. 17.10 Anteroposterior and lateral views of the right knee demonstrating a comminuted periprosthetic supracondylar femur fracture. Note the large medial butterfly fragment extending proximally

used as a landmark if too much comminution is present. At this point, the collateral ligaments are removed subperiosteally with electrocautery. A small, sharp bone hook is then passed underneath the anterior flange of the femoral component. With an assistant providing gentle anterior traction with the bone hook, the femoral component with attached distal femoral bone is dissected subperiosteally from proximal to distal. All posterior capsule is left undisturbed to protect the neurovascular structures. The femoral component and associated bone is then removed (Fig. 17.11). The removed segment is measured to plan for appropriate reconstruction with the distal femoral replacement.

The fracture site of the distal femur is exposed and a freshening cut is made. The minimum amount of distal femur is resected to accommodate the distal femoral replacement component. Preservation of metaphyseal bone facilitates the use of cones or sleeves to augment metaphyseal fixation of the final reconstruction. In this case,

the large medial butterfly fragment was anatomically reduced and stabilized with two Luque wires. The Luque wires should be twisted and not cut at this point. The twisted loop can serve as a retractor and elevator of the femoral diaphysis, providing control of the femur during further preparation.

Attention was then turned to the tibia. It was translated forward and retractors were placed laterally. The implant-bone interface was identified, and the tibial component was removed with a combination of micro-sagittal and reciprocating saw blades and osteotomes. To expose the lateral augment, a release of the lateral capsule off the anterolateral tibia was performed with careful retraction of the patellar tendon.

There was significant osteolysis beneath the tibial baseplate. Despite meticulous technique during removal, there was a considerable amount of lateral tibial bone loss after component removal. The proximal tibia was then prepared

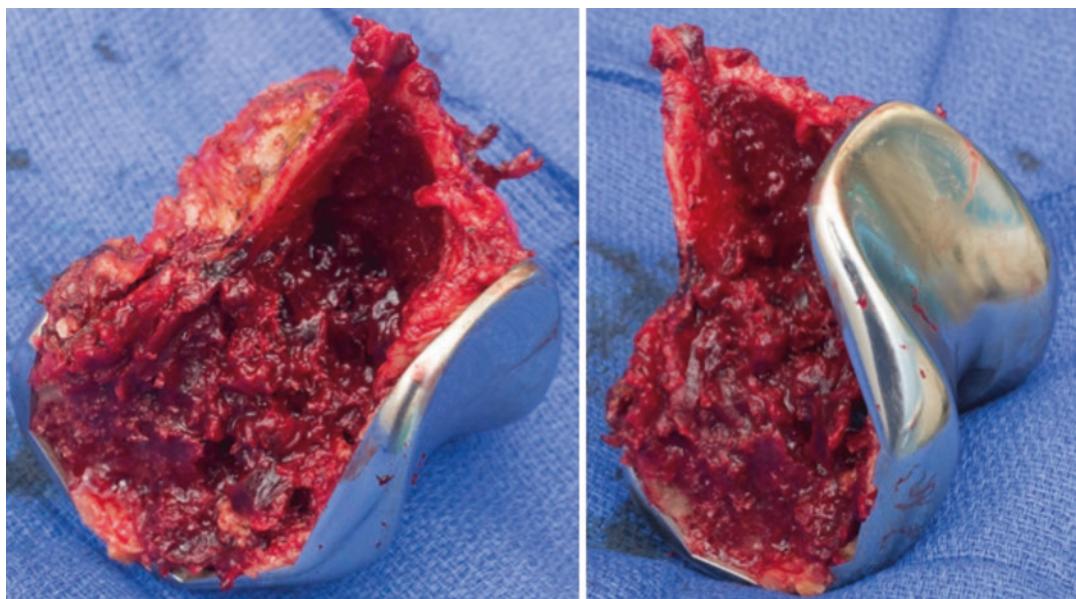


Fig. 17.11 Intraoperative photo of femoral component with associated bone. Note osteolysis and compromised cortical bone stock prohibiting attempt at internal fixation

for an asymmetric tibial cone. Our preference is to use cemented stems that can be shorter and do not need to fully engage the diaphysis, especially when metaphyseal fixation cones are used.

On the femur, a long diaphyseal engaging stem is used to sufficiently bypass the medial fracture. There was insufficient femoral metaphysis to accept a metaphyseal cone. The intramedullary canals were sized and reamed to only 2 mm larger than final implant. This preserves as much cancellous bone as possible to allow for cement interdigitation. Appropriately sized trials were inserted, and an intraoperative radiograph was obtained to confirm alignment and sizing and assess for iatrogenic fractures during implant removal. At this point, femoral rotation is set. Setting appropriate external rotation is difficult whenever the epicondyles and collateral ligaments are absent. If an appropriately rotated implant is present, scoring the anterior cortex prior to implant removal helps determine appropriate rotation during implantation. This can be difficult to assess in the periprosthetic fracture setting, however. The linea aspera can also be identified and used as a landmark to confirm appropriate rotation. With the trials in place, an

additional 3–5° of external rotation can usually be incorporated. Patellofemoral dislocation is a common cause of failure in distal femoral replacements. In our experience, there is little downside to additional external implant rotation in a hinged device, but significant downside to poor patellofemoral tracking. All trials were removed, and after preparing the bone for cementation, the implants were cemented into appropriate position.

Postoperative Result

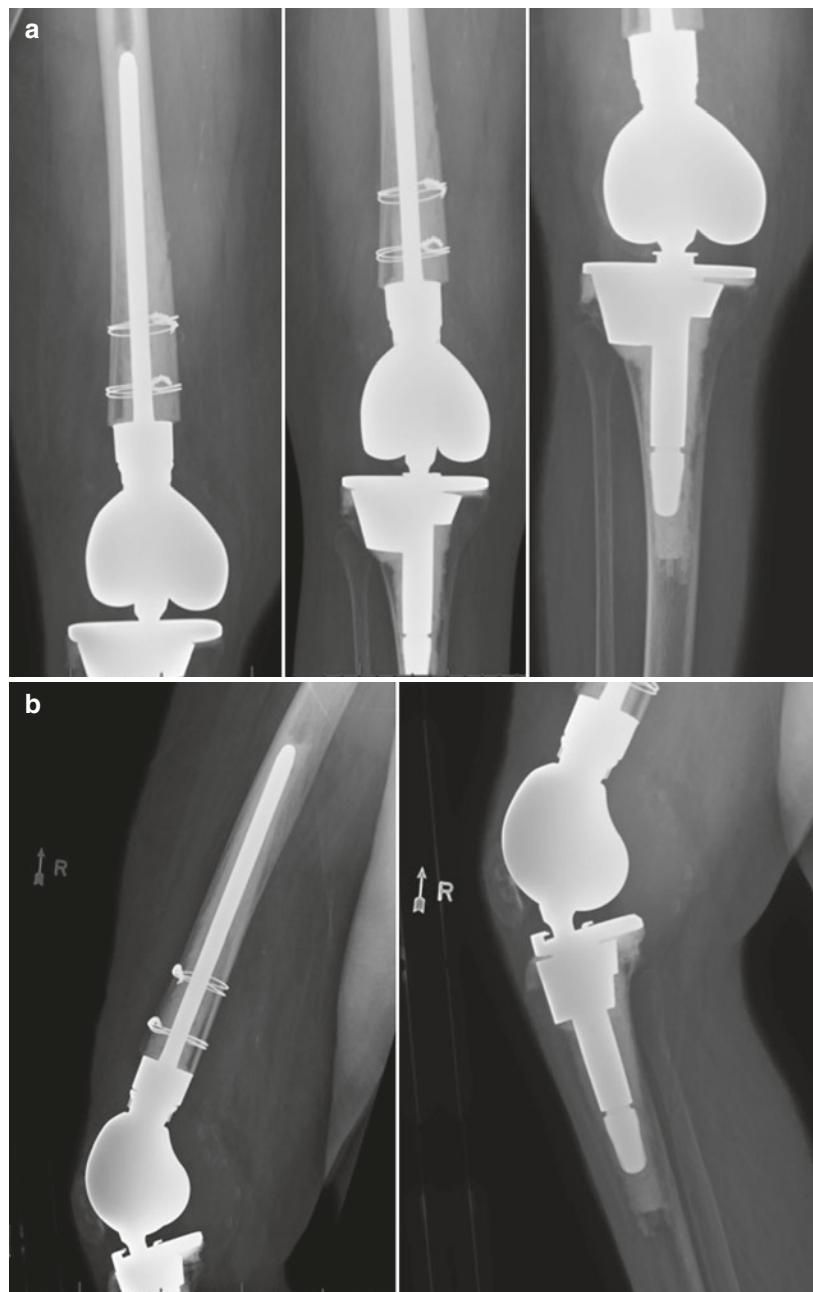
The patient was made weight-bearing as tolerated immediately postoperative. She progressed well and at 3 months had regained all abilities for activities of daily living with a walking tolerance of 1 mile. Knee range of motion is 0–110° (Fig. 17.12).

Clinical Results

Distal femur fractures are the most common periprosthetic fractures following TKA [1]. While the optimal treatment of periprosthetic distal femur fractures remains controversial, appropriate stability with standard internal fixation is difficult to obtain in very distal fractures with

Fig. 17.12 (a, b)

X-rays taken 3 months postoperatively show well-fixed cemented implants (Zimmer Segmental System distal femoral replacement with trabecular metal tibial cone, Zimmer Biomet, Warsaw IN, USA)



associated osteopenia and osteolysis [17]. When there is inadequate bone for distal fixation, distal femoral replacement is an attractive option in patients with poor bone stock [32, 33]. Some authors have suggested that revision arthroplasty offers improved chance of both survival and avoidance of reoperation in the setting of periprosthetic fractures [34–36].

There are few published series assessing distal femoral replacement for the management of supracondylar periprosthetic fractures. While the overall failure rate is low and short-term patient outcomes are improved compared to internal fixation, there is a substantial complication rate (up to 33%) associated with distal femoral replacement for periprosthetic fractures [4, 37].

In a review of 291 periprosthetic fractures from our institution, we found 13% mortality and 12% revision rates in all periprosthetic fractures at 1 year. The risk of reoperation and survival is improved in distal femoral replacements when compared to those patients treated with open reduction and internal fixation [36].

In an elderly population, high nonunion and fixation failure rates have been reported following open reduction internal fixation (ORIF) of distal femur periprosthetic fractures [38]. In a recent study from our institution looking at distal femur fractures without a prosthesis, 20% of patients older than 70 years developed a nonunion after ORIF of an intra-articular distal femur fracture. At 1-year follow-up, all patients in distal femoral replacement (DFR) group were ambulatory, while one in four in the ORIF group was wheelchair bound [2]. While this cohort did not include periprosthetic fractures, it does highlight the potential downside of internal fixation in the elderly. The short-term results of DFR appear to be durable. A recent study with an average 4-year follow-up demonstrated that the functional scores (Harris HipScore, OxfordHipScore, Funktionsfragebogen Hannover, and SF-36 Questionnaire) of DFR patients were slightly higher, and their visual analog scale (VAS) scores were significantly lower than the scores of the patients after ORIF [39]. Long-term results and substantial follow-up, however, are limited in this elderly population.

With high reported loosening rates with cemented megaprosthesis [40], our preferred technique to is to use supplemental metaphyseal fixation and short cemented stems that do not fully engage the diaphysis. Cementing into meta-diaphyseal bone allows for better interdigitation and fixation than cementing into diaphyseal bone. There is substantial literature to support the use of metaphyseal cones or sleeves in the revision TKA setting [41–43]. Whenever possible, cones or sleeves should be used in combination with DFR. In elderly osteoporotic patients, cementless fixation should be avoided.

Key Points

- Medial parapatellar arthrotomy is preferred exposure.
- Extensile exposures are usually unnecessary.

- Mark rotation of femoral component on anterior cortex of femur prior to removal if possible. Linea aspera can be used for reference. If not, use trials and add additional external rotation.
- Must measure removed femoral component, fracture site, and planned “freshening” osteotomy to ensure that sufficient resection has been made for each corresponding implant (e.g., Zimmer Segmental requires 90 mm resection).
- Removal of components should be meticulous and systematic using thin saw blades and osteotomes. Avoid unnecessary bone loss in osteoporotic patients.
- Use Luque wire around remaining femur for prophylaxis against fracture propagation and to provide control of femur during preparation.
- Low threshold to perform lateral release if patellar maltracking is noted.
- Patella should be inspected and rarely needs to be revised.
- Supplemental metaphyseal fixation with cones/sleeves is encouraged.
- Longer stems should be used when bypassing fractures.
- Avoid cementless fixation in elderly osteoporotic bone.

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Management of Failed Unicondylar Arthroplasty

Fred D. Cushner, Christopher Dodd,
Hemant Pandit, and David J. Mayman

Introduction

Fred D. Cushner

The Failed UNI

The success of partial knee arthroplasty is well described in the literature. Both mobile-bearing knee and fixed-bearing knee designs have good long-term survivorship described in the literature. While long-term success is well described, there is still a certain amount of failures that are noted and revision of this partial knee is required. Because only a partial knee is performed, one could argue that there is inherent risk of revision for the unhappy patient. For example, a TKA patient with anterior knee pain may be sent to physical therapy,

told to lose weight, and prescribed some activity modification. Given the nature of a full revision, it is often done only as a last resort. But if you take the same patient with anterior knee pain who had a partial knee arthroplasty at their indicated procedure, then it is often claimed that this patient is more likely to get revised. Perhaps it would be revised because of the unresurfaced patella or perhaps revised cause the patient is unhappy, but it often does appear to be a double standard when it comes to revision of partial knee arthroplasty.

Sierra et al. reviewed the multicenter experience with revision of partial knees and found 175 revisions over a 14-year period [1]. The average time to failure was 71.5 months with a revision rate of 4.5% noted. The most common reasons for revision were femoral/tibial loosening (55%) and progression of the arthritis (34%). Less common reasons for revision were polyethylene failure (4%) and infection (3%).

It is interesting to note that a second study evaluating unicompartmental knee arthroplasty versus total knee arthroplasty in patients over 75 years of age did not have similar results [2]. The partial knee patients demonstrated shorter OR time, shorter hospital stays, and less blood loss and transfusions. They also demonstrated better range of motion and increased activity at the time of hospital discharge. In this series, there was no difference in Knee Society scores or survivorship at midterm analysis.

What is clear from these studies as well as others is that early failure is often related to surgical

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error. For example, poor cement technique can often lead to failure of the tibia, while overcorrecting the deformity can lead to overload of the opposite compartment leading to degenerative changes in the originally uninvolving compartment. Even polyethylene wear can be secondary to surgical technique. If proper component positioning is not achieved, then edge loading can occur leading to increased poly wear, hence failure.

What is clear from the literature is that there is learning curve with partial knee arthroplasty, and it has been suggested that those who rarely perform this procedure may be more at risk for early prosthesis failure. Fortunately, with the advent of new technology, this learning curve may be less steep. Robotic technology has already shown improved radiographic appearance, and long-term studies are needed to see if this will improve survivorship.

If revision is required, the options include adding another partial knee to the other compartment or

To convert the partial to a total knee arthroplasty is a “slam dunk,” meaning not much more difficult to perform than a primary, and primary component can be utilized [3, 4]. Sierra et al. in their revision paper found out this is often not the case with complex deformities and bone loss often encountered.

Thienpont describes the early revision of a failed uni and for late-stage revision to be avoided so more severe deformities are not encountered. In other words, early intervention may allow the use of primary components rather than a revision prosthesis.

As with most of orthopedics, the key to prevent revision of a uni-arthroplasty is prevention and proper surgical technique is the key for this to occur.

Option 1: Converting Medial Unicondylar Arthroplasty to Total Knee Arthroplasty

Christopher Dodd and Hemant Pandit

Case Presentation

History

A 79-year-old man presented to our practice with a history of increasing pain and swelling in his left knee aggravated by weight bearing. He had

also noticed a slight change in the alignment of his knee with increased medial angulation over the past 6 months.

The patient had undergone an Oxford unicompartmental knee arthroplasty (UKA) 11 years previously and had an excellent clinical outcome and function for the past 10 years. His Oxford Knee Score (OKS) at the time of presentation to our office was 31 (out of a maximum of 48), which was a significant worsening as compared to that at his previous routine follow-up visit at 10 years (OKS 41/48). He also suffered from chronic obstructive pulmonary disease and was on antihypertensives and anticoagulants for unrelated medical conditions. He had suffered a mini-transient ischemic attack 12 months previously without any residual weakness.

Physical Examination

Clinical examination revealed a well-healed medial parapatellar incision on the left knee with a large effusion. The knee was stable, and the valgus deformity was correctible to neutral with varus stress. There was no distal neurovascular deficit, and hip and spine examinations were unremarkable.

Blood counts were normal (in particular, inflammatory markers were not raised), and the patient was cleared for surgery (ideally under regional anesthetic and a short surgical procedure in view of his comorbidities).

Radiographs and Advanced Imaging

Weight-bearing radiographs (Fig. 18.1) of the affected knee confirmed significant reduction in the lateral joint space with a well-fixed cemented medial Oxford UKA without any obvious evidence of implant loosening or significant polyethylene wear. Radiographs of the pelvis were unremarkable.

Surgical Approach

We explained the diagnosis to the patient (progression of osteoarthritis [OA]) and offered him the surgical options of either converting the UKA to total knee arthroplasty or adding a lateral UKA. Associated risks to the knee as well as his general health were also outlined. Patient decided to go ahead with lateral UKA procedure, as it was

Fig. 18.1 (a)

Preoperative:
anteroposterior standing
radiograph showing
progression of arthritis
in the lateral
compartment 11 years
after cemented medial
unicompartmental knee
arthroplasty. (b)
Preoperative lateral
radiograph



less invasive and safer and allowed him quicker recovery and a shorter hospital stay.

The leg was positioned free hanging on a leg holder. The previous skin incision was used and extended as appropriate. A lateral parapatellar arthrotomy incision was made to expose the knee joint. The knee effusion was clear serous fluid, which was sent for bacteriological as well as histological examination along with soft tissue and bony samples to rule out infection. Anterior cruciate ligament was intact with some longitudinal splits. There was full-thickness cartilage loss on both the lateral femoral condyle and the tibial plateau, confirming the diagnosis of lateral compartment OA. There were areas of exposed bone in the trochlea as well as over the patella, but the patella tracking was satisfactory, and there was no evidence of patella grooving or lateral subluxation of the patella. A decision was taken to proceed with implanting a mobile-bearing domed lateral UKA while completely ignoring the medial UKA which was functioning optimally.

Key Surgical Steps

1. Vertical cut on the tibial plateau: The bearing tends to move more medially with extension, so the vertical cut is internally rotated to prevent

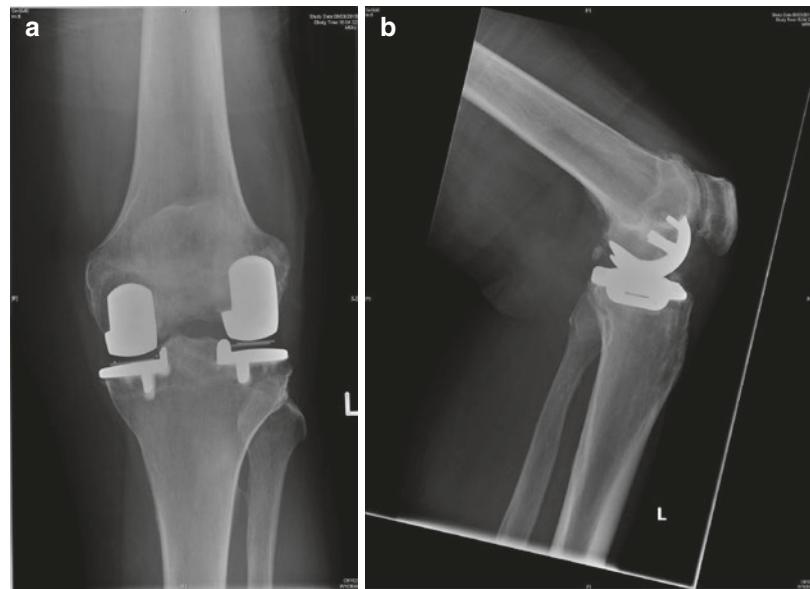
impingement between the bearing and the wall. This is difficult to achieve if the saw cut is made lateral to the patellar tendon; therefore, the cut was made through the center of the patellar tendon. The saw cut was made on the medial side of the lateral condyle, just lateral to the apex of the lateral tibial spine, and was directed toward the ipsilateral anterior superior iliac spine of the pelvis. The cut was advanced to the depth of the saw.

2. Horizontal cut on the tibial plateau: In general, more bone is removed from the lateral tibial plateau than during medial Oxford UKA because the domed tibial component is thicker. The extramedullary sawing jig was applied in the same manner as for the medial side with the slope set at 7°. The jig was placed parallel to the tibial crest. The cut was made just superior to the Gerdy tubercle, 3 mm below the defect. The Z-retractor was used to protect the soft tissues. Care was undertaken not to undermine the tibial eminence.
3. An assessment was made to ensure that an adequate resection has been undertaken by inserting an appropriate tibial template and a 3 mm feeler gauge. The knee was then brought into full extension to assess the ligament tension. The final bearing thickness was selected in full extension so that the gap in full extension with

- the tibial template in place is an estimate of the final bearing thickness.
4. Femoral preparation: This is fundamentally different to the medial UKA philosophy. On the lateral side, ligament balance is impossible because the lateral collateral ligament is slack in flexion. The aim is to place the femoral component anatomically. The cartilage in lateral OA is relatively preserved at 0° and 90° flexion. The technique aims to position the implant flush to the condyle surfaces at 0° and 90° flexion. This is achieved using the standard femoral sawing jig, referencing from the posterior cartilage for anteroposterior (AP) position, and by milling with a 4 spigot for distal positioning.
 5. Femoral drill guide: Operator disorientation is quite common with this step of the procedure and malpositioning of the femoral component can occur. The aim is to position the 6 mm hole in the center of the condyle parallel to the mechanical axis and flexed about 5°. Positioning of the intramedullary (IM) rod is critical. The entry hole was made 1 cm above and 0.5 cm lateral to the lateral border of notch. The IM rod was then inserted. A line was drawn down the center of the condyle to aid anatomical positioning. An appropriately sized femoral component (medium in this case) was selected based on gender and height. This is usually one size smaller than that used for the medial condyle (we had used large femur on the medial side). The appropriate femoral drill guide was set to fill the flexion gap. The lateral adapter was applied and clamped in place. This flexed the femoral component about 5° relative to the IM rod. The femoral drill guide was inserted in the knee and linked to the IM rod. The guide was adjusted so that the 6 mm hole was central on the femoral condyle, making sure that the femoral component did not overhang antero-laterally. Having confirmed that the drill guide was satisfactorily positioned, the small and large drill holes were made.
 6. Femoral condyle preparation: The posterior saw guide was used in the standard method to remove posterior femoral bone, thereby accurately restoring the joint line and positioning the femoral component anatomically in the AP direction. The lateral meniscus was then removed. The next step is to place the femoral component anatomically, which is usually achieved by milling, using the 4 spigot. Baseline milling was therefore undertaken using 0 spigot. The gaps were then measured to ensure the flexion gap at least 4 mm larger than the extension gap, which is nearly always the case. The distal femur was then milled with 4 spigot. The aim of the final step of preparation is to select the bearing thickness in extension to restore the ligament tension and leg alignment to normal. A one peg femoral component should be used. We ensured that all impingements were prevented. Any posterior femoral osteophytes were removed with the chisel and slotted anti-impingement guide. The anterior mill must not be used on the lateral side, as this will remove too much bone and the patella can jam in the defect, causing the knee to lock in flexion. A trial reduction with an appropriately sized bearing (size 4 in this case) was attempted to confirm that the bearing did not impinge on bone anteriorly or on the medial tibial wall. If during trial reduction the bearing subluxes forward in high flexion and there is no posterior impingement, then the popliteus tendon should be divided. This may help prevent dislocation. However, this was not necessary in this case.
 7. The final tibial preparation is similar to that of the medial side. The template must be flush with the posterior cortex, not overhanging in the region of the Gerdy tubercle. The cemented keel cut saw was used to prepare the keel slot. The cement pick was used to clear out the bottom of the keel slot.
 8. Careful cementation was then begun. Care was taken to remove all retained cement. Definitive bearing assessment was made. A bearing that is just gripped in full extension is ideal. This may be loose in flexion. If it is difficult to insert the bearing from the front, it may be inserted anterolaterally. Routine closure was undertaken.

Fig. 18.2 (a)

Postoperative anteroposterior radiograph showing bi-unicompartmental knee arthroplasty. **(b)** Postoperative lateral radiograph showing bi-unicompartmental knee arthroplasty



Postoperative Result

Patient was able to demonstrate a straight leg raise with minimal pain on the following morning. He was able to go home on day 2. Radiographs (Fig. 18.2) demonstrated a normally aligned knee with staged bicompartamental UKA (bi-UKA).

Clinical Results and Discussion

At 6-week follow-up, he had regained around 100° of knee flexion, and at 1 year follow-up, his OKS was 39/48 with normal leg alignment and no residual symptoms.

We recently published our experience of this procedure [5] in a consecutive series of 25 patients for a total of 27 knees of staged bi-UKA. The mean time interval between primary medial UKA and the subsequent lateral UKA was 8.1 years ($SD \pm 4.6$ years). The mean age at the time of the bi-UKA was 77.1 years ($SD \pm 6.5$ years). There was no radiological evidence of failure. None of the patients needed blood transfusion, and there were no significant complications related to the surgical procedure without further surgeries or revisions at final follow-up. In our series, the same thickness bearings were used in the two compartments in 47% of cases, while a thinner lateral one was used in 24% of cases and a lateral bearing one size thicker in the remaining. In the current series, we

had no avulsions of the tibial eminence and suspect that it is less likely to occur with staged rather than simultaneous bi-UKA, as the bone medially will have had time to heal and strengthen.

Progression of OA in the retained lateral compartment and/or in the patellofemoral compartment has been reported after UKA, a well-established treatment option for managing end-stage OA of the knee. UKA has many advantages when compared to TKA. It is less invasive, preserves the cruciate ligaments, allows a better range of movement, and restores normal knee kinematics [6, 7]. In our practice, one in three patients requiring a knee replacement for OA is suitable for mobile-bearing UKA. As a result of this, interest in the UKA has increased in the past decade. There are many large series demonstrating good long-term results of UKA. However, with increasing use, there is increasing incidence of failure where the need for revision is likely. It is imperative that the treating surgeon is familiar with the possible reasons for a failed UKA prior to embarking on revising it. Although this book chapter refers primarily to the Oxford UKA (Zimmer Biomet, Warsaw IN, USA), the principles can be extended to other types of UKA.

The Oxford UKA is patella-friendly because of its design features, and the designing surgeons

themselves have never had to revise an Oxford UKA solely for the diagnosis of symptomatic patellofemoral OA. On the other hand, progression of OA into the lateral compartment is well known, although the incidence is low. In the authors' hands, the incidence of lateral compartment OA in a consecutive series of 1000 cases, followed up to 15 years postsurgery, was found to be 2.5% at a mean time of 7 years (range, 1.9–11.4) [6].

The diagnosis of lateral progression is usually straightforward. Patients have pain in the knee usually, but not always, on the lateral side. The first radiographic sign is narrowing of the lateral compartment joint space, and this may long precede the onset of pain. Subchondral sclerosis and disappearance of the joint space will eventually ensue. Osteophytes around the margins of the lateral compartment are very common and therefore do not necessarily suggest the presence of progression of lateral compartment OA. As lateral compartment OA tends to be a disease of flexion as against a disease of extension (medial compartment OA), radiographic diagnosis may not be straightforward, and special views may be necessary in suspected cases. The author quite regularly uses Rosenberg views in cases where there is any suspicion [8].

Some authors have regarded OA of the contralateral compartment in UKA as a time-dependent consequence of the gradual spread of OA throughout the joint, perhaps hastened by the presence within the joint cavity of the foreign materials of the prosthesis. If this were true, presumably the incidence of failure from this cause would rise steadily with the passage of time, but there is some evidence that lateral compartment OA causes short- and midterm failure. In the authors' experience, overcorrection of the varus deformity into valgus is the usual cause of progression of OA, and therefore one should aim to leave the UKA knee in a few degrees of varus to avoid this. A varus malalignment in TKA causes eccentric loading, tilting, and loosening of the components; however, in UKA, although the components have increased loading, this is not necessarily eccentric and therefore does not have any deleterious effects in the long run. An intact

medial collateral ligament is very important to avoid overcorrection at the time of the primary procedure.

In some rare circumstances, the authors have noticed early progression of lateral compartment OA either due to development of avascular necrosis in the lateral femoral or tibial condyle or in cases where an inflammatory type of OA and/or diagnosis of rheumatoid arthritis was made subsequent to the primary procedure. In these cases, early and rapid progression of chondrolysis in the retained lateral compartment is well known; if the symptoms are significantly bad, conversion of the UKA to TKA is recommended. If one is careful in removing the implant at the time of the revision, ensuring that no excess bone is removed, then in the majority of cases, primary TKA (non-stemmed, cruciate retaining, or posterior stabilizing, depending upon the surgeon's choice) can usually be implanted and satisfactory outcome ensured. If, at the time of revision surgery, the medial UKA is found to be functioning well without any evidence of loosening, a lateral UKA can be implanted, resulting in a bicompartamental UKA as discussed in the previous sections.

If the surgeon prefers to revise a UKA to a TKA for progression of OA in the lateral compartment, the surgeon should extend the previous medial approach and perform a standard medial parapatellar arthrotomy. Patella eversion and removal of bearing are usually straightforward. Perform the distal femoral cut based on the femoral component before removing it. Take care when removing the femoral component. The surgeon must work on the interface between the cement and the prosthesis and not the interface between cement and bone. Another key area is femoral component rotation. Use the usual landmarks to ensure that the femur is adequately externally rotated. For the tibia, sublux the tibia forward, and take great care again not to destroy too much bone. One can use the TKA saw to cut around the keel while ensuring minimal bone loss. After removing the tibial component, assess the medial bone loss. The tibial cut should be as conservative as possible and is typically at the top of the medial tibial defect, which is usually contained. It can be filled with cement or bone graft (typically

autograft form the bone cuts of the retained compartment). In the majority of cases, a primary TKA (with slightly thicker poly than usually used) can be implanted. It is up to the surgeon to decide whether a posterior cruciate retaining (CR) or posterior stabilized (PS) TKA is used. In our practice, we prefer to use a CR design.

Key Points

- Lateral UKA for progression of OA after medial UKA is a viable treatment option with faster recovery and lower morbidity and helps the patient regain good flexion in the early postoperative period.
- It should only be used if the medial UKA is fixed securely and functioning optimally.
- A mobile-bearing (domed) lateral UKA (Fig. 18.3) can be used, as it is ideal in restoring normal knee kinematics. However, it is not available for use in the USA. A fixed-bearing lateral UKA can be used instead, using the same surgical principles.



Fig. 18.3 Domed lateral Oxford lateral unicompartmental knee arthroplasty (Zimmer Biomet, Warsaw IN USA)

- Using previous skin incision with a lateral parapatellar arthrotomy gives excellent exposure in such cases.
- Vertical tibial cut is made through the patellar tendon to ensure optimal orientation.
- When implanting the lateral UKA, the position and orientation of the medial UKA components can be ignored. Convergence or divergence of the components does not matter because of their spherical design and the fully congruous freely mobile bearings. Although the slope of the tibial components should be similar (about 7° as set by the tibial saw guide), the height of the components does not matter, as the bearing thickness on the lateral side can be adjusted.
- If the medial UKA is not functioning optimally or the anterior cruciate ligament is not intact, the surgeon may wish to convert a UKA to a TKA. In such cases, previous incision could be extended to a standard medial parapatellar arthrotomy and the UKA removed with care. One must ensure that there is minimal bone loss while removing the implant, which is usually well-fixed, and take care that optimal implant rotation is achieved when preparing the femur and the tibia. In almost all cases, the surgeon will be able to use a primary TKA with a slightly thicker polyethylene insert as compared to a primary UKA.

Option 2: Converting Lateral Unicondylar Arthroplasty to Total Knee Arthroplasty

David J. Mayman

Case Presentation

History

A 53-year-old female presented with isolated lateral compartment osteoarthritis (OA) of the knee. She had pain and swelling isolated to the lateral aspect of her knee. She failed conservative treatment including anti-inflammatory medications, physical therapy, corticosteroid injections, and

Fig. 18.4 Preoperative anteroposterior flexion x-ray



visco-supplementation injections. She continued to have persistent pain. Physical examination revealed a fully correctable valgus deformity with normal range of motion. Weight-bearing radiographs of the affected knee confirmed isolated lateral compartment arthritis (Fig. 18.4). Based on the patient's symptoms, physical exam, and radiographs, the decision was made to perform a lateral unicompartmental knee arthroplasty (UKA). The patient underwent a robotic-assisted lateral UKA (Fig. 18.5). Initially, the patient did well for the first 12 months, but then she began having increased pain. She localized her pain over the lateral aspect of her knee. The patient did not have any wound healing problems after the initial surgery, but stated that she had increasing pain over the past few months. She had been wearing an unloader brace, which did give her some symptomatic relief.

Physical Examination

There was a moderate effusion in the knee with a range of motion from 0° to 115° of flexion. There was tenderness to palpation over the lateral joint line with mild patellofemoral crepitus. There was a well-healed incision on the knee with no evidence of wound complication. The knee was stable and her leg was aligned in slight valgus. There was no distal neurovascular deficit, and hip examination and neurovascular examination of the entire lower extremity were unremarkable. The

patient walked with an antalgic gait, but there was no change in the length of her stance phase to indicate a significant flexion contracture.

Laboratory values revealed an erythrocyte sedimentation rate of 12 and C-reactive protein of 0.9. Both inflammatory markers were within normal range, and there was not a high clinical suspicion for infection. An aspiration of the knee joint was performed, and the fluid was sent for a cell count and differential as well as culture. The white blood cell count was 400 and her cultures were negative. Based on the results of her laboratory values and knee aspiration, there was no clinical suspicion for infection.

Radiographs and Advanced Imaging

Radiographs taken in the office showed lucent lines around the tibia (Figs. 18.6 and 18.7).

After a complete discussion, the patient elected to proceed with a revision total knee arthroplasty.

Surgical Approach

The right leg was scrubbed and prepped and draped in standard sterile fashion. An Esmarch bandage was used to exsanguinate the leg, and the tourniquet was inflated to 250 mmHg. A longitudinal incision approximately 15 cm in length was made using her previous scar from her surgery and then extending proximally. A soft tissue flap was elevated over the patella in order to give

Fig. 18.5 Postoperative x-rays (a–c) after a lateral unicondylar knee arthroplasty

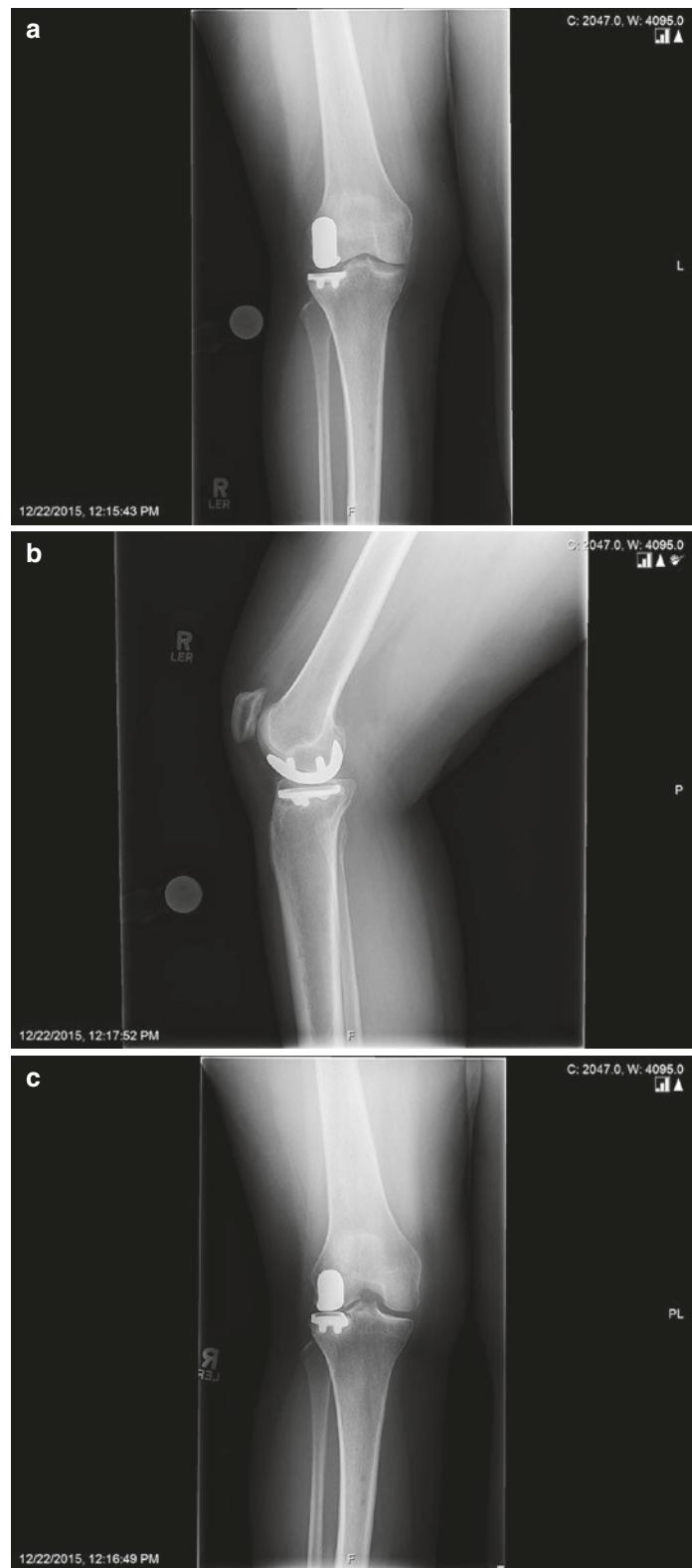


Fig. 18.6 X-ray shows lucent lines around the tibia



Fig. 18.7 X-ray shows a stress reaction beneath the implant



exposure to the medial side of the patella. A medial parapatellar arthrotomy was performed. Soft tissue was elevated off the proximal medial tibia for exposure of the knee joint. The patella was dislocated laterally. The knee was flexed. The OrthAlign computer navigation system (OrthAlign, Aliso Viejo CA, USA) was pinned to the distal femur. Points were taken from the center of the knee and center of the hip for mechanical axis of the femur. The distal femoral cutting block was set at 3° of flexion and neutral mechanical axis varus/valgus. The OrthAlign navigation system was removed, leaving the distal femoral cutting block. Two millimeter of extra bone was

resected from the distal femur in order to allow for the implant resection, and the implant was removed with minimal bone loss. The distal femoral cut should be made perpendicular to the mechanical axis of the femur. This can be done using an intramedullary guide set to the appropriate valgus angle or can be set using a computer navigation device. The depth of cut should be based off of the intact medial femoral condyle. Once the femoral cutting block is set and is in place, the femoral implant can be removed. At this point, an assessment needs to be made as to whether or not the standard distal femoral cut will be sufficient to give you a fresh lateral femoral

condyle cut. If the lateral partial knee replacement was done well, then enough bone should be remaining to have an appropriate cut. If there is no bone cut from the lateral femoral condyle, then one of two choices can be made. Option 1 would be to cut more distal femur. It is reasonable to cut an extra 2 mm of bone in order to get good bone laterally. Option 2 would be to use a revision femoral implant with a lateral distal femoral augment. If more than 2 mm of extra bone cut is required, then a revision implant with an augment is a better choice in order to avoid excessive joint line elevation.

The OrthAlign navigation system was pinned to the proximal tibia. Points were taken from the center of the knee as well as the medial and lateral malleoli in order to obtain mechanical axis of the tibia. The tibial cutting block was then pinned in place in 3° posterior slope with neutral varus/valgus mechanical axis alignment. The block was positioned to resect 8 mm, the thickness of the implant, from the lateral tibial plateau. This removed approximately 10 mm of bone from the normal medial plateau. The resection would lead to a relatively thick polyethylene liner in our total knee arthroplasty; however, this was felt to be acceptable in order to get a good lateral tibial bone base. The tibial implant was removed with minimal bone loss. The proximal tibial cut should be assessed in a similar fashion to the distal femoral cut. A standard tibial cutting guide should be used (extramedullary, intramedullary, or computer navigated). The cut should be set perpendicular to mechanical axis alignment in the varus/valgus plane with an appropriate amount of posterior slope. Preoperative planning will help to assess whether a standard cut thickness will be below the tibial implant, whether a slightly thickened tibial cut will be necessary, or whether a lateral tibial augment will be required. Thicker tibial cuts will require a thicker polyethylene but will not affect the joint line. Disadvantages of thicker tibial cuts are the potential for a mismatch between tibial and femoral sizes due to the shape of the proximal tibial and decreasing tibial bone quality below the tibial subchondral bone.

The extension gap was examined and was well balanced with a 13 mm spacer thickness. The

femoral sizing guide was pinned in place referencing the anteroposterior (AP) and epicondylar axis. The posterior condyles could not be used for referencing because of the previous lateral femoral condyle resection for the partial lateral replacement. The next critical step to performing a successful conversion of a lateral unicompartmental knee replacement to a total knee replacement (TKR) is assessment of femoral rotation and sizing. It is critical to remember that there will be bone missing from the posterior lateral femoral condyle. The AP cutting block was pinned in place and all cuts were completed on the femoral side. The tibia was sized and a tibial trial was pinned in appropriate rotation. The femoral intercondylar notch was completed. A trial polyethylene was inserted and the knee was taken through the range of motion. The patella was resurfaced. An intramedullary stem was used on the tibial side to enhance stability. The tibia was reamed through the central hole to 16 mm, and a 14 mm cemented stem was used.

Once the distal femoral and proximal tibial cuts have been made, an assessment of bone stock should be performed to decide if revision implants, augments, stems, or bone graft are required.

Femoral size should be measured off of the medial posterior condyle of the femur and the anterior cortex. It is imperative that rotation is set correctly and that the posterior medial femoral condyle is not over-resected. Internal rotation of the femur can cause patellar maltracking and flexion gap laxity on the lateral side. Over-resection of the posterior medial femoral condyle can cause flexion instability. The lateral posterior condyle should be assessed, and a posterior lateral femoral condyle augment should be used if required in order to ensure appropriate femoral rotation.

After all bone cuts are completed, soft tissue balancing should be performed.

Although it is tempting to use primary implants when converting a lateral partial knee replacement to a TKR, this should be done only if this can truly be accomplished without compromising on joint line, tibial cut height, femoral sizing, and femoral rotation. If there is any question, then revision implants with appropriate stems and augments should be used.

Postoperative Result

At 6 months postoperatively the patient was doing well. Her range of motion was 0–115° of flexion, and she returned to her normal activities. Weight-bearing x-rays showed good position of the implant (Fig. 18.8). Although a thick polyethylene was used, the joint line was restored. An anatomic replacement with an anatomic joint line and semi-constrained polyethylene were used.

Clinical Results

Traditionally, the treatment for OA is a total joint replacement; however, as technology and minimally invasive techniques become available, patients are being offered a traditional TKR or a

UKA [9]. UKAs were controversial when they were first introduced in the 1970s. Recent studies prove that UKAs are reliable procedures that can last 8–10 years; they have become a more viable surgical option for treating OA of the knee [5, 10–12]. The indications for a UKA vary widely, and there is no defined treatment path among surgeons. In 2001, Deshmukh et al. defined unicompartmental candidates as having (1) noninflammatory arthritis, (2) a mechanical axis that deviates no more than 10° from neutral for a varus knee and no more than 5° for a valgus knee, (3) the anterior cruciate ligament should be intact without signs of mediolateral subluxations of the femur on the tibia, and (4) the patellofemoral

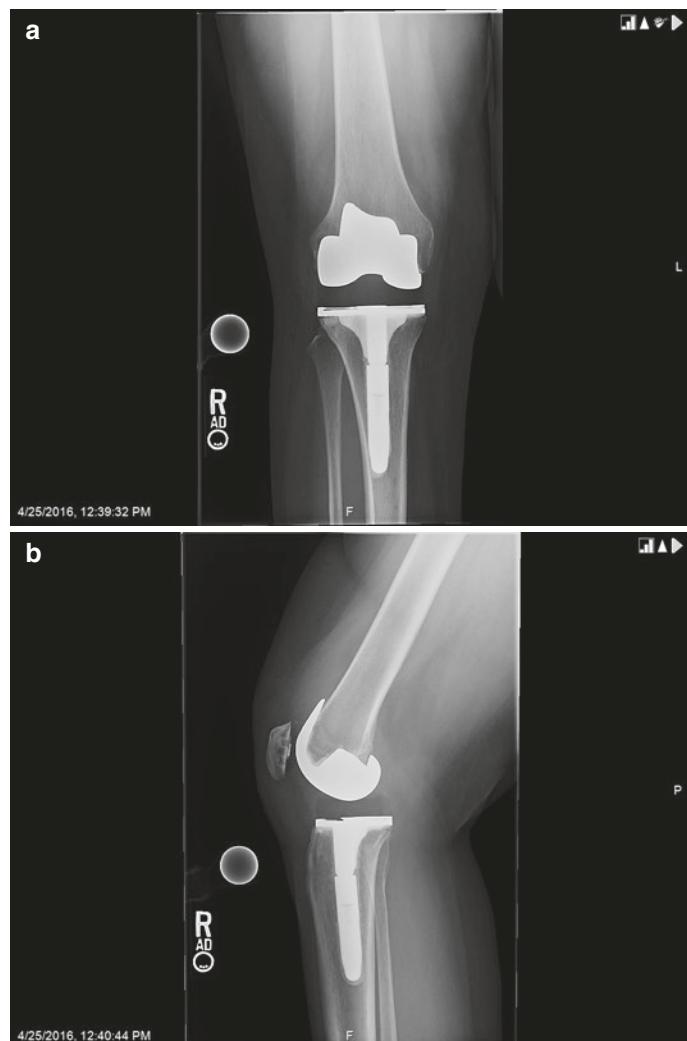


Fig. 18.8 Postoperative revision x-rays showing a stemmed tibial component and good alignment

compartment can have grade II or III changes without patellofemoral joint symptoms [13]. Patient demographics are often controversial as well. Historically, UKA has been a new procedure, but in recent years, UKA has become a well-established treatment option for managing single-compartment OA in a subset of patients.

Current studies have focused on the outcomes of UKAs with good results at 8–10 years; however, these outcomes are a combination of medial and lateral UKAs. Lateral UKAs differ from medial UKAs in anatomic and kinematic characteristics; therefore, their failure modes differ and should not be presented in combination with medial UKA outcomes. Since the introduction of UKAs by Skolnick et al. in 1964, UKA is used in 8–12% of all knee arthroplasties; however, only 5–10% of these are lateral UKAs [14–20]. Lateral UKAs are performed more infrequently than medial UKAs; therefore, the studies available to assess their outcomes are limited [21]. Failure on the lateral side of the knee can occur for all of the same reasons as failure on the medial side; however, the unique anatomy and flexibility of the lateral side of the knee introduce some additional failure mechanisms.

Common Failure Mechanisms

1. Infection
2. Bearing dislocation (in the mobile-bearing setting)
3. Aseptic loosening of the tibial or femoral implant
4. Persistent unexplained pain
5. Tibial plateau fracture
6. Medial compartment osteoarthritis
7. Popliteus tendonitis
8. Iliotibial (IT) band pain

Medial Compartment Osteoarthritis

The lateral side of the knee is much more flexible than the medial side of the knee, and partial knee replacement should be considered only in patients who have correctable deformities. For that reason, it is quite easy and tempting to fill the gap on the lateral side of the knee and overcorrect the mechanical axis alignment. If the lateral compartment is overstuffed, this will lead to overcorrection of the mechanical axis of the knee and

increase the risk of progressive medial compartment arthritis. Computer navigation or robotic techniques where mechanical axis alignment can be observed during the surgical case can be very helpful to avoid these concerns.

Maltracking of Implants and Edge Loading

The anatomy and kinematics of the knee joint are different on the lateral side of the knee joint than on the medial side of the knee joint, but until now most lateral compartment partial knee replacements have been the same implants that have been used on the medial side of the knee. This has made fit of the implants and matching of kinematics quite difficult. The screw home mechanism and lateral rollback must be considered when planning implant placement in lateral partial knee replacements. Failure to consider these factors can lead to edge loading, polyethylene wear, and ultimate failure of the implant.

Tibial or Femoral Loosening

Tibial loosening in lateral UKA is higher than loosening on the medial side of the knee, likely due to the kinematics. Physiologic lateral rollback on the lateral side of the knee can be 15 mm or more as the knee goes into flexion. The loads on the posterior aspect of the implant can cause compression of the posterior aspect of the implant and lift off of the anterior aspect.

Popliteus Tendonitis

Popliteus tendonitis is a complication that is seen in lateral partial knee replacement but not in medial. The popliteus tendon wraps around the posterior aspect of the lateral femoral condyle and can rub or snap over the border of an overhanging implant. It is important when performing a lateral partial knee replacement that there is no posterolateral femoral condyle overhang. This complication can be easily diagnosed with an ultrasound-guided lidocaine injection into the popliteus tendon sheath. If this provides relief of symptoms, the diagnosis is made. Treatment of this entity involves either revision of the implant or a popliteus tendon release. Popliteus tendon release has been effective in treating this condition and has not been seen to cause instability in these knees.

Iliotibial Band Pain

Lateral-sided knee pain has been reported in both lateral partial knee replacements and TKAs. There are several theories as to the cause of this pain, but it can be quite difficult to alleviate. The most common and explainable cause of this pain is component overhang. Tibial implant overhang anterolaterally at the insertion of the IT band has been implicated in lateral-sided knee pain. Excessive lateral rollback has also been implicated in some implant designs as this increases the tension on the IT band as the knee goes into flexion.

Lateral Failure Modes

Progression of OA and bearing dislocations are the most common modes of failure in cohort studies (53%), while registry-based studies found aseptic loosening and OA progression to be the most common failure mode (52%) [21]. The variation may be attributed to the fact that registry-based studies are 90% comprised of medial UKAs; thus, there is a smaller number of lateral UKAs assessed, whereas cohort studies consist of only lateral UKAs [20, 22, 23]. The varying mechanical and kinematic differences between medial and lateral UKAs explain the difference in reported failure modes seen; lateral UKAs need to be assessed separately from medial UKAs. Recent meta-analyses of failure rates of lateral UKAs suggest that progression of OA is the more common failure in lateral UKAs, whereas aseptic loosening is the more common cause of failure in medial UKAs.

Key Points

- Rule out infection.
- Assess mechanical causes of failure.
- Be cognizant of old incisions.
- Femoral anatomy after removal of femoral implant.
 - Don't over-resect the distal femur and raise the joint line.
 - Don't internally rotate the femur.
 - Don't over-resect posterior condyle.
- Tibial cut—over-resection of the tibia can lead to a size mismatch between the femur and tibia and poor tibial bone quality.
- Use revision implants if necessary.

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Fred D. Cushner, Adam Norwood,
and Giles R. Scuderi

Introduction

Fred D. Cushner

Patellofemoral arthroplasty has become more common over the last decade. Perhaps this increase is related to advances in technology. It is now much easier to perform a successful patellofemoral arthroplasty.

Part of the improvement is related to the design of the prosthesis. In the past, an inlay design was used with high complications of patella subluxation or dislocation noted. Current designs are more often an onlay design which allows the surgeon to correct at the time of surgery the factors that led to the development of the patellofemoral arthritis pattern in the first place. Lonner reviewed the complication rate of only versus inlay and found a significant reduced complication rate with the onlay design [1]. With less complications, there are less reasons for revision,

hence the increased appeal of patellofemoral arthroplasty.

There are also technological advances that allow for more proper placement of the patellofemoral replacement. There are not only patient-specific jigs that can be created for the patient, but advances in robotic technology also aid in proper prosthesis placement.

Fixation has also been improved with causes of revision now most likely secondary to advanced arthritic changes in a previous uninvolved compartment rather than loosening of the patella or femoral components.

Certainly, should arthritis progress, there are several options on how to address the new compartment involvement. One such option is conversion to a bicompartamental knee. The previous knee incision can be utilized and a new partial knee arthroplasty placed in a standard fashion. Care must be taken to not only select the proper femoral size but the surgeon must also make sure there is no impingement on the trochlea. It is often required to downsize the femoral component to ensure a proper fit.

The next option is to perform a full revision, removing the trochlea component and placing a full total knee arthroplasty design. Often the patella can be left in place for removing a well-fixed patella can remove a significant portion of patella hence making it more difficult for a revision patella to be placed. If the patella is elected to remain, one must make sure that indeed it is

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properly secure with no evidence of loosening. The pseudo-meniscus rim around the patella component can be removed, and the patella component can be visualized for excessive wear. A scalpel blade can be pushed toward the patella cement interface to also help allow for confirmation of proper fixation. If no signs of wear and indeed secure, it can be left in place even if not an exact match to new implant placed.

Removing the previously placed trochlea is often quite easy. By utilizing a small sagittal saw and thin osteotomes, even a well-fixed trochlea can be removed without significant bone loss. If indeed a small amount of bone loss occurs, it is usually around the anterior femur and does not comprise fixation of the revision component. In most cases, a standard component can be used, not a revision design, and no stems or augments are required.

As with all revisions, one should not revise unless the surgeon can document the cause of prosthesis failure. Revising for anterior knee pain may leave the patient with similar pain but now a revision prosthesis.

Option 1: Management of Failed Patellofemoral Arthroplasty

Adam Norwood and Giles R. Scuderi

Case Presentation

History

A 46-year-old female presented with persistent left knee pain with weight-bearing and flexion activities. She had a prior left knee surgical arthroscopy with partial medial meniscectomy and debridement chondroplasty of the patellofemoral joint that was followed by a course of physiotherapy and nonsteroidal anti-inflammatory medication. Two years later, due to persistent complaints of anterior knee pain and evidence of patellofemoral arthritis, she had a left knee patellofemoral replacement with a lateral retinacular release. The postoperative course was complicated by recurrent patella instability and subluxation, which was corrected with a proximal patella

realignment 1 year later. While this procedure stabilized the patella for a short period of time, she continued to have pain with weight-bearing activity and began to limit her daily activities, such that the left knee became a functional disability.

Physical Examination

On examination, she walked with a mild left antalgic gait. The left knee revealed a healed anterior midline incision with a trace effusion. There was medial and lateral joint line tenderness. The active range of motion was 0–135° with pain through the arc of motion and patellofemoral crepitus. Patella maltracking was noted with an increased Q-angle and a J-sign. The knee ligaments were stable with good quadriceps strength.

Radiographs and Advanced Imaging

The preoperative radiographs (Fig. 19.1) revealed a patellofemoral replacement with internal rotation of the femoral component and lateral patella tilt. There was also narrowing of the femoral tibial joint with evidence of osteoarthritis.

Surgical Approach

Based upon her prior history, current symptoms, physical findings, and radiographic evaluation, it was determined that this patient had a failed patellofemoral arthroplasty due to patella instability caused by an internally rotated femoral component and progressive osteoarthritis. It was determined that she would require revision of the patellofemoral arthroplasty to a total knee arthroplasty (TKA).

Once regional anesthesia was obtained, the left knee was prepped and draped in a sterile fashion for a TKA. The prior anterior midline skin incision was used and extended through the subcutaneous layer exposing the extensor mechanism. A medial parapatellar arthrotomy was performed and the knee was exposed. Following lateral subluxation of the patella, the femoral component was seen (Fig. 19.2). Using thin flexible osteotomes, the cement-prosthesis interface was carefully loosened and the femoral component was removed with preservation of the adjacent femoral bone (Fig. 19.3).

Fig. 19.1 Preoperative radiographs: (a) Anteroposterior view; (b) lateral view; and (c) Merchant view demonstrate internal rotation of the patellofemoral arthroplasty and osteoarthritis of the femoral tibial joint



Fig. 19.2 Intraoperative view of the patellofemoral arthroplasty



Fig. 19.3 The femoral component was removed with reservation of the adjacent bone

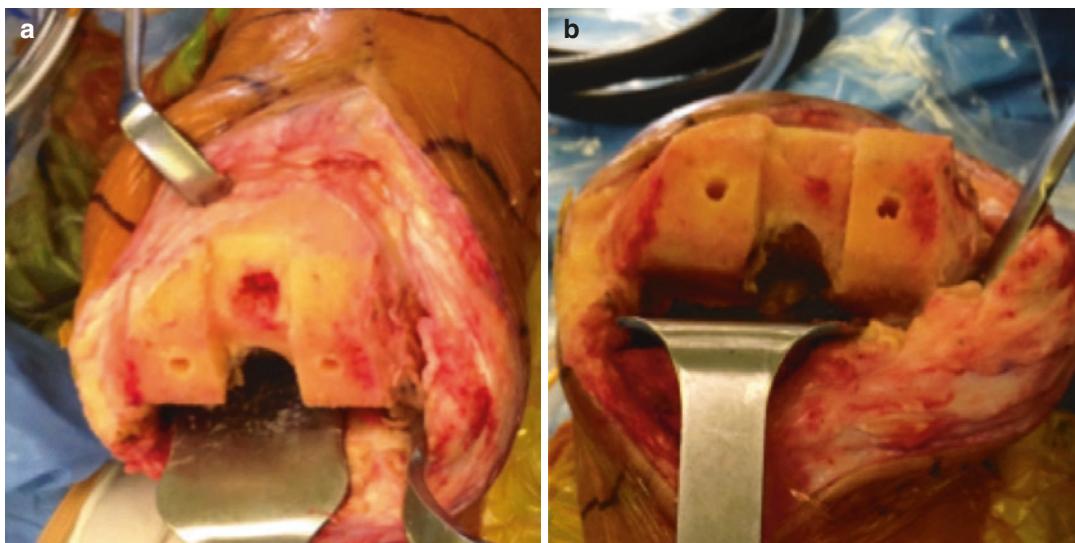


Fig. 19.4 The bone defect is negated by the anterior femoral bone cut (a) and the distal bone cut (b)



Fig. 19.5 The patella component

Using standard conventional instrumentation, the distal femur and proximal tibia were prepared for a posterior stabilized TKA. In preparing the distal femur, specific attention was directed to setting the femoral rotation along the epicondylar axis to ensure appropriate patella tracking. The bone defect created by the removal of the femoral component is negated by the anterior and distal bone cuts (Fig. 19.4). The patella component was

inspected and retained, since it was of appropriate thickness, well fixed to the patella bone, and showed no evidence of polyethylene wear (Fig. 19.5).

The final primary TKA components were cemented in place (Fig. 19.6). At the conclusion of the procedure, the knee was stable and the patella tracked in a central position without any evidence of tilt or subluxation. The post-operative radiographs showed the components to be in good position and alignment (Fig. 19.7).

Postoperative Result

Following the procedure, the patient was placed on routine prophylactic antibiotics, deep venous thrombosis (DVT) prophylaxis, and began a standard rehabilitation program. She was discharged from the hospital on the third postoperative day without complication. At 2-year follow-up, her range of motion was 0–130°, with no patella instability and good quadriceps strength.

Clinical Results

Isolated patellofemoral arthritis is not a rare condition and is observed in 17.1–34% of female patients and 18.5–19% of male patients over the age of 50 years [2]. Patellofemoral arthroplasty is considered for isolated patellofemoral arthritis

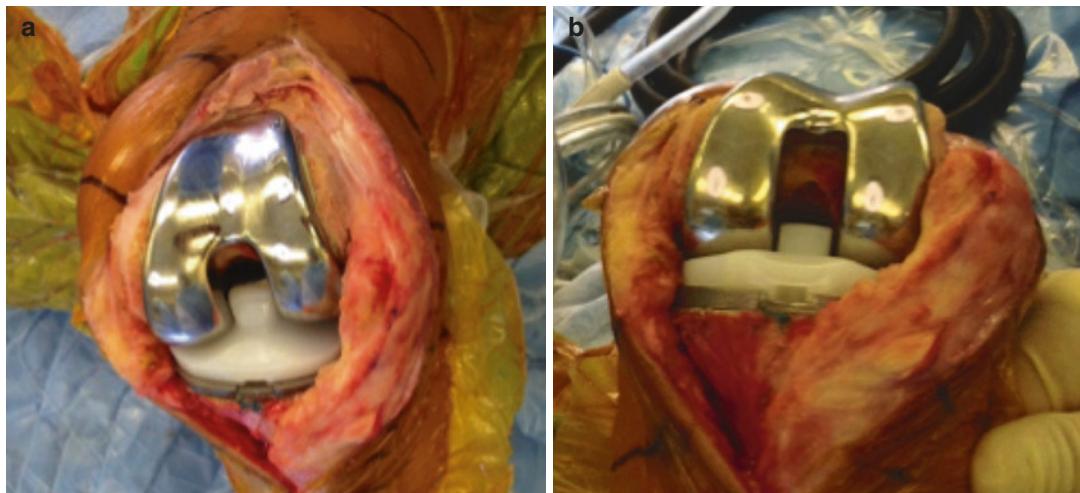
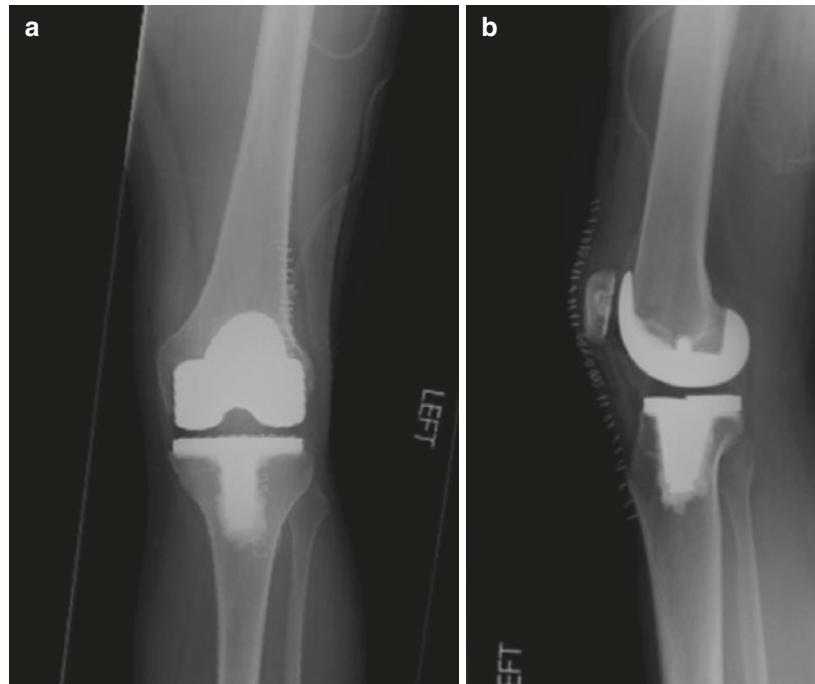


Fig. 19.6 The final primary components in place: (a) anterior view; (b) distal view

Fig. 19.7 The postoperative radiographs: (a) anteroposterior (AP) view; (b) lateral view



after an extended period of ineffective nonoperative treatment. The first isolated patella replacement was performed by McKeever, who implanted a screw on Vitallium patellar shell in 1955 [3]. Early reports with this prosthesis revealed satisfactory results with poorer results in those patients with osteoarthritis in other compartments of the knee joint. Lubinus [4] and Blazina [5] introduced

the concept of patellofemoral replacement in 1979. The initial results were disappointing due to problems related to patient selection, surgical technique, extensor mechanism complications, and durability. Revision rates for patellofemoral arthroplasty to TKA have been reported at 15–44% at 10–17 years for inlay designs and 10–21% at 6–10 years for onlay designs. Ackroyd

reported a survivorship of 96.4% at 5 years with patellofemoral arthroplasty [6]. However, careful patient selection and meticulous surgical technique, with attention to soft tissue balancing and patella tracking, are paramount to the success of patellofemoral arthroplasty.

The reasons for revision to TKA include progression of arthritis, patella maltracking and subluxation, and persistent pain and infection. Progression of osteoarthritis into the femoral tibial joint is not uncommon with reports of up to 15% of patients developing symptomatic arthritis in the other compartments of the knee, especially those patients with inflammatory arthritis and chondrocalcinosis, between 4 and 10 years following patellofemoral arthroplasty. There has also been a clinical observation that patients with a BMI > 30 had a higher incidence of failure and conversion of the patellofemoral arthroplasty to TKA [7, 8].

Improper positioning of the femoral component, especially if it is internally rotated, will result in patellar maltracking and instability [7, 9]. Misalignment of the femoral component and oversizing of either the femoral or patellar component are also a source of persistent anterior knee pain. Oversizing of either component can result in overstuffed of the patellofemoral joint, and a recent study showed that patients with the worst functional outcome following patellofemoral arthroplasty had a greater increase in patellar thickness following the procedure [10].

Infection for patellofemoral arthroplasty has been reported as high as 3% and should be treated with removal of the implants followed by antibiotic treatment in preparation for a staged reimplantation [11]. There is a paucity in the literature on the need for placing an antibiotic spacer likely due to the small amount of bone involved and the few cases of patellofemoral arthroplasty that become infected. Simple explant with antibiotic therapy should be adequate prior to reimplantation.

Conversion of a failed patellofemoral arthroplasty should be a relatively easy procedure with careful removal of the femoral trochlea component, preserving the integrity of the distal femur, such that standard preparation of the femur for

TKA can be performed [12]. In most cases, a femoral stem is not needed for fixation, because the bone defect created by the removal of the trochlea component is negated by the anterior and distal femoral bone cuts. Depending on the shape of the patella component, thickness of the patella bone-implant composite, angle of patella resection, and integrity of the patella polyethylene surface, the original patella may be retained. In all cases, following conversion, it is imperative that patellofemoral tracking is satisfactory with the patella tracking centrally within the trochlea groove without tilt or subluxation.

Van Jonbergen compared the outcomes of 14 patellofemoral arthroplasties converted to TKA with a control group of 14 primary TKA [7]. While the knee scores and WOMAC scores were comparable, there were three cases in the conversion group that required manipulation, and he concluded that patellofemoral arthroplasty had a negative effect on the results of future TKA. Parratte et al., in another matched study, concluded that conversion of patellofemoral arthroplasty was similar to primary TKA in all aspects, although the complication rate was higher in the conversion group [13].

First generation patellofemoral arthroplasty designs have been reported to have a higher incidence of reoperation and revision [14]. The introduction of modern patellofemoral arthroplasty prostheses, focusing on more anatomic designs, with refined surgical techniques has improved the surgical outcome. While short-term and midterm results seem to be encouraging, with little evidence of implant loosening and wear, further long-term assessment is needed. When conversion to TKA is needed, the use of primary TKA and instruments and implants are adequate.

Key Points

- Careful removal of the femoral component allows routine preparation of the distal femur for a standard total knee femoral component.
- Onlay patella components may be retained if appropriately positioned and are determined to be of appropriate thickness.

- In cases of patella maltracking, attention should be directed to position the femoral component rotation along either the AP axis or epicondylar axis.

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Alfred J. Tria and Dror Paley

Introduction

Alfred J. Tria

Fusion of the knee is a singularly difficult operation to accomplish. The indications are usually chronic infection after multiple previous total knee procedures, complicated traumatic injury to the knee leaving no significant surfaces for a replacement procedure, or a tumorous condition. Fusion for failed TKA often requires more than one operative procedure to be successful [1]. Fusions are performed using external fixators, intramedullary rods, or cortical plate fixation [1–3]. On occasion, there may be an unusual case that is considered for conversion to total knee arthroplasty after a successful fusion. This presents one of the most difficult of all reconstructive procedures for the knee. Infection must be ruled out, the condition of the extensor mechanism must be evaluated, and the status of the skin must be clarified [4, 5]. The case presentation in this chapter reviews the indications for the procedure and the technical considerations.

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Option 1: Knee Replacement After Knee Fusion or Ankylosis Combined with Paley modified Judet Quadricepsplasty

Dror Paley

Case Presentation

History

Case 1: A 26-year-old man with arthrogryposis affecting both lower limbs. Previously treated for bilateral clubfeet. Still has residual foot deformity on the right side. Left knee fused since age 6 years old. Complains of difficulties related to inability to flex left knee. Due to his stiff ankles and foot deformities, he was unable to compensate for the knee fusion. He requested conversion to a knee replacement.

Case 2: A 24-year-old woman with post-traumatic post-infection knee fusion since age 20 years. There was no evidence of residual infection. She requested revision to a knee replacement. She found great difficulty with activities of daily living, including getting in and out of a car, climbing stairs, and sitting on a bus, plane, or in a movie theater. She had no problem walking on flat ground. She could not run.

Physical Examination

Case 1: The left knee is fused in full extension. Right foot is in equinovarus. Left foot is

plantigrade but completely stiff at ankle. Hips fully mobile and normal hip musculature. Cannot feel quadriceps contraction on the left side. Right quadriceps is functional. Right knee 90° range of motion (ROM) with full extension and no quadriceps lag. Gait on flat surface is unsteady due to both left knee and right foot. Has significant hip hike on left.

Case 2: The right knee is fused in 10° flexion and has mild varus. There was a 3 cm leg length discrepancy, shorter on the right than the left. The right knee is fully mobile and has mild genu valgum. The hips, left knee, and both ankles and feet are normal with full ROM. There is no pain at the knee. There is a previous anterior midline incision at the knee. Gait on flat surface is very good with small hip hike.

Radiographs and Advanced Imaging

Case 1 (Fig. 20.1): Anteroposterior (AP) and lateral radiographs of knee prior to surgery showing well-healed knee fusion with the patella fused to the femur and tibia in a very baja position.

Case 2 (Fig. 20.2): Standing full length AP radiograph showing left knee fused in slight valgus. The equinovarus of the right side is seen. Lateral fluoroscopic radiograph showing complete knee fusion and very osteoporotic patella alta.

Surgical Procedure

Case 1 (Fig. 20.3a–i), *Case 2* (Fig. 20.4a–k): Under general anesthesia the patient is positioned supine on a radiolucent table. A continuous epidural catheter is inserted for intra- and postoperative pain management. The anesthesiologist should be advised of the need for the epidural to last for 1 week, so that they tape it in and dress it accordingly. The entire lower limb is prepped and draped free from the ribs to the toes. A sterile tourniquet is used for the first half of the procedure. To maximize exposure a tourniquet with a small cross-sectional area is preferred. The author prefers to use the HemaClear (OHK Medical Devices Inc., Grandville, MI, USA) tourniquet for this reason.

Step 1: Incision. The choice of incision varies, depending on pre-existing incision scars from

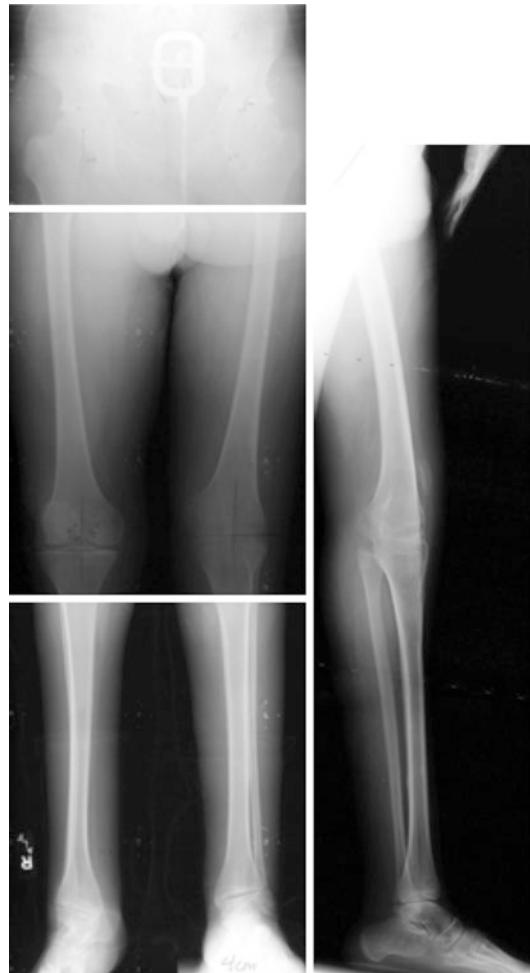


Fig. 20.1 *Case 1:* Standing anteroposterior (AP) (left) and lateral (right) radiographs of 26-year-old male with history of arthrogryposis and knee fusion. Note that he also has equinovarus deformity of the right foot. The knee fusion is in about 5° of flexion

previous surgery. If a previous midline incision is present, then it is used distally. If a previous lateral incision is present, then a long lateral incision as previously described by the author [6] is used through the old incision.

A midline anterior incision is made from just below the tibial tuberosity to one third of the way up the thigh. The incision goes down to and through the underlying fascia to expose the patellar tendon, patella, and quadriceps muscle. A subfascial plane of dissection is developed medially and laterally to expose the quadriceps muscle up to its lateral and medial borders. On the lateral

Fig. 20.2 Case 2:
Anteroposterior (AP)
(left) and lateral (right)
radiographs of right
knee fusion in a
24-year-old woman



side, the dissection is also carried out on both sides of the iliotibial band down to the intermuscular septum.

Step 2: Osteotomy of knee fusion. There are two ways to do this osteotomy. One way is to pass a Gigli saw percutaneously around the knee, and the other way is to perform the osteotomy open with a saw. The advantage of the Gigli saw is that it can be passed across the back of the knee joint very safely and that the cut is away from all of the neurovascular structures. With the saw the cut proceeds toward the neurovascular structures.

To pass a Gigli saw, the image intensifier is used to mark the medial and lateral locations of the back of the knee. A small incision is made in line with these two marks. A periosteal elevator is used to dissect a path and a space between the back of the knee and the soft tissues. The elevator stays on bone the whole way. A long straight clamp can then be used to pull a suture from the posterior aspect of the knee through this space. Two more 1 cm incisions are made anteriorly on the medial and lateral sides of the femur. Subperiosteal dissection from front to back cre-

ates a path for passage of the suture around the side of the femur and out the front on either side. The Gigli saw is then tied to one end of the suture and pulled around the knee joint. The Gigli saw can then be pulled through the bone, cutting the knee fusion site. This allows the knee to begin to flex through and opening wedge of the osteotomy.

To cut the bone with the saw, the quadriceps muscle must be elevated off of the femur in its entirety. This is a vastus sparing approach. No parapatellar incision is made. The medial and lateral borders of the quads are elevated toward the middle. If the patella is fused, it is osteotomized off of the femur at this point. The patellar tendon can also be dissected, leaving it attached to the tibial tuberosity. Two guide wires are then inserted, one AP and one latero-medial. The saw is used to cut the bone along these two wires. The saw cut should stop short of the posterior cortex. The posterior cut can be completed with an osteotome, using image intensifier to guide the depth of the osteotome. The osteotome handle can be twisted 90° to crack the back cortex.

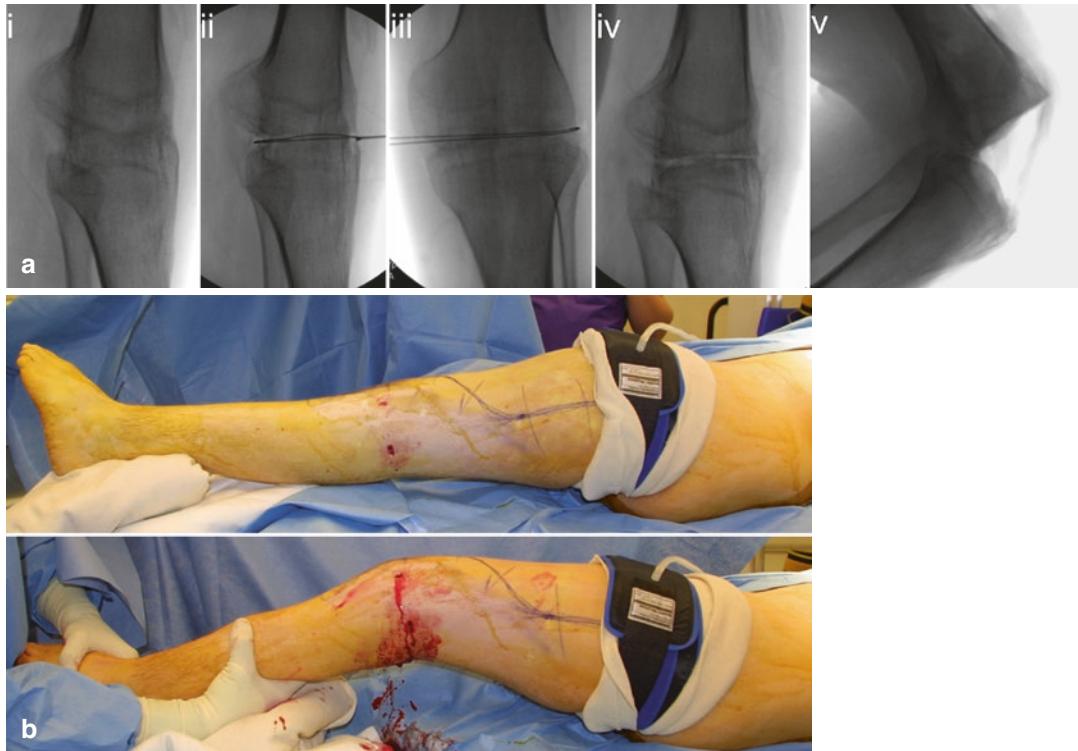


Fig. 20.3 Case 1: (a) Passing Gigli saw around the femur. Lateral image from image intensifier of the knee fusion (i). Through two posterior incisions, a path is created posterior to the knee and a suture followed by a Gigli saw is pulled through (ii). The Gigli saw is brought under the soft tissues toward the front of the knee joint by again passing a suture, which is more flexible to get around corners. The Gigli is then pulled through using the suture (iii). The bone can now be cut using the Gigli saw through the knee fusion site (iv). Once the Paley modified Judet quadricepsplasty is completed, the knee can flex through the osteotomy (v). (b) Intraoperative photo showing the leg immediately after the arthrodesis was cut with a Gigli saw. There are four 1 cm incisions that were used for the Gigli saw passage (two can be seen). After cutting the bone, but before making the midline incision, the knee already has about 20° of flexion. A pneumatic sterile tourniquet is in place (current preference is for the HemaClear tourniquet, which takes up much less space). (c) The lateral distal part of the quadricepsplasty is done (top). The patella was osteotomized off of the femur. The knee flexion has increased to 40° (bottom). (d) The medial vastus sparing approach elevating the quadriceps muscle. The superficial medial collateral ligament is exposed (asterisk, top) and released distally (bottom). (e) The knee flexion is checked after the medial release and quadricepsplasty (bottom). The knee flexion has increased to about 60°

after the medial release. The distal incision is wrapped with an elastic bandage and the tourniquet removed so that the proximal incision can be made (top). (f) A midlateral incision was connected to the midline anterior incision with an S-shaped connection. The proximal quadriceps was elevated off of the femur extraperiosteally to and including the lateral trochanteric ridge and the intertrochanteric line, and the rectus femoris was released off of the anterior inferior iliac spine (top). At this point the knee flexion is greater than 100°. No further release is required. (g) At the end of the Paley modified Judet quadricepsplasty, the entire quadriceps except some of the most medial proximal parts are detached from the femur (bottom seen from the lateral side). The patellar tendon remains attached. The quadriceps can be dislocated in either direction to give access to the knee for arthroplasty (top left and right seen from the medial side). With the quadriceps detached in this manner, it can slide distally to permit full knee flexion. This is why this is often referred to as a muscle slide. (h) Knee arthroplasty: cutting jig (left), trial (middle), cemented (right). (i) Since the knee has not flexed in 20 years, a trial is done to see if the skin closure can tolerate the knee flexion. Towel clamps are placed in the skin with the knee extended (bottom left), and then the knee is flexed with the towel clamps in place. The skin tolerates the flexion with the towel clamps in place (top left and right).

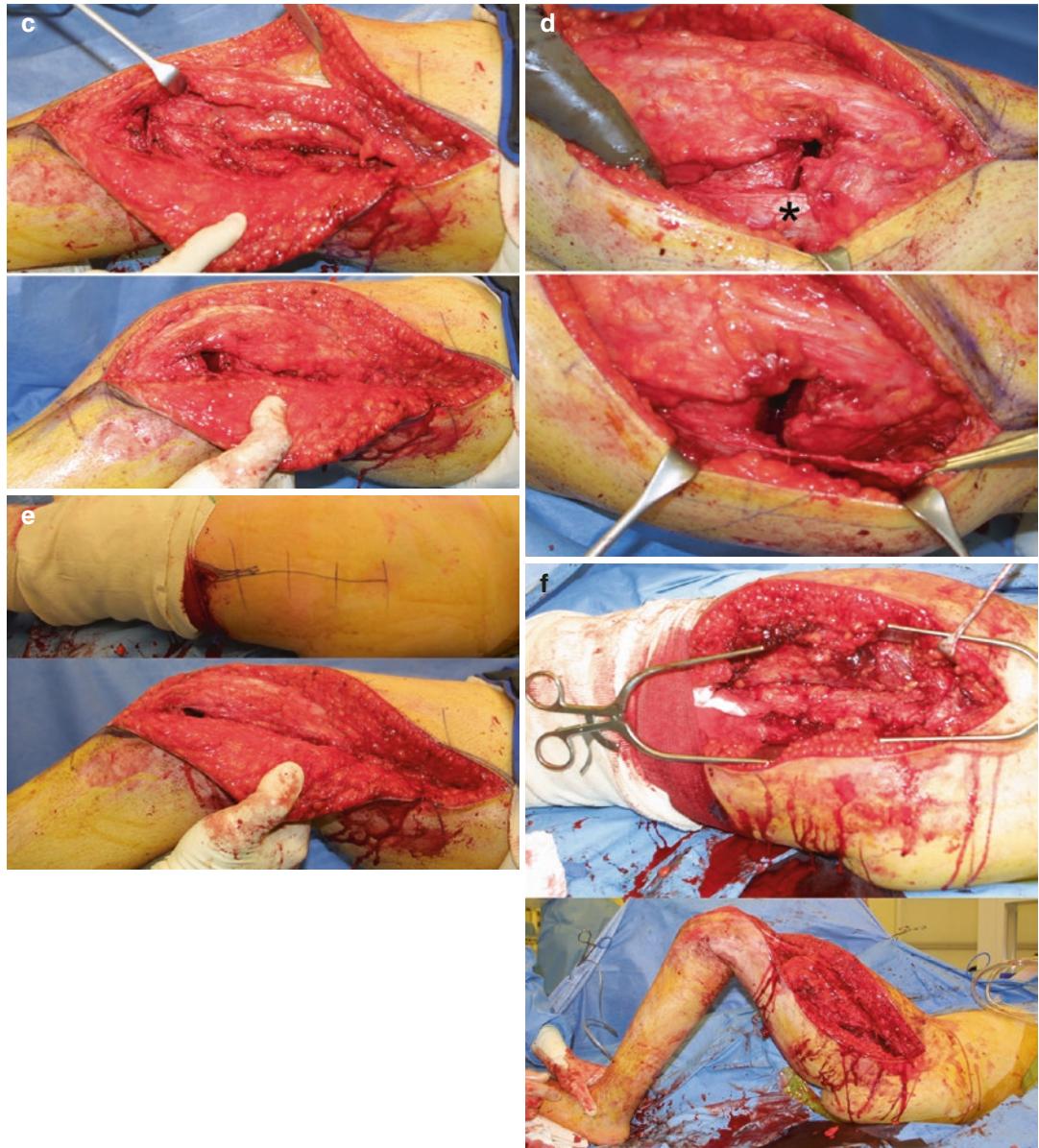


Fig. 20.3 (continued)

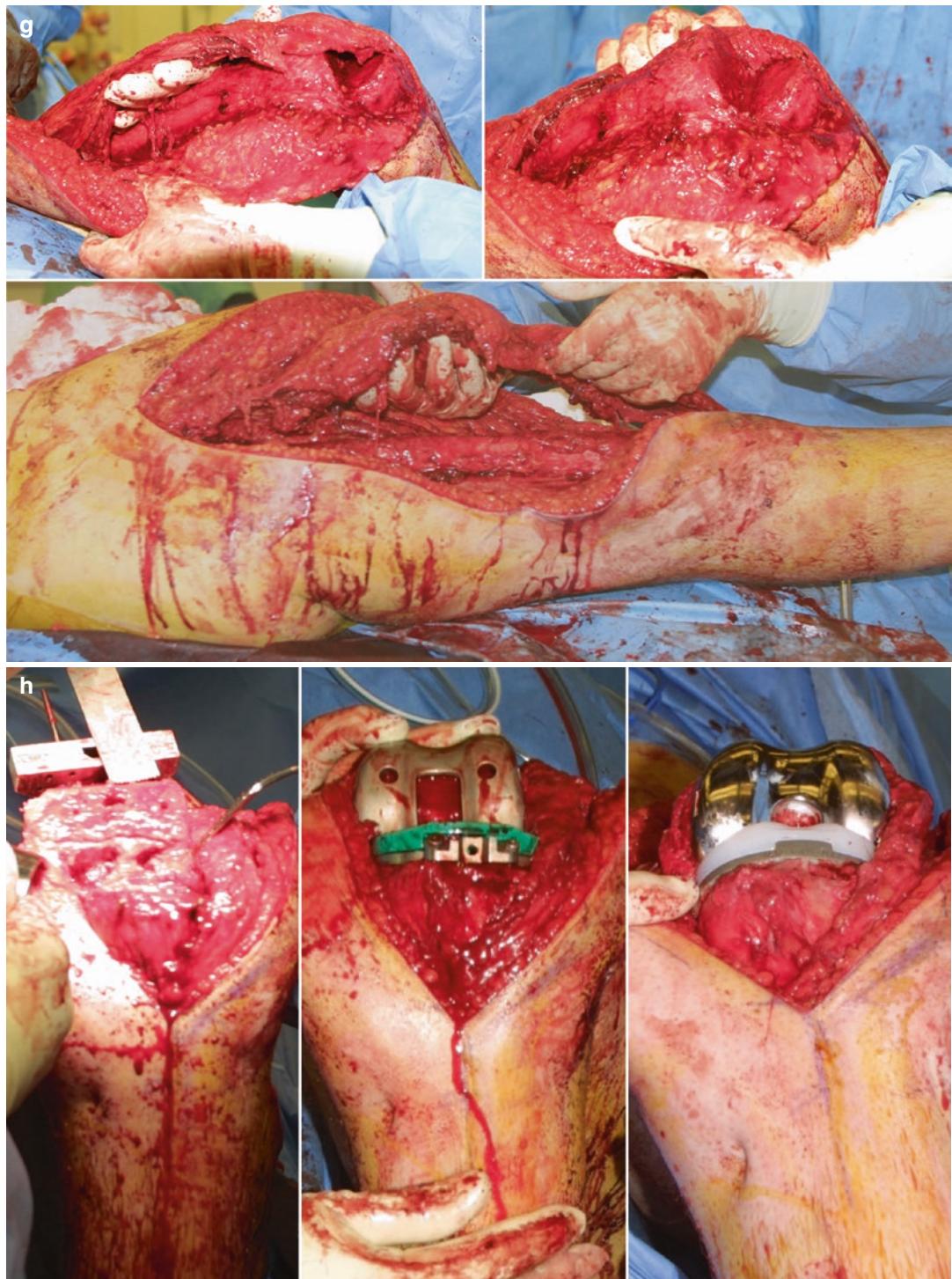


Fig. 20.3 (continued)



Fig. 20.3 (continued)

Step 3: Distal quadricepsplasty. The distal quad release continues proximally, medially, and laterally. The quads are dissected off of the femur in an extraperiosteal fashion. The degree of proximal release needed depends on the range of knee motion achieved. Once the knee can be bent over 90°, sufficient release has been done.

Step 4: Medial quadricepsplasty. The medial quads are removed in a vastus sparing approach, which is extended proximally, gradually dissecting the quads off of the femur. As one progresses proximally, care should be taken not to injure the femoral vessels. These lie immediately posterior to the very thin medial intermuscular septum.

Step 5: Iliotibial band (ITB) release and lateral distal quadricepsplasty. The ITB should be cut at the upper end of the anterior incision and should be dissected free of the overlying fat. It should be incised longitudinally at its confluence with the intermuscular septum. This segment of ITB will be used as a patch graft for a retinacular repair at the end of the surgery. The lateral quads are elevated in an extraperiosteal fashion off of the septum and the femur posteriorly to meet the dissection of the quads from the medial side.

Step 6: Medial collateral ligament (MCL) release. The MCL can be sleeved distally to un tether knee flexion (the MCL is longest at 60° flexion). Occasionally, the MCL will tear off of its

origin on the femur. This is repaired at the end of the surgery as part of balancing the knee stability.

Step 7: Second incision. In most cases the entire quadricepsplasty is required. The incision either needs to be extended proximally or a separate second incision is needed. The extended or second incision is midlateral. This incision can be connected to the anterior midline incision by an S-shaped connection. The distal surgical field is wrapped with an elastic bandage, and the HemaClear tourniquet is cut off.

Step 8: Release of proximal quadriceps. The lateral dissection of the quads is continued up the lateral side of the femur along the linea aspera up to the trochanteric ridge of the greater trochanter. The quads should always be elevated from posterior to anterior to avoid denervation. The perforator vessels should be cauterized or clipped at each level. At the trochanteric ridge, the quads should be incised off of the trochanteric ridge and elevated off of the proximal femur toward the intertrochanteric line. The quads can then be released off of the intertrochanteric ridge from lateral toward medial. As long as one stays deep, the femoral nerve is avoided.

Step 9: Release of rectus femoris off of the anterior inferior iliac spine (AIIS). The rectus femoris tendon can be identified as overlying the

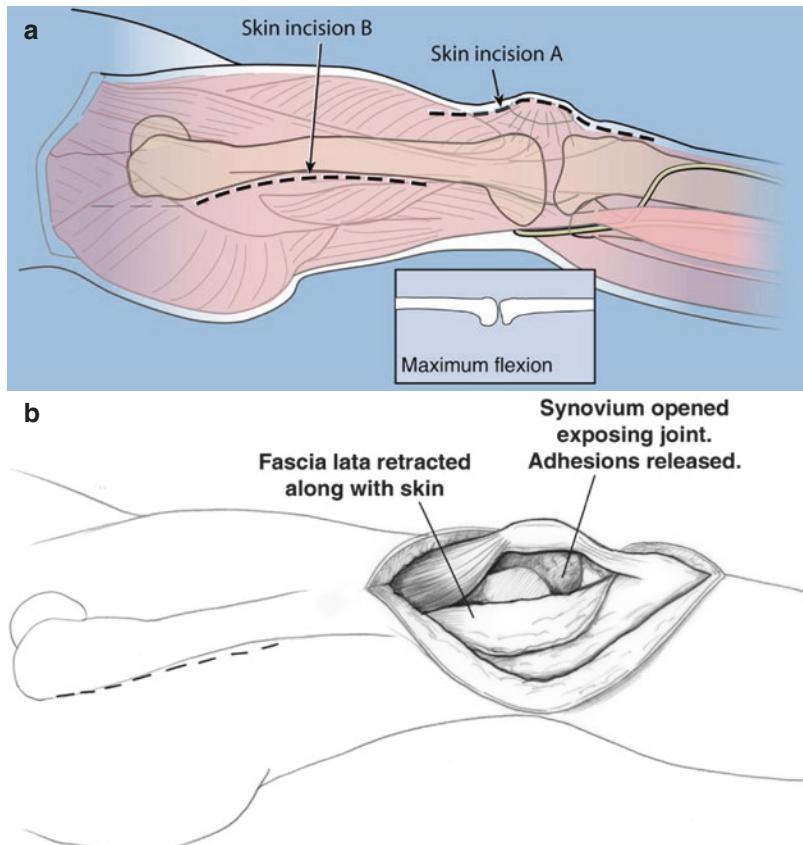


Fig. 20.4 Case 2: (a) Distal incision A: anterior midline ending at tibial tuberosity. Lateral incision B: midline lateral incision extending up alongside of the femur. This incision can extend up to level of anterior inferior iliac spine if the rectus femoris tendon is to be visualized and cut (narrow dashed lines). (b) When a knee joint is present, arthrolysis is carried out from the lateral side. The patella is freed up from the femur in a vastus sparing fashion. When a knee fusion is present, the same is done with the patella being separated from the femur, either by sharp dissection or osteotomy, depending on whether or not the patella is fused to the femur. The iliobibial band (fascia lata) is dissected free of the quadriceps and reflected back for later use. (c) The quadriceps is elevated from the femur in an extraperiosteal fashion as far as the anterior incision allows. (d) The same is done from the medial side. The vastus medialis sparing approach is used to separate the quadriceps from the femur extraperiosteally. Care should be taken to avoid injury to the superficial femoral artery and vein as one progresses proximally. They lie just under the very thin medial intermuscular septum. The knee flexion is checked after each step. Not illustrated here is the distal release of the medial collateral ligament. (e) The release continues proximally through

the second incision. The quadriceps is elevated off of the lateral intermuscular septum and off of the femur. (f) The quadriceps insertion on the lateral trochanteric ridge and then along the intertrochanteric ridge is cut (*RF* rectus femoris, *AIIS* anterior inferior iliac spine). (g) The rectus femoris tendon direct head is released from the AIIS. (h) At this point the flexion of the knee has been restored by the quadricepsplasty releases. If additional exposure is needed to treat knee flexion deformity and decompress the peroneal nerve, the lateral part of the anterior incision can be reflected back, exposing the biceps tendon, gastrocnemius lateral head, and peroneal nerve. The biceps can be Z-lengthened, and the peroneal nerve decompressed before correcting flexion or valgus of the knee. (i) The lateral head of gastrocnemius can also be released to aid in flexion correction of the knee and to expose the posterior capsule if needed. (j) The posterior capsule can be dissected free to re-excite heterotopic bone or for release. This is done if the anterior approach through the knee replacement cuts is not sufficient. (k) The fascia lata can now be used to repair the lateral knee retinaculum and to cover the knee replacement prior to closure. On the medial side, the prosthesis is mostly covered by the vastus medialis, which drapes over the side of the knee

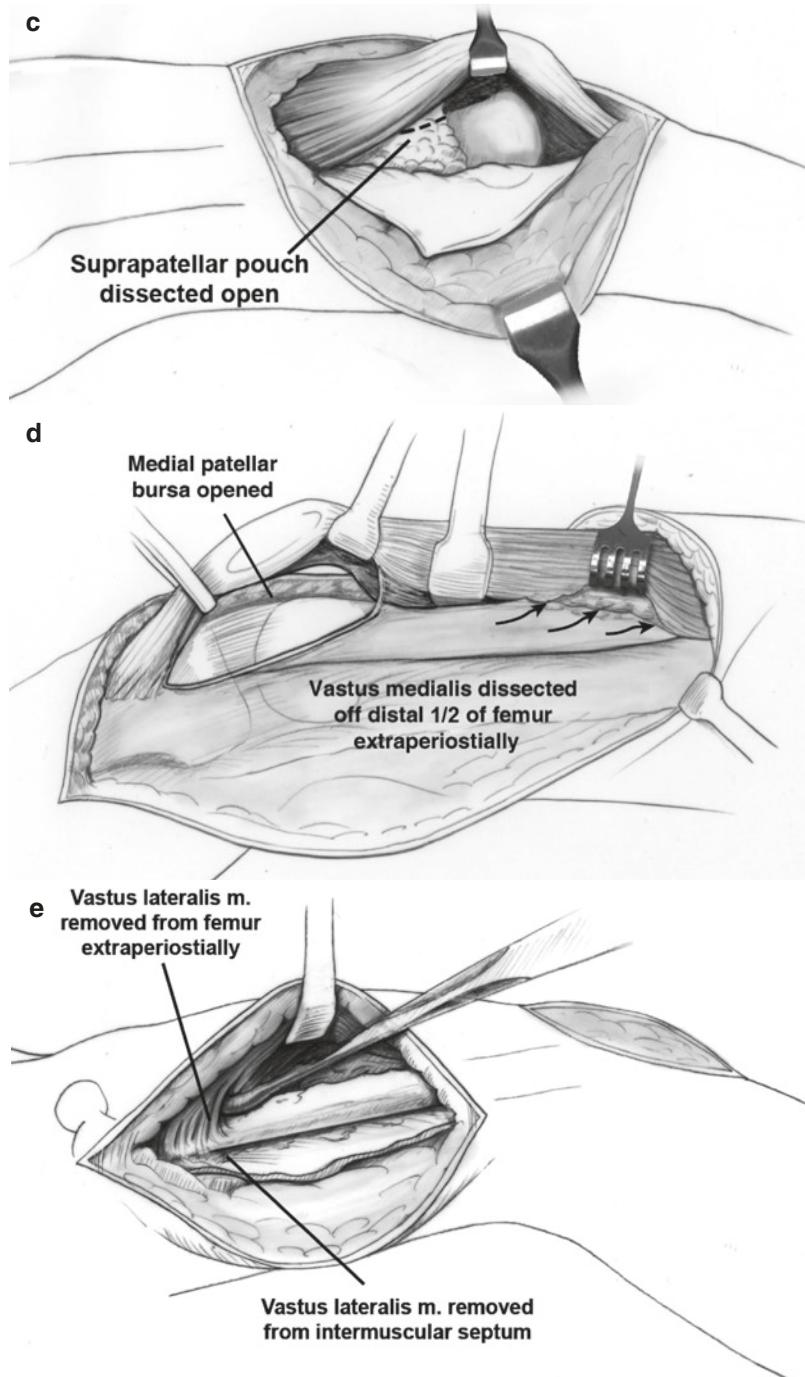


Fig. 20.4 (continued)

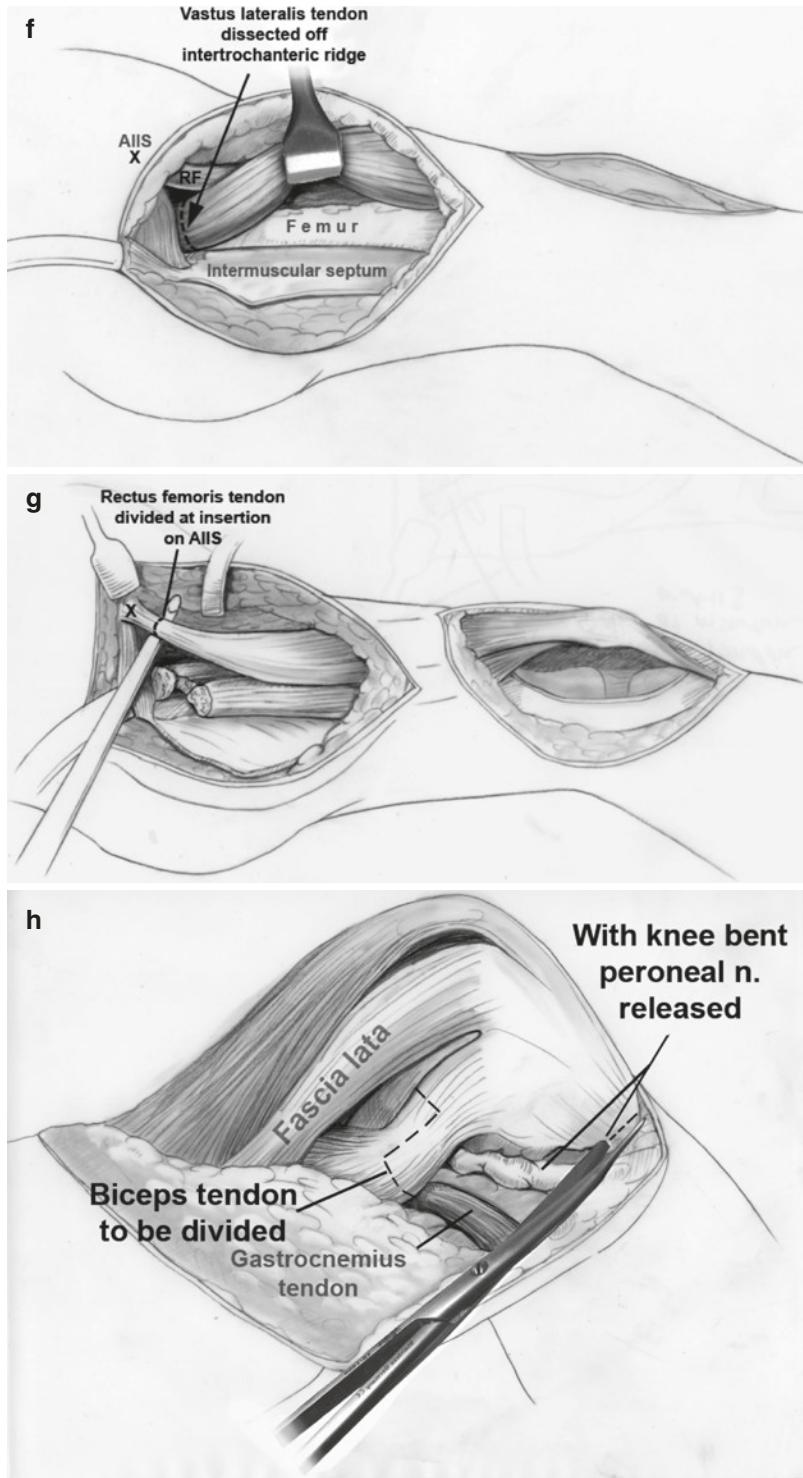


Fig. 20.4 (continued)

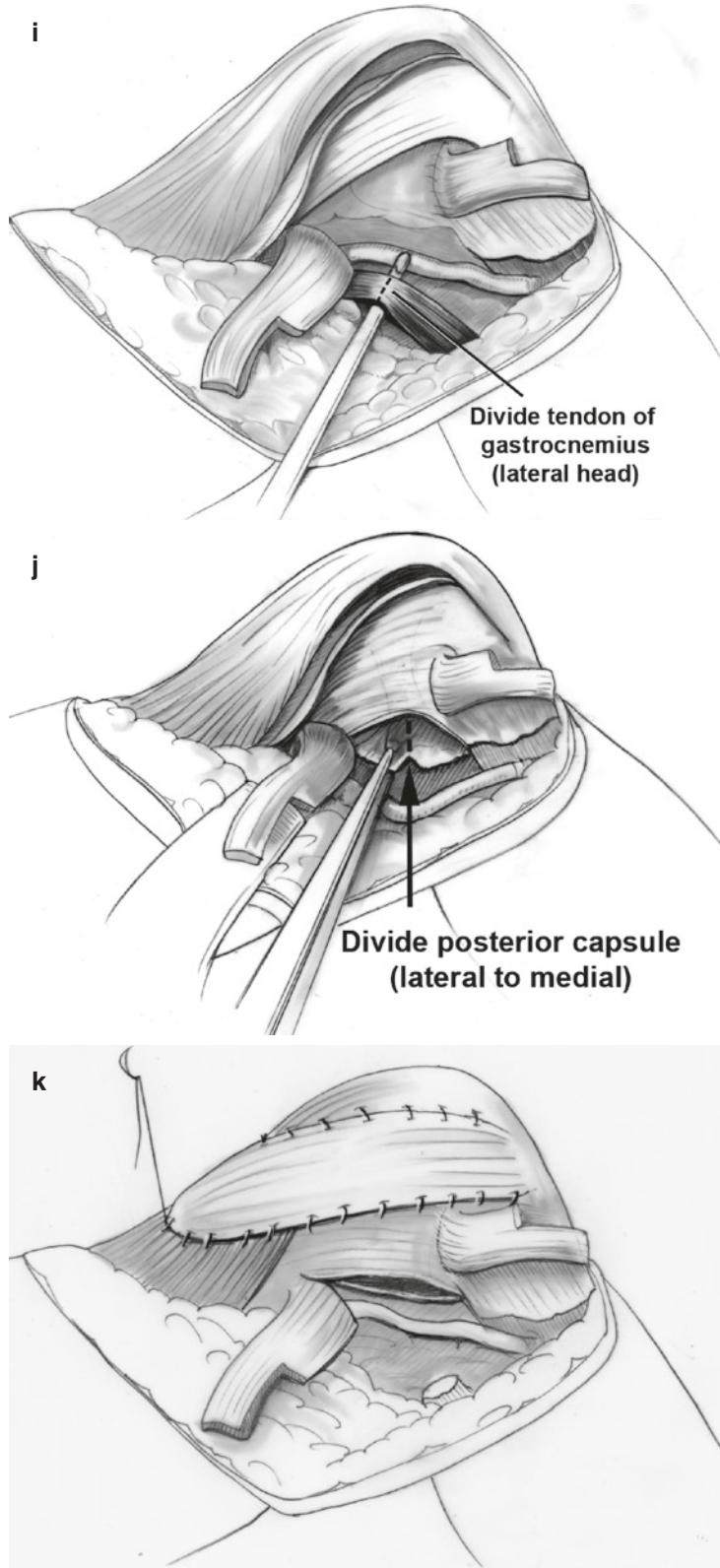


Fig. 20.4 (continued)

vastus muscles. The incision may need to be extended proximally to better visualize its insertion. To test if the rectus femoris is contracted, the hip can be slightly abducted and the knee flexed off of the side of the operating table with the hip fully extended. If the knee flexion is more restricted in this position than it is with the hip flexed, the rectus femoris is contracted and should be released off of the AIIS. The rectus tendon is followed to the AIIS and released. Care should be taken to avoid going too medial, since the femoral nerve passes just medial to this tendon on the anterior medial surface of the iliopsoas muscle.

Step 10: Proximal medial quadricepsplasty. If the knee is not fully flexing at this point, the medial quadricepsplasty is extended more proximally with care taken to avoid damaging the vascular pedicles of the quadriceps muscle.

Step 11: Lateral collateral ligament. The lateral side of the knee is preserved but can be mobilized and sleeved as needed. This release is no different than is normally done with knee replacement. Sleeving is usually done proximally off of the femur.

Step 12: Posterior release. At this point the knee can fully flex, and the quadriceps can be dislocated laterally or medially to move it out of the way of the bone ends. The posterior aspect of the knee can be accessed through the back of the femur, as it would in any knee replacement. Usually the femoral and tibial cuts are done first, and then the posterior capsule is released as needed. If additional release is needed due to flexion deformity of the knee, the lateral part of the anterior incision can be reflected back to expose the biceps tendon, gastrocnemius lateral head, and peroneal nerve. The peroneal nerve should be decompressed to avoid stretch injury due to acute correction of flexion or valgus deformity. The posterior capsule can also be accessed from the lateral side. This is especially useful when resecting heterotopic ossification, or when performing this procedure, or when performing this procedure without replacing the knee.

Step 13: Knee replacement. The knee replacement is then carried out according to the hard-

ware chosen. The degree of constraint is decided according to the integrity and competence of the medial and lateral collateral capsulo-ligamentous structures.

Step 14: Patella and patellar tendon. If the patella is present, a decision should be made to resurface it or not. This decision is made depending on the size and integrity of the patella. If the patellar tendon is short with a patella baja, a further decision is made whether or not to osteotomize the tuberosity and move it proximally. This should be avoided in most cases to avoid notching the tibia and to avoid the associated delay in rehabilitation.

Step 15: Collateral ligament repair. The collateral ligaments are tested for their competence. If they were sleeved, they should be fixed back in place. In most cases they can be stapled down to the femoral or tibial side as needed. Rarely is collateral ligament augmentation with allograft indicated.

Step 16: Retinaculoplasty with ITB. The distal ITB, which was released in Step 5, can now be used to patch the lateral side of the knee to cover the knee replacement. The medial side is mostly covered by the vastus medialis and, if necessary, the sartorius muscle can be mobilized to cover the medial side of the knee.

Step 17: Insert drains. Two long drains are inserted. These drains should be tunneled proximally exiting far from the incision site. The drains extend from proximal to distal, draining the medial and lateral gutters to eliminate dead space.

Step 18: Closure. The incision(s) should be closed in layers. Distally where the ITB was harvested, the underlayer of the fat serves as the fascial layer. Staples are used for skin since they are resistant to incision separation that occurs with repetitive knee flexion. A clear Tegaderm (3M, Minneapolis, MN, USA) is applied with the knee flexed to 90°.

Postoperative Care

The patient is placed on a continuous passive motion (CPM) machine in the recovery room. The patient continues with this machine for a week in hospital on continuous epidural analgesia.

In some cases if the soft tissue vascularity is tenuous, hyperbaric oxygen treatment is used to prevent any flap necrosis. If this is used, it should be started within 24 h. Cooling of the knee can be used but balanced against the decreased circulation this creates to the flap. Avoid anti-inflammatory meds and anticoagulants for the first week due to the wound drainage. Do not remove the Hemovac drains until the drains are almost dry or until 7 days after surgery, whichever comes first. After discontinuing the drains, the patient can be placed on naproxen to prevent heterotopic ossification. This should continue for 6 weeks. The CPM range starts at 60° and is increased daily by 5°. In the hospital the CPM is used 20 h a day, including at night. The patient is mobilized out of bed and taught to walk using a walker or crutches. They are permitted weight-bearing according to the usual knee replacement protocol for the type of total knee arthroplasty (TKA) used. They should have a lockable knee hinge brace for use while ambulating and weight-bearing. The patient is discharged home on a rental CPM for 6 weeks. At home it should be used halftime during the day and all night. The patient starts outpatient physical therapy (PT) immediately after discharge. The PT should focus on passive ROM of the knee to obtain the maximum flexion and to maintain full extension. Electric muscle stimulation of the quads is started. Isometric and active assisted exercises for the quads are started. Gradual strengthening of the quads is carried out according to the patient's progress. During the first 6 weeks, passive ROM is more important than active motion. Within 2 weeks of surgery, the quadriceps begins to scar down and the scar tissue starts to contract. This leads to rapid loss of knee ROM. Therefore the most important goal of PT is to prevent this loss of motion. Active motion will come later when the passive range is secure. By 6 weeks the tendency to lose passive ROM stops and continued PT can increase this range. During the second 6 weeks of PT, the quadriceps lag starts to decrease. Beyond 12 weeks either continued PT or continued strengthening and stretching exercises in a gym should be done for at least another 3 months.

Postoperative Result

Case 1 (Fig. 20.5a–d): The original surgery was performed in March 2003. At latest follow-up March 2017 (14-year follow-up), he had a passive ROM from 0° to 90°. He had a quadriceps lag of 25°. He walked without any walking aids and was gainfully employed running his own business. He had lived with the knee fusion for 20 years (age 6–26 years). According to him the surgery allowed him to sit anywhere, do stairs and inclines, be much more active, and enjoy life much more. He had no limitations. He had no pain. His knee never buckled. The surgery also allowed him to exercise on a bike and elliptical, activities he could not do before. In his words, this was a life-changing surgery and he would do it again. Most of his functional improvement occurred in the first year, but he continued to see functional gains for about 3 years. This case serves to encourage knee fusion takedown surgery even after 20 years and even in arthrogrypotic adult patients.

Case 2 (Fig. 20.6a, b): This patient lived with her knee fusion for 4 years before undergoing a knee fusion takedown in 2006. After 10-year follow-up, the patient had no pain, no quadriceps lag, no limp, and knee ROM from 0° to 110°. Her quadriceps strength returned to normal. She returned to sports activities as well as all activities of daily living. She felt her quality of life had greatly improved with this surgery.

Clinical Results

Two recently published reviews of the literature on the subject of knee fusion takedown summarize the results of this type of surgery using more standard parapatellar approach with or without the use of tibial tuberosity osteotomy. Many also required tissue expanders and V-Y quadricepsplasty. Jauregui et al. [7] did a meta-analysis on 98 knee fusion conversions to TKA from ten published studies. Most patients were satisfied with the outcome and were happier after the TKA than when they had a fused knee. There was an overall complication rate of 47% and an overall revision rate of 25%. When analyzing complications, data were available on 70 of these cases. There were 28 complications from 70 knee fusion takedowns. There were 8

infections out of 70 cases. There were 15/70 skin edge necrosis. Extensor mechanism failure occurred in 2/70, and revision arthroplasty in 17/70. Repeat fusion was performed in 6/70 and amputation in 1/70. Knee flexion to 90°

was achieved by most of the reported studies. Residual fixed flexion deformity of the knee remained in six of the ten studies.

Kernkamp et al. [8] did a meta-analysis of 123 knees that underwent conversion from

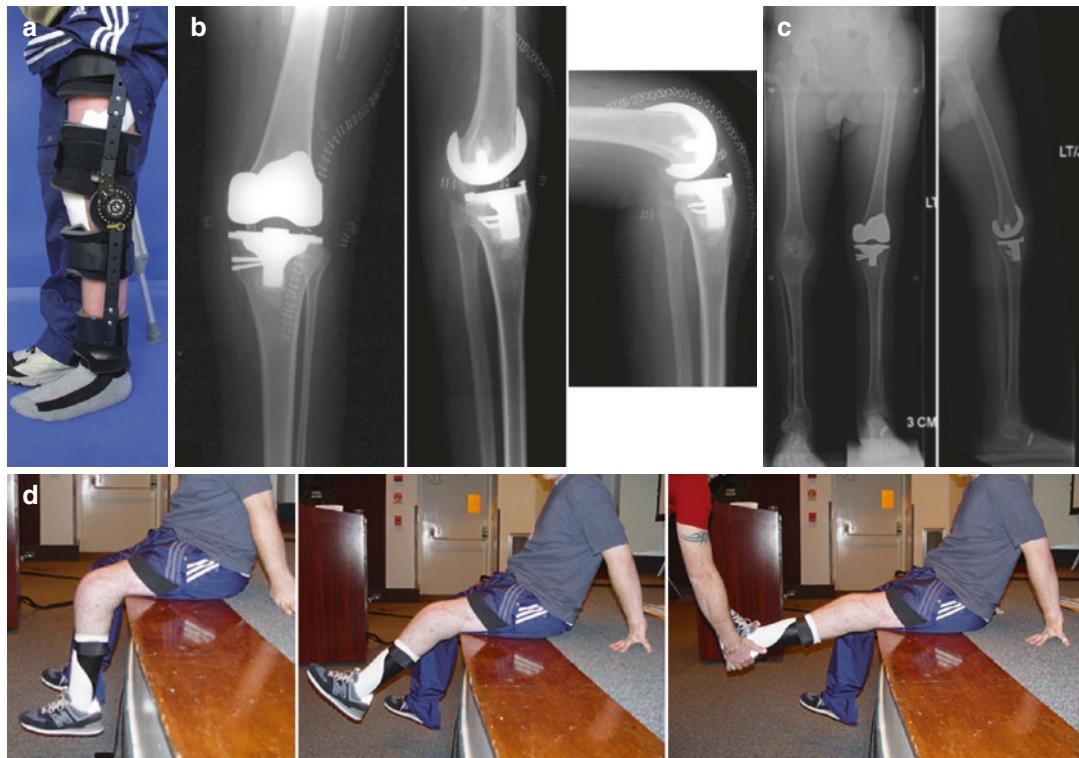


Fig. 20.5 Case 1: (a) After surgery the patient ambulates in a lockable knee brace until the patient regains quadriceps control and can walk without the knee buckling. (b) Immediate postoperative AP (left) and lateral (middle) radiographs of the knee in extension and lateral radiograph of the knee in flexion (right). Note the two Hemovac drains in the medial and lateral gutters on the AP radiograph. Also note the skin was closed with staples to resist the continuous knee flexion with the continuous passive

motion machine. (c) Follow up standing radiographs 14 years after surgery. Knee prosthesis remains well positioned and no evidence of loosening. The lateral radiograph is done in maximum extension and shows a 10° flexion deformity of the knee. (d) Knee flexion is 90° (left). Active knee extension has a 20° quadriceps lag. Passive knee extension comes to 10° because of a slight flexion deformity

Fig. 20.6 Case 2: (a) Two-year follow-up long AP radiograph (left), AP (top right) and lateral (bottom right) radiographs after quadricepsplasty with knee replacement. There are excellent frontal plane alignment and full knee extension seen on the lateral view. A staple was used to repair the medial collateral ligament, which had been sleeved at the femoral end. A 6 mm solid stainless steel rod was inserted into the femur to protect against fracture

due to the anterior notching of the distal femur. (b) Two-year follow-up photographs showing right knee alignment from the front (left), right knee bending to 95° from the side (middle), and active right knee extension with no lag (right). The well-healed S-shaped incision can be seen. In this case the distal anterior and the proximal lateral incisions were connected into one long incision, as was done in Case 1 (Fig. 20.1)



arthrodesis to knee replacement. They reported a complication rate of 65%, skin necrosis 25%, arthrofibrosis 13%, revision 11%, infection 11%, extensor mechanism problem 5.6%, repeat fusion 4.9%, death 2.7%, amputation 2.2%, and myositis ossificans 1.8%. Gain in ROM varied from 60° to 100°.

I modified the technique of Judet quadricepsplasty more than 20 years ago [6]. I started applying it with knee replacement in the year 2000. The only difference between taking down a completely ankylosed knee and performing a TKA and taking down a knee fusion and performing a TKA is the osteotomy of the knee fusion. Between 2001 and 2015, I have performed knee fusion takedown with conversion to knee replacement in ten cases with an average of 6-year follow-up and minimum of 2-year follow-up. The preliminary experience with this was referenced in 2004 by Conway et al. [9]. The unpublished results of these ten knee fusion takedowns show that there have been no revision surgeries on any of these patients, no refusions, and no amputations. There was one wound edge necrosis, which required debridement and skin grafting. One patient with a previous knee infection had a positive alpha-defensin without any organism cultured. He developed a reankylosis and heterotopic ossification (HO). He required repeat quadricepsplasty and HO resection. His knee motion was restored and is now 110°. There were no other infections or HO. Knee motion was at least 90° in all cases with the exception of one case, which ended up at 60°. Knee extension was full or at most 10° flexion deformity. There was a quadriceps lag averaging 20° in 5/10 patients. Knee stability was excellent in all cases. All patients were satisfied and said they would do it again.

Key Points

- Paley modified Judet quadricepsplasty can be combined with TKA.
- This quadricepsplasty is a proximal quadriceps muscle slide and avoids changing the muscle tendon length ratio, thus decreasing the weak-

ness associated with more distal type of quadricepsplasties such as V-Y and Thompson.

- The arthrodesis osteotomy is made prior to the quadricepsplasty so that as the muscle release is carried out, the knee can progressively bend. This reduces the amount of release needed.
- A vastus sparing approach should be used both medial and lateral to the patella to avoid denervating and devascularizing the quadriceps muscle.
- The ITB can be used to cover the lateral part of the knee as a retinaculoplasty.
- Epidural anesthesia and CPM are useful to maintain knee motion after surgery.
- Physical therapy is critical for the first 6–12 weeks to maintain knee ROM.

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Management of Soft Tissue Defects

21

Giles R. Scuderi, Michael P. Nett,
Germán A. Norambuena, H. John Cooper,
Oren Lerman, and Irena Karanetz

Introduction

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Wound complications following total knee arthroplasty (TKA) can be a serious and challenging problem. As the number of TKAs increases annually, the number of complications is expected to rise. Impaired wound healing or

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soft tissue compromise can lead to more devastating complications, such as extensor mechanism disruption and infections. An organized approach to wound complications includes identification of the lesion, classifying the severity and depth of the defect, and initiating appropriate treatment [1]. Optimal treatment requires a comprehensive interdisciplinary approach with collaboration between orthopedic surgery and plastic surgery. Critical for a successful outcome and implant retention is timely reaction to the appearance of a wound problem and restoration of complete soft tissue coverage [2].

Current techniques in the management of wound complications focus on early closure of the soft tissue defect over the extensor mechanism and knee prosthesis with the intention of not compromising future procedures that may be necessary. Once a wound complication is noted (Fig. 21.1), an appropriate treatment plan should be initiated. Simple serous drainage within the first couple of days following surgery may respond to rest and immobilization. Persistent drainage may require a return to the operating room for wound exploration, irrigation, and debridement. Primary closure is an option for a wound with minimal necrosis or dehiscence when the tissue is mobile enough to get a tension-free closure following wound debridement. As an adjunctive temporary wound treatment, negative-pressure wound therapy (NPWT) provides an environment that continually removes fluid from



Fig. 21.1 Proximal wound dehiscence and delayed healing following primary TKA

the exposed wound and promotes epithelial migration from the edges toward the center of the wound. While NPWT may have some value in early wound management, more definitive procedures may need to be considered.

Split-thickness skin grafts are useful in the management of small non-infected wound defects that have a base of granulation tissue and are not extending deep into the subcutaneous layer. The role of split-thickness skin graft across the knee joint is limited because of the probable contracture of graft impeding knee motion and may limit future procedures through the surgical site.

Soft tissue reorientation, fasciocutaneous flaps, and musculocutaneous flaps are chosen by the three-dimensional shape of the wound defect. The medial gastrocnemius rotational flap is the workhorse for soft tissue defects on the medial side of the knee joint, primarily in the region of the patella tendon and tibial tubercle. The lateral gastrocnemius rotational flap tends to be smaller and is used for lateral and anterior soft tissue

defects. Fasciocutaneous flaps consist of skin and subcutaneous tissue with the underlying fascia and receive their blood supply from the perforating arteries. These flaps are useful in reconstructing defects around the knee because they are thin and pliable and can be easily contoured to cover the soft tissue defect. Microvascular free tissue transfer has utility in the salvage of complex knee wounds with large defects, exposed implants, and infection. Free flaps are used when no suitable local options are available.

Wound complications following TKA can be a devastating problem, such that understanding a systematic approach to soft tissue management is critical to a successful outcome. Numerous options are available in the management of soft tissue defects depending on the location and severity of the lesion. The following case reports will outline the indication and techniques for managing some of these complex problems.

Option 1: Local Wound Care

Michael P. Nett and Germán A. Norambuena

Case Presentation

History

The patient is a 58-year-old male who presents with chronic progressive knee pain and deformity. He had a remote injury to his knee as an adolescent but never received treatment. He is currently in a treatment program for adults with history of prior substance abuse. His pain and varus deformity have increased significantly over the past 3 years. He has failed to respond to appropriate conservative treatment including NSAIDs, cortisone injection, and physical therapy. He is unable to ambulate more than three city blocks. He has extreme pain with stairs and uneven grounds. He is interested in knee replacement surgery.

Physical Examination

Height 5'10, weight 198 lbs. Unkempt but not disheveled. Alert, oriented, and appropriate. He ambulates with a cane and demonstrates a

significant antalgic gait with a large varus thrust. He has no significant effusion. His knee has a fixed varus deformity of 15° and a flexion contracture of 10°. No prior incisions are present. His range of motion is 10–90°. He has marked crepitus and pain with range of motion. His neurovascular exam is normal with slight venous stasis but no edema or open sores.

Radiographs and Advanced Imaging

Anteroposterior (AP), lateral, and Merchant views of the patient's (Fig. 21.2) left knee prior to surgery demonstrate severe osteoarthritis with varus deformity and posteromedial bone loss.

Surgical Technique

The knee is exposed with a straight anterior skin incision extending from the medial aspect of the

tibial tubercle to two fingerbreadths proximal to the superior patellar pole. Full-thickness subcutaneous flaps are developed. A straight medial parapatellar capsular arthrotomy is performed. With the knee in the flexed position, the anterior cruciate ligament (ACL) is transected off the tibia surface. The tibia is now subluxed anteriorly. We cut the tibia with the OrthAlign® device (OrthAlign, Aliso Viejo, CA, USA) (Fig. 21.3a). The cut is made at 90° to the mechanical axis of the tibia, with 3° of posterior slope in the antero-posterior plane (Fig. 21.3b).

The femoral alignment guide is then inserted into this intramedullary channel with a 5° valgus angle. The distal femoral cutting block is elevated 1 mm to help address the preoperative flexion contracture by slightly elevating the joint line by turning the adjustable dial to “1” (Fig. 21.4). The



Fig. 21.2 (a) Anteroposterior (AP), (b) lateral, and (c) Merchant views of the patient's left knee prior to surgery demonstrate severe osteoarthritis with varus deformity and posteromedial bone loss

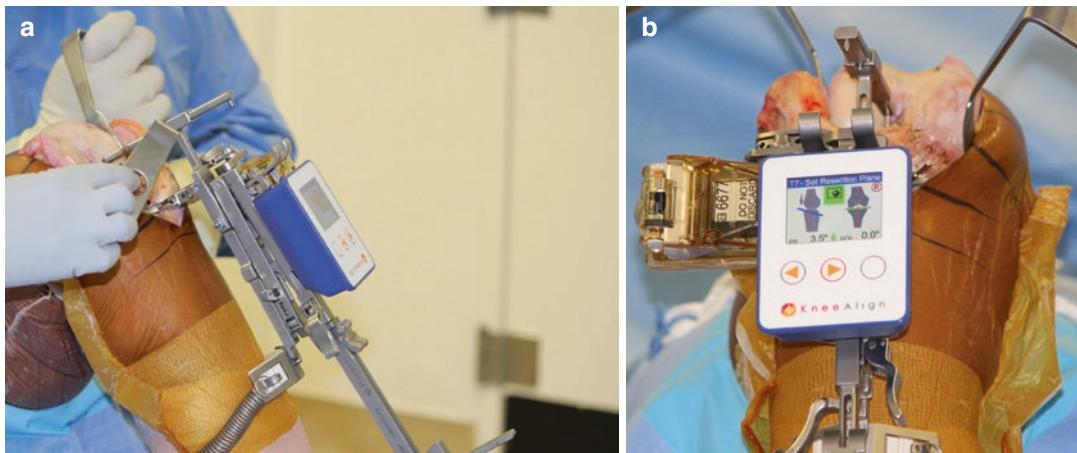


Fig. 21.3 The OrthAlign device (OrthAlign, Aliso Viejo, CA, USA) (a) is utilized (b) to reproducibly resect the tibia perpendicular to the mechanical axis and in 3° of posterior slope

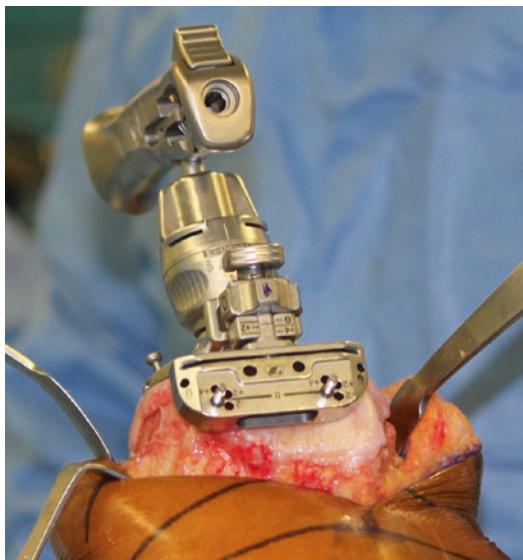


Fig. 21.4 An additional 1 mm of distal femoral bone is resected in this case to slightly elevate the joint line and help address the preoperative flexion contracture

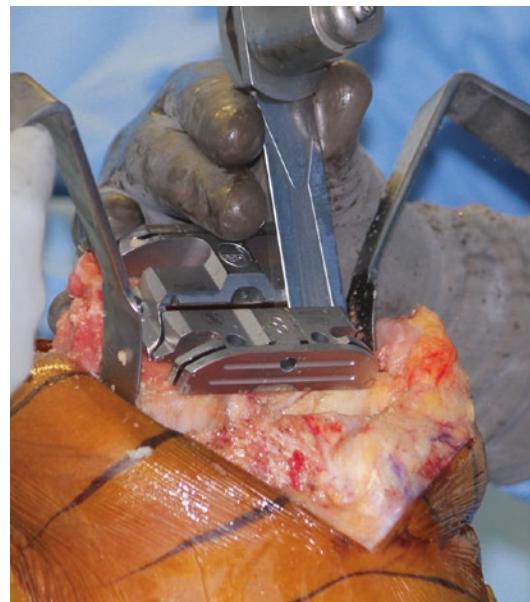


Fig. 21.5 The 4-in-1 guide is pinned to the distal femur after the size has been determined with an anterior referencing guide. Rotation is set at 3° of external rotation based off the posterior femoral condyles

4-in-1 femoral finishing guide is then pinned to the distal femur. The distal femur is then cut in a sequential order (Fig. 21.5). Laminar spreaders are then inserted into the lateral joint space with the knee flexed to 90°. The ACL, posterior cruciate ligament (PCL), and menisci are excised. An alignment rod is placed through the end of a

block and checked to ensure that its distal end aligns with the center of the ankle. With the correct size block inserted to adequately balance soft tissue tension in flexion, the knee is brought into extension (Fig. 21.6). The collateral ligaments are then assessed to ensure correct knee balance. In this fixed varus knee, a more extensive medial

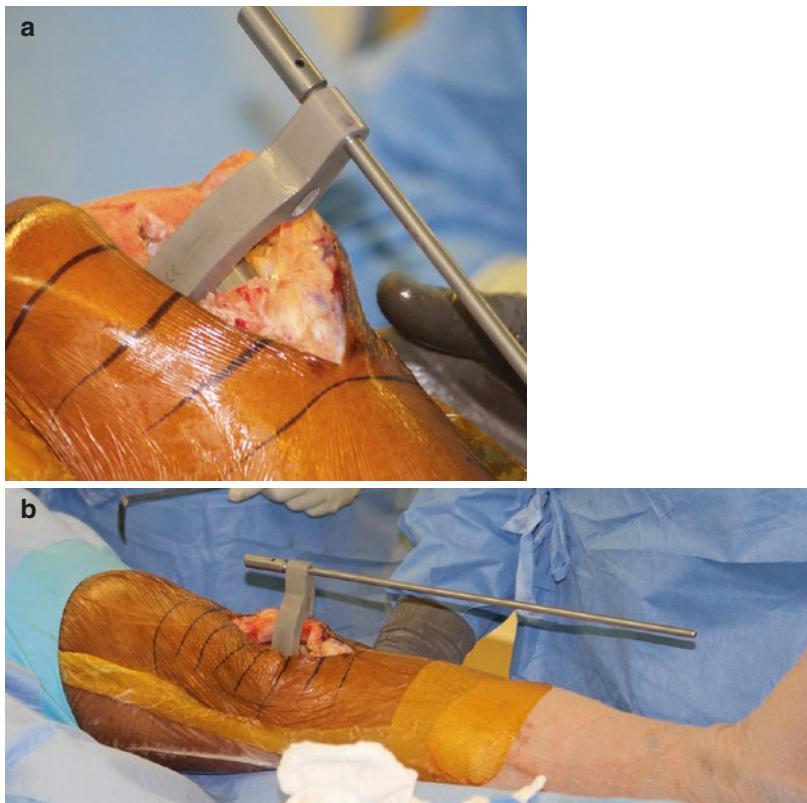


Fig. 21.6 A spacer block and drop rod (a) are used (b) to confirm the alignment of the tibial resection and to check for ligamentous balancing of the knee

release is required. An osteotome is used to subperiosteally strip the distal insertion of the superficial medial collateral ligament. Importantly, the deep portion of the medial collateral ligament (MCL) and a portion of the semimembranosus insertion on the tibia are released prior while the foot is externally rotated (Fig. 21.7). The remaining bone cuts are completed. The tibial template is slightly downsized, and a “reduction osteotomy” of the tibia is performed to minimize the residual posteromedial tibial defect present (Fig. 21.8). The tibial component rotation is based off the medial one-third of the tibial tubercle. The tibial stem hole is prepared for the tibial stem including a 15×30 mm stem extension due to the tibial bone loss. The femoral trial component is then impacted onto the distal femur.

We prepare the patella with a patellar reaming system. The trial polyethylene tray is inserted.

The knee is checked to ensure adequate balance of the collateral ligaments. The knee is inspected with regard to limb alignment. Finally, full range of motion without flexion contracture, excessive tightness, or laxity is ensured. Patella tracking is assessed (Fig. 21.9). Two small fragment 3.5 mm screws are placed in the posterior medial tibial defect as a “cement and screws” technique. The components are cemented in place in one stage. While the cement polymerizes, a periarticular injection is completed, and the knee is bathed in a dilute Betadine solution (Fig. 21.10). The final tibial insert is snapped into place. The arthrotomy is carefully closed with a barbed running suture. The skin is closed with a Prineo® skin closure system (Ethicon Products, Somerville, NJ, USA) (Fig. 21.11). Final X-rays are taken, a sterile occlusive dressing is applied, and the patient is transferred to the recovery room (Fig. 21.12).



Fig. 21.7 The proximal tibial dissection is first carried around (a) to release the semimembranosus. The superficial medial collateral ligament (MCL) is released (b) subperiosteally to correct the fixed varus deformity

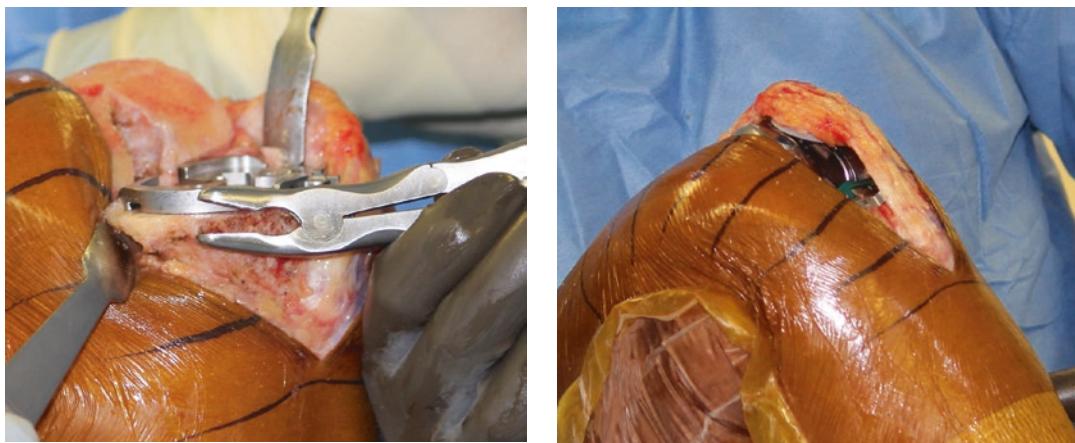


Fig. 21.8 In the varus knee, the tibia component is often downsized slightly and positioned to the lateral edge of the tibial plateau. This allows the appropriate rotation, and a “reduction osteotomy” is performed to further correct the varus contracture

Fig. 21.9 With the trial components in place, patella tracking is assessed, and final ligamentous balance is confirmed

Postoperative Wound Complication

At the 5 weeks postoperative with a small wound dehiscence distally and light serous drainage (Fig. 21.13). The fibrinous bed of the wound was debrided in the office. Santyl® collagenase is applied directly to the wound bed twice daily and covered with a slightly moist 4 × 4 dressing. The wound is followed closely over 4 weeks and heals with secondary intention without complication.

Discussion/Results

A large retrospective study from Mayo Clinic demonstrated that patients with early superficial wound complications requiring surgical intervention after primary total knee arthroplasty (TKA) had increased 2-year cumulative probabilities of major subsequent surgery and deep infection compared with patients not requiring early surgical intervention of 5.3% and 6.0% versus 0.6% and 0.8%, respectively [3]. This study not only

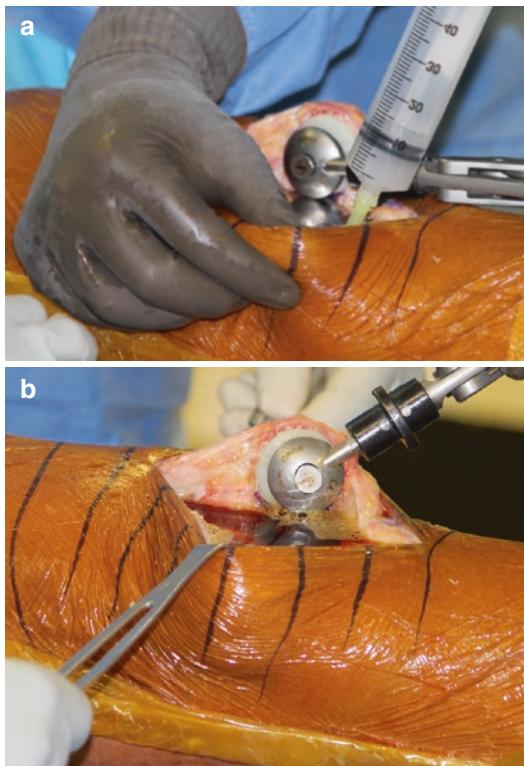


Fig. 21.10 A multimodal periarticular injection including liposomal bound Marcaine is administered (a), and the knee is soaked in a dilute Betadine solution while the cement polymerizes (b)



Fig. 21.11 Prineo® skin closure system (Ethicon Products, Somerville, NJ, USA), which consists of a topical skin adhesive and a flexible self-adhesive mesh

highlights the importance of avoiding early post-operative wound complication but also demonstrates the importance of managing simple wound complications with local wound care to prevent

progression requiring a return to the operating room.

Preoperative Management

The knee has a thin overlying soft tissue envelope that must be protective, well vascularized, and supple enough to allow for the large degrees of stretch and shear required for a functional range of motion. Although most TKAs and total knee revisions (TKRs) can be performed with standard protocols, a comprehensive approach to soft tissue management is mandatory in complex cases. Preoperative evaluation for TKA should include not only a complete history and physical examination, including radiographic and clinical assessment of degree of deformity and joint space narrowing, but also a thorough history and evaluation of the skin. Systemic concerns include vascular compromise, obesity, malnutrition, prolonged corticosteroid or nonsteroidal anti-inflammatory drug use, diabetes mellitus, an immunocompromised state, or a history of smoking [4–7]. Diabetes mellitus has been significantly associated with the development of early wound complications requiring surgical intervention in TKA [3]. Local factors that affect wound healing include the inability to incorporate a previous incision into the planned incision, a small skin bridge between the previous incision and the planned incision, local radiation or burns, and dense, adherent scar tissue. The correction of severe deformity may make subsequent closure difficult. Special caution should be used in patients with severe varus and rotational deformity because there may not be enough skin to close the inferior aspect of the wound over the subcutaneous surface of tibia. Prior trauma about the knee may also affect adequate wound closure from previously placed skin incisions, significant scarring, and loss of skin. A preoperative consultation with plastic surgery is advisable in any patient undergoing complex knee surgery in conjunction with systemic or local risk factors for wound complications. This will help both before and after the procedure.

Previous anterior incisions present a concern regarding both the planned approach and the healing potential of the skin and underlying

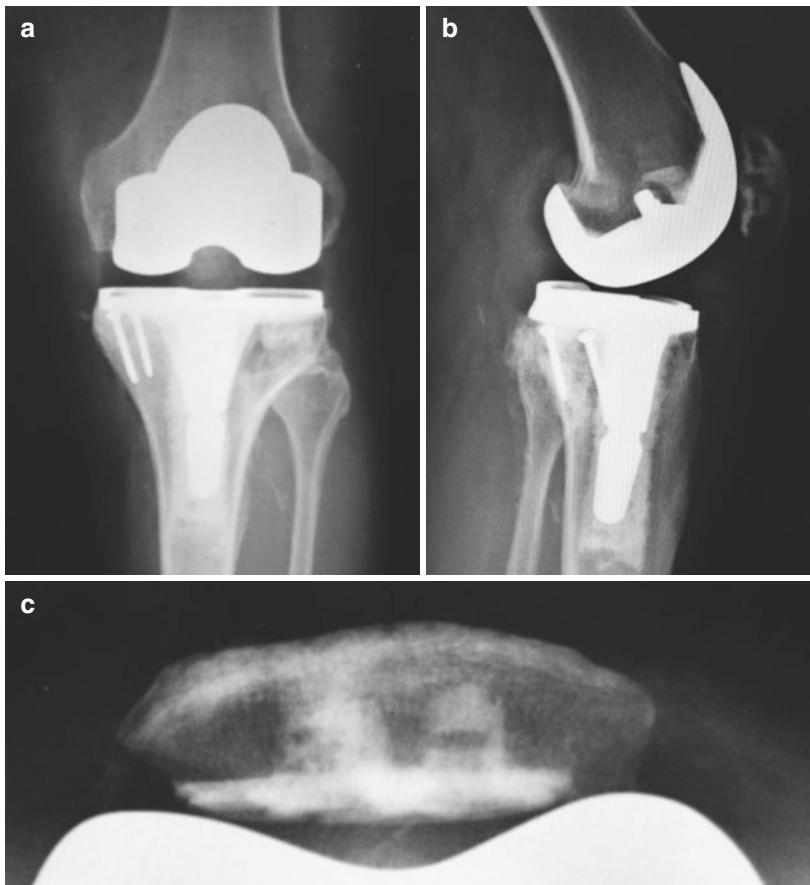


Fig. 21.12 Final (a) anteroposterior, (b) lateral, and (c) and Merchant X-rays

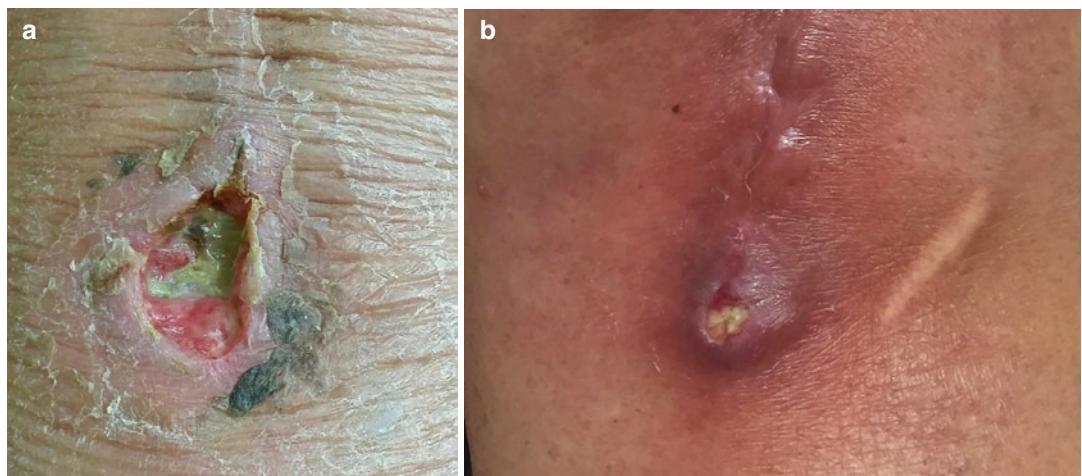


Fig. 21.13 (a, b) Typical cases of superficial wound dehiscence with fibrinous bed that is amenable to local wound care with a topical collagenase

tissue. A balance must be achieved between the ability to expose the knee through a prior incision and avoiding extensive undermining of the subcutaneous flaps.

Terminal branches of the peripatellar anastomotic ring of arteries are responsible for most of the blood supply to the anterior skin and subcutaneous tissues. This occurs through a subdermal plexus supplied by arterioles in the subcutaneous fascia. Thus, flap formation over the anterior aspect of the knee must be limited and performed deep to the subcutaneous fascia. A midline skin incision is optimal and should be used whenever possible. This approach reduces the dimensions of the lateral skin flap where lower skin oxygen tension is noted. Previous longitudinal incisions can be used safely. Some degree of modification is often required to incorporate previous paramedian incisions. If multiple parallel longitudinal incisions exist, the most lateral incision is chosen, as the predominant blood supply enters medially. Johnson [8] has shown a reduction in oxygenation of the skin in the lateral region after skin incisions about the knee by the measurement of transcutaneous oxygen. Transverse skin incisions, such as those from previous patellar surgery or osteotomy, can be safely approached at a 90° angle. Short oblique incisions, such as from previous meniscectomies, can often be ignored. Caution should be exercised when crossing longer oblique incisions or oblique incisions that cross the midline, as crossing these incisions may result in a narrow point where the incisions intersect. When the planned surgical incision and prior incision create an angle of less than 60°, alternative techniques should be considered including prophylactic flap coverage or soft tissue expansion [9].

Intraoperative Soft Tissue Defect

Management

The treatment of soft tissue defects about the knee depends on the site or location, the presence of infection, and, perhaps the most important, if there is bone, tendon, or implant exposure. Necrotic tissues and contaminated foreign materials must be removed. The size of the soft tissue defect should be estimated with the knee at a

maximum flexion and the “like with like” tissue replacement principle should always be applied. Generally speaking, the options are conservative wound management and debridement with or without reconstruction. When the resulting defect is deep with exposed bone or hardware, or infection is documented, flaps are needed for successful salvage of the lower extremity [10]. In general, the ability to perform a medial gastrocnemius muscle flap and skin graft is an invaluable skill in complex cases where primary wound closure cannot be achieved.

Our Current Protocol

Our wound closure and management has changed dramatically over the past 5 years. The changes have led to an anecdotal improvement in patient satisfaction, less surgeon involvement for routine wound care, a lower superficial wound complication rate, and, ultimately, a trend toward a lower infection rate.

We use #2 polydioxanone bidirectional barbed suture wound closure for the knee arthrotomy. The subcutaneous fat is then re-approximated with #0 polydioxanone bidirectional barbed suture, and the subcuticular layer is closed with bidirectional barbed 3-0 monofilament suture. By using bidirectional barbed suture, we have seen a reduction in our TKA wound closure times by 50% from an average of 22–12 min. The incision is then reinforced with the Prineo® skin closure system (Ethicon Products, Somerville, NJ, USA), which consists of a topical skin adhesive and a flexible self-adhesive mesh. The combined use of barbed suture and the liquid adhesive, in our experience, has reduced any immediate wound drainage or leakage. This has allowed for a simple approach to the surgical dressing with a single layer of non-adherent gauze and a transparent film (3M Tegaderm®, 3M, St. Paul, MN, USA).

Incisional negative-pressure wound therapy (NPWT) systems (Prevena Incision Management System, Acelity, San Antonio, TX, USA) are utilized in our high-risk patients. Pre-sized and customizable options exist depending on incision length and shape. Our practice has not established a strict protocol, but morbid obesity (body mass index > 50), revision surgery,

reimplantation surgery, and surgery for active infection are our current indications for use. The incisional NPWT dressing is left in place for 7 days postoperatively and then discarded.

Minor Superficial Wound Complications

For the routine suture reaction, observation without antibiotics and wound care frequently results in wound healing without complication. If oral antibiotics are considered, it is our opinion that the knee should always be aspirated first. In the event that the presumed superficial wound complication is the first sign of a more substantial “deep” infection, it will be critical to obtain an accurate wound culture for subsequent treatment before antibiotics are implemented. Encouraging results have been reported using a topical *Clostridium hemolyticus* collagenase Santyl ointment (Smith & Nephew, Fort Worth, TX, USA) for treatment of diabetic foot ulcers [11, 12]. Although there is no literature to support the use of this debridement ointment in knee surgery wound complications, we have adopted this practice to treat superficial wound dehiscences associated with devitalized tissue, and our preliminary results have been satisfactory. The wound is cleaned with sterile saline, and then the collagenase is liberally applied directly to the open wound daily and covered with sterile gauze. The collagenase is most effective in a moist environment, so if the wound is very dry, some additional saline may be added to the wound bed. The collagenase is continued until the wound is epithelialized.

Wound Drainage

If slight spotting on the surgical dressings is noted during the first 3 days post-op, our postoperative protocols are not changed. Our rescue plan is employed if the dressings become saturated early or any drainage persists after 3 days. The initial rescue plan consists of holding aggressive chemical anticoagulation (low-molecular-weight heparins are changed to aspirin), the placement of a bulky compressive dressing, and knee immobilization. Daily dressings are then performed, and routine postoperative care resumes once the wound is dry for 24 h. If drainage persists more than 2 days despite immobilization and a bulky

compressive dressing or if drainage remains significant, we will consider the placement of an incisional NPWT dressing. Commercially available systems can be used, but if drainage is significant, a standard NPWT system with a larger canister is often necessary. The incisional NPWT dressing is left in place up to 7 days post-op. If any drainage persists after 1 week, return to the operating room is strongly considered.

Key Points

- Early wound complication places patients at significant risk for deep infection and major subsequent surgery.
- Preoperative assessment must include recognition of local risk factors for wound complication as well as systemic risk factors.
- The surgeon must work closely with the internist to address systemic risk factors and optimize the patient for surgery.
- When local risk factors are present including multiple prior incisions, a preoperative plastic surgery consult is critical. Tissue expansion or prophylactic flap coverage may be appropriate.
- Barbed suture closure and liquid adhesive for the skin helps to reduce early wound drainage.
- Establish a rescue protocol to quickly address postoperative wound drainage.
- If postoperative drainage persists, early surgical intervention must be considered.
- Topical *Clostridium hemolyticus* collagenase ointment has worked well in our practice to address superficial wound complications.

Option 2: Negative-Pressure Dressing Approach

H. John Cooper

Introduction

Negative-pressure therapy (NPT) has a robust clinical history across many surgical

subspecialties and has been utilized with increasing frequency in recent years in managing a variety of orthopedic problems. Negative-pressure dressings work through a variety of mechanisms, applying both mechanical and biological forces to wound bed to improve the local environment and healing [13]. These include application of macrostrain, which pulls the wound edges together and removes exudate and infectious materials, as well as microstrain, which reduces edema, promotes perfusion, promotes formation of granulation tissue, and increases cellular proliferation [13]. Randomized controlled trials have demonstrated superiority of negative-pressure dressings over conventional dressings in various orthopedic trauma settings, with shorter healing times and decreased need for secondary soft tissue coverage [14, 15].

This chapter introduces the concept of NPT, utilized through two different mechanisms, to manage compromised periprosthetic tissues in complex total knee arthroplasty. The goals of this chapter are (1) to demonstrate the operative technique through an illustrative case example, (2) to briefly describe the mechanism of action and basic science supporting NPT, and (3) to review published clinical results of NPT in the management of surgical wounds and incisions.

Case Presentation

History

A 65-year-old woman presented to her local emergency department with 2 days of severe left knee pain accompanied by fever and chills. This acute episode was preceded by 2 weeks of mild discomfort in her knee. She had a history of hypertension, atrial fibrillation requiring warfarin anticoagulation, non-insulin-dependent diabetes, and a BMI of 37.0. She was a nonsmoker and a retired but active community ambulator without assistance.

Her left knee had undergone total knee arthroplasty (TKA) approximately 16 years prior to the current episode, followed by two subsequent revision procedures, each performed by other surgeons. The first revision was performed

5 years prior, for aseptic femoral and tibial loosening and a periprosthetic medial condyle fracture. The subsequent revision was performed 2.5 years later for femoral loosening, stiffness, and synovitis. She stated that, aside from the preceding 2 weeks when she noted discomfort, her revision TKA had been functioning very well without any significant pain or functional limitation. Given the clinical concern for infection, she was transferred urgently to a tertiary medical center.

Physical Examination

On inspection, she had an extensile, well-healed anterior incision. The skin at the proximal aspect was thin, and the scar had widened and spread, while the skin at the distal aspect of the incision was tight and adherent to the proximal tibia (Fig. 21.14). There was little mobility of the skin from the underlying bone at the distal aspect, likely related to the multiple prior surgeries.



Fig. 21.14 Preoperative photograph of a 65-year-old woman's knee, with an acute periprosthetic joint infection, status post three prior knee arthroplasty procedures. Note the tight, adherent appearance of the distal aspect of the incision

There was no significant erythema but the knee was warm to touch. She had a large, tense effusion and a painful arc of motion from 10° to 70°. There was global tenderness to the knee. Stability was difficult to assess accurately secondary to pain; however, there was no gross ligamentous incompetence. She had difficulty bearing weight secondary to pain.

Radiographs and Laboratory Data

Anteroposterior and lateral radiographs demonstrated modular revision knee components (Fig. 21.15). Although there were partial metaphyseal radiolucencies around the distal femur and proximal tibia, modular sleeves and stems demonstrated robust meta-diaphyseal hybrid fixation without surrounding lucency on both femoral and tibial sides. Compared to past radiographs, the metaphyseal radiolucencies were stable and non-progressive since her most recent revision. The lateral radiograph (Fig. 21.15b) demonstrated a large effusion, patella baja, and mild heterotopic ossification in the anterior and posterior soft tissues. The lateral radiograph was also suggestive of patellar loosening, with a near-complete radiolucency around the polyethylene pegs.



Fig. 21.15 Preoperative (a) anteroposterior (AP) and (b) lateral radiographs of the patient's well-fixed modular revision total knee components

Initial bloodwork upon transfer to the tertiary medical center documented a C-reactive protein (CRP) of 20.8 mg/dL (normal <0.9 mg/dL). Purulent fluid was aspirated from the knee joint and sent to the laboratory for analysis. Cell count demonstrated 475,000 WBC/ μ L, with a differential of 96% polymorphonuclear cells (PMNs). Aerobic and anaerobic cultures were also obtained from the synovial fluid specimen. Cultures would eventually demonstrate *coagulase-negative Staphylococcus*; however, this result would not be available for two more days.

Surgical Approach

Based on examination and laboratory analysis, the patient was diagnosed with a periprosthetic joint infection (PJI) of her revision knee arthroplasty. The chronicity of her symptoms was uncertain. Her history of several years of a previously well-functioning revision, followed by 2 weeks of acute-onset pain and fevers, suggested an acute hematogenous infection. However, her radiographs with partial metaphyseal radiolucencies and heterotopic ossification raised concern for a more chronic process.

The patient was presented with several options including (1) two-stage exchange with explantation and temporary spacer placement and (2) irrigation and debridement with polyethylene exchange. Complicating this decision, she had several patient-specific risk factors including diabetes, obesity, multiple prior revisions, and a limited soft tissue envelope, each of which diminished her chances of treatment success. Given the potential morbidity in removing well-fixed femoral and tibial stems, as well as the uncertainty surrounding the chronicity of her infection, she instead decided to proceed with another option (3) two-stage irrigation and debridement. The two-stage irrigation and debridement, discussed in detail in Chap. 9, offers the advantages of an urgent debridement and modular implant removal, followed by a delivery of culture-specific antibiotics once culture results are available in several days. It also spares morbidity of full component removal, which may have required femoral or tibial osteotomy in this particular setting.

The patient was brought urgently to the operating room after presentation to the ED. The previous incision was utilized and extended. Soft tissues were mobilized off the proximal tibia as a full-thickness flap to preserve viability of the medial skin. Upon entry into the knee joint, extensive purulence was encountered, and three tissue cultures were taken, each of which would also grow *coagulase-negative Staphylococcus*. The patella was grossly loose and removed. The modular polyethylene liner and modular distal femur were removed, allowing access to debride the bone-implant interface behind the femoral component (Fig. 21.16). An oscillating saw was used to open the proximal bone implant over the proximal tibia to perform a similar tibial-sided debridement. Tibial and femoral stems were inspected and found to be well-fixed as suggested by preoperative radiographs. A thorough, aggressive soft tissue debridement and complete synovectomy was performed with electrocautery, hemostasis was

achieved, and the wound was irrigated thoroughly with 3 L of antibiotic irrigation solution followed by a 500 cm³ dilute Betadine lavage. At the conclusion of the first stage, a specialized negative-pressure sponge designed to allow fluid instillation (V.A.C. VERAFLTM, Kinetic Concepts, San Antonio, TX, USA) was placed loosely throughout the open wound, and a seal was achieved with an adhesive drape (Fig. 21.17a). Negative-pressure therapy with instillation (NPTi) was then initiated at -125 mmHg (Fig. 21.17b), and the patient was transferred to a routine postoperative setting. Radiographs after the first stage are demonstrated in Fig. 21.18.

Postoperatively, the patient was allowed to transfer to a chair in a knee immobilizer but not bear weight. Instillation treatment was cycled through the operative dressing. Negative pressure was maintained for a 3-h cycle, followed by instillation of 150 cm³ of irrigation of an antimicrobial surfactant combination agent containing polyhexanide and betaine (Prontosan[®]; B. Braun Medical Ltd, Sheffield, UK), which was allowed to dwell inside the knee joint for 20 min before being suctioned out at the onset of the next 3-h cycle of NPTi.

After 3 days of intravenous antibiotics, soft tissue rest, and NPTi with the topical cleansing agent, the patient was taken back to the operating room to complete the second stage. The original dressing was removed, demonstrating a robust bed of healthy-appearing granulation tissue (Fig. 21.19). After customary sterile prepping and draping, a secondary irrigation and debridement was performed prior to implantation of new, sterile modular components. A new patellar component was placed. One gram of vancomycin powder and 1.2 g of tobramycin powder were combined with a calcium sulfate mixture to form absorbable pellets, which were distributed throughout the knee joint. The wound was closed in standard fashion (Fig. 21.20). A closed incision negative-pressure therapy (ciNPT) dressing (PREVENATM; Kinetic Concepts Inc., San Antonio, TX) was utilized and maintained at -125 mmHg for 7 days over the closed incision (Fig. 21.21). Postoperatively, the infection was



Fig. 21.16 Intraoperative photograph of the knee joint after partial component explantation of the modular polyethylene insert, distal femoral component, and loose patellar button

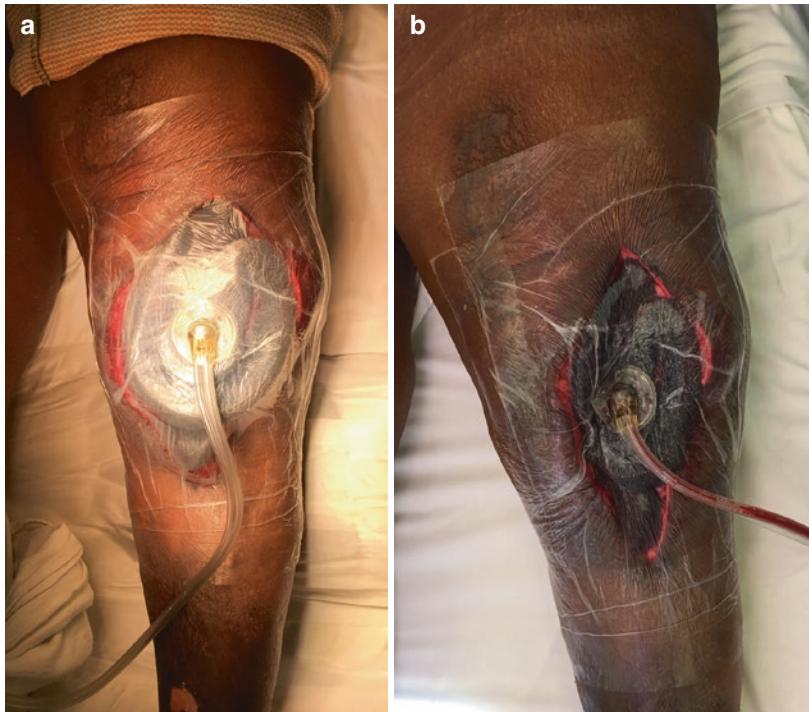


Fig. 21.17 Immediate postoperative photograph (a) before and (b) after application of negative-pressure therapy using a reticulated foam sponge designed for instillation therapy



Fig. 21.18 Postoperative anteroposterior radiograph demonstrating partial component explantation



Fig. 21.19 Immediate preoperative photograph taken just before the second-stage reimplantation, after removing the negative-therapy dressing following 3 days of instillation therapy. Note the healthy, robust granulation tissue present in contrast to that seen in Fig. 21.16



Fig. 21.20 Intraoperative photograph of the knee joint taken near the conclusion of the second-stage reimplantation, demonstrating closure of the soft tissues



Fig. 21.21 Closed incision negative-pressure therapy dressing utilized to manage the complex, high-risk incision following second-stage surgery

treated with 6 weeks of intravenous vancomycin and oral rifampin based on recommendations from an infectious disease consultant. Warfarin anticoagulation was resumed on the first postoperative day with a goal INR of 2.0.



Fig. 21.22 Postoperative (a) anteroposterior (AP) and (b) lateral radiographs after reimplantation of new components and patellar revision. The radiopaque densities represent absorbable calcium sulfate beads impregnated with antibiotic powder

Postoperative Result

Postoperative radiographs are shown in Fig. 21.22. The patient tolerated operative treatment and antibiotic therapy without complication. Her incision healed well without drainage or dehiscence and did not require any additional attention after removal of the ciNPT dressing. A photograph is shown at 7 weeks postoperatively (Fig. 21.23).

She complained of mild knee pain at 3.5 months postoperatively, approximately 8 weeks after stopping all antibiotic therapy. Given the clear concern for infection recurrence, additional testing was performed; CRP was 1.36 mg/dL, synovial fluid aspirate cell count demonstrated 325 WBC/ μ L with 78% PMNs, and aerobic and anaerobic cultures demonstrated no growth. These were interpreted as aseptic results, and the patient was reassured.

At latest follow-up of 19 months, she was pain-free with no clinical signs or symptoms of infection recurrence, with range of motion from 0° to 100° and with a well-healed incision (Fig. 21.24).



Fig. 21.23 Photograph of the patient's incision 7 weeks postoperatively, demonstrating good healing without drainage or dehiscence



Fig. 21.24 Photograph of the patient's incision 19 months postoperatively, demonstrating a well-healed incision, while she remained infection-free

Clinical Results

Negative-Pressure Therapy with Instillation (NPTi)

The addition of cyclical instillation therapy offers several advantages when compared to traditional NPT. Instillation helps to cleanse and treat the wound, removing infectious material from the bed [16]. The solution can be chosen to deliver specific therapy to the wound bed, and studies have demonstrated success with various antimicrobial agents, detergents, antiseptic solutions, and wound cleansers and even with saline [17]. There is abundant evidence surrounding the use of the solution chosen in this case example, which is a dual agent combining a detergent with antimicrobial therapy. Furthermore, benchtop and animal models have clearly shown that

addition of the instillation cycle allows granulation tissue to develop at a significantly more rapid rate than with traditional NPT [18].

These benefits have translated into meaningful clinical advantages of NPTi over traditional NPT. Multiple studies have shown accelerated wound healing, decreased length of hospitalization, fewer trips to the operating room, and fewer days to the final operative debridement when NPTi was compared to NPT [19–21]. Although NPTi has been investigated in Europe as an adjunct treatment of infected hardware, its utility remains uncertain at this time.

Closed Incision Negative-Pressure Therapy (ciNPT)

Closed incision NPT was first introduced in the literature in 2006 [22, 23], initially for the

management orthopedic trauma incisions. Since that time, there have been dozens of publications documenting consistent benefit in reducing wound complications and surgical site infection rates across multiple surgical specialties. A recent meta-analysis of 14 comparative studies across multiple specialties pooled results of over 4600 patients and found a 30% relative reduction in the risk of surgical site infections when ciNPT was used compared to the existing standard of care [24].

Much like with traditional NPT, the benefits of ciNPT appear to come via a variety of mechanisms including reducing the tension across the incision, decreasing subcutaneous hematoma and seroma formation, improving local perfusion to the skin edges, reducing edema, improving lymphatic flow, and a more rapid recovery of mechanical properties [24, 25].

In orthopedics, a prospective randomized multicenter trial found that, compared to standard of care, utilization of ciNPT leads to significantly lower rates of surgical site infection (10% vs. 19%; $P = 0.049$) and wound dehiscence (9% vs. 17%; $P = 0.044$) among patients being treated surgically for high-energy lower extremity trauma injuries [26]. Reddix and colleagues [27] also demonstrated a significantly lower risk of infection with ciNPT in patients undergoing acetabular fracture surgery (1.3% vs. 6.2%) than those treated with traditional wound care. Furthermore, a more recent trial examined the utility of ciNPT compared to an advanced antimicrobial absorptive dressing in 138 patients undergoing revision hip and knee arthroplasty [25]. Authors noted significantly lower rates of wound complications (7% vs. 27%; $P = 0.024$) and surgical site infections (3% vs. 18%; $P = 0.045$), with trends toward lower rates of reoperation and deep periprosthetic joint infection.

Closed incision NPT is ideally applied sterilely in the operating room, with the goal of prevention of wound breakdown and persistent drainage before it occurs. However, it has also been shown to be beneficial in the management of closed incisions that become problematic in the early postoperative period, with the majority of draining wounds resolving after application of ciNPT [28].

Key Points

- Negative-pressure therapy (NPT) has a robust clinical history, with over three decades of clinical experience; it has become the gold standard for the management of many types of chronic and traumatic wounds.
- NPT works through a number of different mechanisms of action via macrostrain and microstrain, including drawing the wound edges together, increasing local tissue perfusion, stimulating granulation tissue formation, increasing cellular proliferation, decreasing edema, and removing exudate and infectious materials.
- NPT with instillation (NPTi) offers several advantages over traditional NPT for the treatment of open wounds. It stimulates granulation tissue formation at a faster rate and can allow more rapid treatment and closure of infected or chronic wounds. It also allows local delivery of various antiseptic, antimicrobial, and other topical irrigation solutions to the wound bed on a cyclical basis.
- The role of NPWTi for treatment of infected hardware remains unclear; however, it can be a useful adjunct in the management of compromised periprosthetic soft tissues.
- Closed incision NPT translates many of the benefits of NPT to the management of a primarily closed surgical incision, in reducing the tension across the incision, decreasing subcutaneous hematoma and seroma formation, improving local perfusion to the skin edges, reducing edema, improving lymphatic flow, and leading to a more rapid recovery of mechanical properties.
- ciNPT has repeatedly been shown, across multiple surgical subspecialties, to decrease the risk of wound complications and postoperative infection rates in high-risk patients and high-risk incisions.
- Retrospective data suggest ciNPT may be highly effective in decreasing postoperative incisional complications in revision knee arthroplasty. Prospective multicenter trials are currently under way.

Option 3: Flap Reconstruction

Oren Lerman and Irena Karanetz

Case Presentation

History

A 71-year-old female presented with advanced primary osteoarthritis of the right knee associated with persistent pain and limitations of range of motion (ROM). Patient has failed conservative management and underwent right total knee arthroplasty at an outside facility. The postoperative course is complicated by wound breakdown, skin flap necrosis with exposed prosthesis requiring excisional debridement, and soft tissue reconstruction with a medial gastrocnemius pedicled muscle flap. Approximately 2 weeks later, she developed wound dehiscence at the site of gastrocnemius flap reconstruction with threatened exposure of the underlying knee prosthesis. Patient was subsequently transferred to our institution for additional care in order to salvage the right total knee prosthesis.

Soft tissue management is an essential component in determining the ultimate success of total knee arthroplasty (TKA). Delayed wound healing can develop in up to 20% of patients following TKA and may lead to skin necrosis, infection, and exposure of the prosthesis, ultimately requiring additional surgical procedures to correct the problem [3, 29–31]. The soft tissue envelope of the knee is thin and pliable permitting extreme flexion-extension capabilities of the knee joint. This characteristic offers advantages in normal range of motion; however, when faced with wound healing complications, this same thin soft tissue coverage combined with limited mobility of the surrounding tissues poses a significant challenge to the reconstructive surgeon.

Physical Examination

Patient had full-thickness soft tissue loss over right total knee arthroplasty with exposed desiccated patella and tendon graft. Nonviable eschar was present along the circumference of the knee wound. There was minimal surrounding soft



Fig. 21.25 Full-thickness soft tissue defect with exposed and desiccated patella overlying right knee prosthesis (Photo courtesy of Dr. Oren Lerman)

tissue edema and erythema and no purulent drainage (Fig. 21.25). Patient had limited active and passive range of motion (ROM) of the right knee associated with pain.

Radiographs and Advance Imaging

Standing anteroposterior and lateral radiographs of the right knee showed nonspecific soft tissue swelling. There was no evidence of periosteal reaction or component loosening.

Surgical Approach

The operation began with debridement of the right knee wound. In conjunction with orthopedic surgery, the wound was irrigated, and the polyethylene articulating surface and patellar component are replaced. The eschar surrounding the wound was excised sharply. The skin edges surrounding the wound were debrided circumferentially, and the skin was separated from the underlying previously elevated medial gastrocnemius muscle flap. The anteromedial calf incision

was opened in order to completely expose the medial gastrocnemius muscle flap and to further dissect the pedicle based on the medial sural vessels in order to more adequately mobilize the flap and achieve complete soft tissue coverage. Despite extensive mobilization of the medial gastrocnemius muscle, there was not enough soft tissue to achieve stable coverage. The decision was made to augment the soft tissue coverage with a pedicled hemi-soleus muscle flap in addition to the previously elevated medial gastrocnemius muscle.

At this time, the medial calf incision was extended inferiorly, and the soleus muscle was identified. It was dissected off the medial tibial border using cautery. The tibial nerve and posterior tibial vascular bundle were identified and preserved. The distal branches to the soleus muscle were ligated leaving the proximal vascular supply, and the muscle was divided along the midline raphe to split the muscle in two. The tendinous insertion of this hemi-soleus muscle flap was incised taking care to preserve the lateral tendinous portion. This allowed the medial half of muscle to be elevated, rotated, and advanced without difficulty. The flap was then tunneled medially along with the gastrocnemius muscle flap and inset to the quadriceps tendon. The knee prosthesis was completely covered with both muscle flaps, and watertight seal was obtained.

In order to achieve a more durable soft tissue coverage, rather than skin grafting the muscle flaps, a laterally based thigh rotation-advancement flap was designed by making a back cut along the thigh laterally. This widely based random pattern skin flap was undermined, and the flap was mobilized until primary closure could be achieved. Closure was performed in layered fashion with 2-0 Vicryl buried deep dermal sutures, followed by 3-0 nylon vertical mattress interrupted sutures. A closed suction drain was placed at the thigh and calf donor sites and an incisional VAC dressing was applied. The patient was then placed into a knee immobilizer.

Postoperative Result

Right knee soft tissue defect following TKA was managed by mobilization and re-advancement of

the original medial gastrocnemius muscle flap and addition of a hemi-soleus muscle flap in order to obtain full muscle coverage of the exposed knee joint. The patient subsequently developed a secondary small wound dehiscence which was successfully managed with surgical debridement and coverage with a superiorly based rotational flap from the medial thigh that was designed in a “freestyle” fashion to include a perforating vascular pedicle to ensure its viability, and a split-thickness skin graft was used to close the donor site defect. Postoperatively the patient demonstrated stable soft tissue coverage of the knee joint and good function (Fig. 21.26).

Clinical Results

Treatment Algorithm

The goals of managing complex wounds after total knee arthroplasty include providing well-vascularized, stable soft tissue coverage of the prosthesis, minimizing donor site morbidity, and maintaining lower extremity function. To achieve these goals, we often consider a variety of reconstructive options that range from the basic such as healing by secondary intention or negative-pressure wound care followed by skin grafting to the more complex methods including local rotation-advancement flaps, pedicled muscle or fasciocutaneous flaps, and finally microsurgical tissue transfer of distant flaps. This progression of options is known as the “reconstructive ladder” (Fig. 21.27). The treatment of choice depends on the wound dimensions, presence of infection, and exposure of the bone, tendon, or implant.

Early recognition followed by expeditious debridement of devitalized tissue, washout of the exposed prosthesis or joint space, proper antibiotic coverage in the setting of infection, and early soft tissue coverage is of paramount importance in the setting of an exposed or threatened prosthesis which can ultimately threaten the functionality of the limb itself.

In patients with small superficial wounds involving partial thickness skin loss, early skin grafting is preferable to secondary wound healing to avoid contracted scars in the knee region.



Fig. 21.26 (a) Small area of wound dehiscence with exposed hardware at the site of previously rotated gastrocnemius and hemi-soleus muscle flaps. (b) Reconstruction with medial thigh rotational fasciocutaneous flap based on

freestyle perforators and split-thickness skin grafting of the donor site. (c, d) Postoperative photographs demonstrating well-healed incision and skin graft (Photos courtesy of Dr. Oren Lerman)

In deeper full-thickness wounds without exposed bone, tendon, or implant, vacuum-assisted closure (VAC) therapy can be implemented in order to accelerate granulation tissue formation, remove exudate, and control microbial load, thus facilitating secondary skin grafting [32–34]. However, if the knee wound results in the exposure of bone or hardware, flap coverage is mandatory.

Reconstructive Escalator

Although the “reconstructive ladder” is a staple of plastic surgery, when dealing with the threatened prosthesis, it is sometimes necessary to choose the option that will achieve stable soft tissue coverage and preserve limb function utilizing

the most advanced and dependable reconstructive options without attempting a “simpler” procedure with less chance for success. Skipping the lower rungs of the reconstructive ladder and taking the “escalator” directly to the top can sometimes be the difference between successful salvage of a threatened prosthesis and loss of the implant.

New Flap Options

Although pedicled muscle flaps for knee coverage such as the gastrocnemius or soleus flaps have been well described in the literature and their anatomy has not changed over time, a new category of local named or freestyle pedicled, fasciocutaneous flaps have come into vogue and

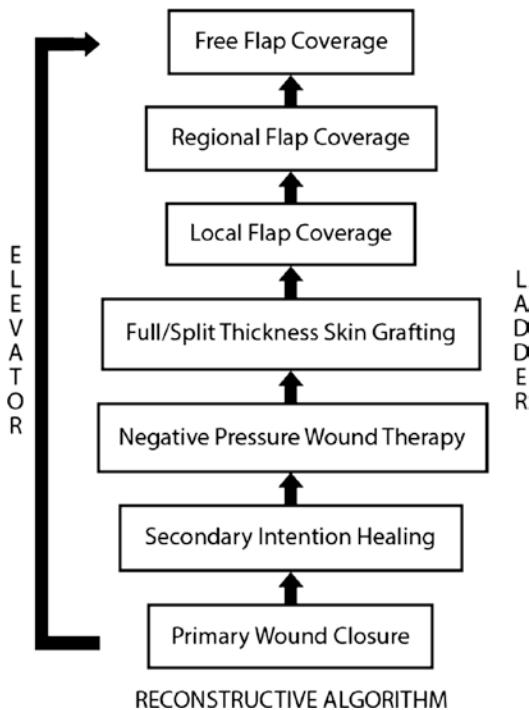


Fig. 21.27 The reconstructive “ladder” and “elevator” (From Rao et al. [31], with permission)

are gaining popularity as the techniques of perforator dissection become more commonplace. These flaps have the advantages of being highly customizable and specific to the local anatomy, thus the name “freestyle” flaps as well as the avoidance of sacrificing a functional muscle. The reverse pedicled anterolateral thigh (ALT) flap is such an example as is the freestyle propeller or rotational perforator flap. These new reconstructive options, however, are not as popular as the standard pedicled muscle flaps, because the vascular perforator anatomy around the knee is highly variable and can often be compromised by the total knee arthroplasty itself.

Pedicled Muscle Flaps

Pedicled muscle flaps are the workhorse for coverage of knee defects because of their consistent vascular anatomy, rich blood supply, and ability to adequately obliterate the defect. A skin paddle can be included with the muscle flap; however,

skin grafting is often preferred since the donor site defect can be undesirable.

The gastrocnemius muscle flap with skin grafting is the most commonly used flap for soft tissue knee reconstruction. Originally described by Feldman et al. in 1978, this flap offers robust axial blood supply and easy dissection [35]. The gastrocnemius muscle has two independent heads that originate from the femoral condyle and insert into the Achilles tendon distally. Each head has a dominant blood supply from the sural artery off the popliteal artery and can be harvested independent of each other. The medial gastrocnemius head is the larger one, has a longer vascular pedicle, and can more easily reach the knee area [36] (Fig. 21.28). The arc of rotation can be further increased by scoring the muscular fascia, detaching the muscle’s origin off the femur, and carefully dissecting the pedicle [37]. During the harvest of the lateral gastrocnemius, care should be taken not to damage the common peroneal nerve as it wraps around the fibular head. Patients should be counseled regarding a 5% incidence of postoperative nerve palsy [38].

The soleus muscle receives its dominant blood supply from the popliteal artery and additional blood supply from proximal branches of the posterior tibial and peroneal arteries. Based proximally the soleus muscle flap can reliably reach the lower knee area, or it can be combined with the gastrocnemius as a “bi-muscle” flap based on vascular perforators between the two muscles for larger infrapatellar defects [39].

Recently, gracilis and sartorius muscle flaps have been described for use in coverage of knee defects. They are both associated with minimal donor site morbidity and have rich vascular blood supply. The reverse gracilis muscle flap based distally on the segmental vascular pedicle originating from the superficial femoral artery (SFA) can successfully cover wounds of the superolateral aspect of the proximal knee area or can be combined with a gastrocnemius flap for larger patella defects [40]. The sartorius muscle flap is supplied by numerous segmental vessels from the SFA and can be transposed based on the distal pedicle to reach the knee [41, 42].



Fig. 21.28 (a) Anterior knee defect, with potential extension to the knee joint after total knee arthroplasty. (b) Medial calf access incision and rotation of the medial gastrocnemius muscle anteriorly. The arthroplasty was revised before muscle coverage. (c) Anterior view of the defect covered by the medial gastrocnemius flap. The muscle was covered with a split-thickness skin graft (From Soltanian et al. [38], with permission)

A pedicled vastus lateralis myocutaneous flap is a highly versatile flap with a wide arc of rotation and allows for primary closure of the donor site. The dominant blood supply is the

descending branch of the lateral circumflex femoral artery (LCFA), but it can be successfully harvested on its distal blood supply from the lateral superior genicular artery branches to cover the knee and proximal lower leg defects [36, 43, 44]. The vastus medialis muscle can be used in a similar fashion, based distally on the branches of the descending genicular artery [45].

Despite the variety of available muscle flaps, they are not all commonly used due to the donor site morbidity and limited reach of many of them without extensive mobilization of their pedicles which requires a relative familiarity and comfort level with the anatomy. The Achilles heel of most pedicled muscle flaps is their limited arc of rotation and the fact that distal aspect of the flap that is most needed to reach and cover the defect has the least soft tissue bulk and most tenuous vascularity.

Local Fasciocutaneous Flaps

Local fasciocutaneous flaps are less frequently applied in the knee area; however, with ongoing development of perforator and propeller flaps, they have become a viable alternative to muscle flaps in select cases, secondary to limited donor site morbidity and improved contour [46, 47]. Perforator flaps are pedicled or free flaps based on vessels that “perforate” and traverse the muscle before piercing the fascia to reach the skin or travel between the muscle bodies along the investing fascia and septae of the muscle groups as in “septocutaneous” perforators. The concept of a propeller flap belongs to Hyakusoku et al., who described it as an adipocutaneous flap based on a central subcutaneous pedicle, with a shape resembling a propeller that was rotated 90° [48]. In 2006, combining the concept of propeller and perforator-based flaps, Hallock reported a fasciocutaneous flap that was similar in shape to the one described by Hyakusoku but based on a skeletonized perforating vessel that was rotated 180° on an eccentric pivot point [49, 50] (Fig. 21.29).

Peroneal artery perforator flaps can be transferred in the propeller fashion to cover inferior knee defects. Ideally, the dominant perforator should be located proximal enough to allow an adequate arc of rotation to cover the knee [34].

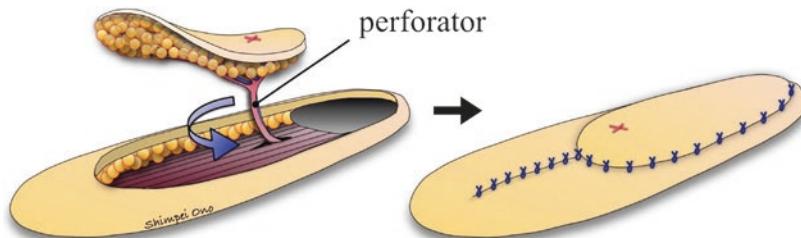


Fig. 21.29 A perforator-based propeller flap that is rotated 180° into the defect. Red cross: the point where the perforator penetrates the deep fascia (From Ono et al. [50], with permission)

The disadvantage of this flap is the variable number and location of the perforators. Preoperative imaging with duplex ultrasound or computed tomography angiography (CTA) can be helpful for surgical planning [51, 52]. Anterior tibial artery perforator flaps based on predictable perforators identified approximately 10–12 cm distal to the femoral condyle can provide reliable coverage of patella and knee defects [53, 54].

The distally based (or “reverse”) ALT flap originally described by Zhang et al. can be harvested with a skin paddle large enough to resurface the entire knee area [55]. The ALT flap is less bulky than the gastrocnemius, has better color and texture match, and has a long arc of rotation that can reach distal knee defects. The donor site can be closed primarily or covered with a split-thickness skin graft [56]. The blood supply is based on the anastomoses between the lateral superior genicular artery and descending branch of lateral circumflex femoral artery, and in the case of venous congestion, microvascular venous supercharging can be performed [57]. Anteromedial thigh perforator flaps can be based distally on the descending branch of an LCFA perforator that penetrates through the rectus femoris muscle instead of vastus lateralis as is the case of the ALT.

The superior lateral genicular artery (SLGA) perforator flap is a fasciocutaneous flap based on the cutaneous perforators of the SLGA and is also an option for soft tissue reconstruction around the knee. The flap is thin and pliable and conforms well to the requirements of knee reconstruction. However, it does have a limited arc of rotation, especially for the medial and inferior

region of the knee, which is a disadvantage of this flap. Donor site morbidity is minimal with inconspicuous scars on the lateral aspect of the thigh [58]. Alternatively, the proximally based sural artery flap which is nourished by the sural artery perforators can be harvested as a medial or lateral sural flap depending on the location of the knee defect [48, 59].

In the past two decades, freestyle perforator flaps have gained popularity due to decreasing donor site morbidity and improved aesthetic outcome [46, 47]. Perforator flaps can be harvested in freestyle fashion based on any major cutaneous perforator using preoperative Doppler examination [60]. The initial incision is made only at the anterior edge of the designed skin island, followed by microsurgical dissection, identification, and isolation of the required perforator, subsequently followed by the posterior skin incision and completion of flap elevation [61]. Venous congestion of the distal tip or the entire flap is the most common complication and is due to insufficient flow in the perforator pedicle, either because of inadequate selection of the perforator or insufficient dissection around the vascular pedicle. This can be managed with intraoperative vascular flow analysis utilizing indocyanine green fluorescence angiography to identify and remove watershed zones of vascular insufficiency in the harvested flap.

Together, ICG angiography, preoperative Doppler CTA mapping, and meticulous microvascular perforator dissection can make the free-style cutaneous pedicled perforator flap a reliable, reproducible, and robust option for coverage of the exposed TKA. It does, however, require

advanced dissection techniques and technical skills that are often only necessary with microvascular free tissue transfer and therefore is less commonly utilized.

Free Flaps

Microsurgical free tissue transfer is usually indicated for larger and more extensive soft tissue defects of the knee or where local options are unavailable or inadequate. Free tissue transfer provides well-perfused tissue from outside the zone of injury and avoids further scarring and additional donor site morbidity to the already debilitated lower extremity. Free flaps are based on the vascular pedicle supplying the primary angiosome of the donor tissue, and they are not limited by the arc of rotation of the pedicle unlike perforator or pedicled muscle flaps. In addition, the vascularity of the tissue transferred is often superior to pedicled or local flaps where the distal and least well-perfused aspect of the flap is often the only part used to cover the defect.

Availability and selection of recipient vessels deserves a separate discussion and is often the most complicated aspect of microvascular free flap reconstruction of the knee. The extent and depth of soft tissue loss in the knee region will also affect recipient vessel availability and suitability for microvascular anastomosis. To accommodate for these limitations, vein grafts or arteriovenous loops that increase the reach of the vascular pedicle to the recipient vessels are often needed, raising the degree of difficulty [62]. Arterial anastomosis can be performed in end-to-end or end-to-side fashion using one of the major vessels of the lower extremity (anterior tibial and posterior tibial) as well as more proximal options such as the sural arteries; superior, middle, and descending genicular arteries; descending branch of LCFA; or one of the numerous branches of the superficial femoral system [63–68]. Preoperative CTA may be helpful to delineate available recipient vessels and should be considered in patients with diabetes mellitus or peripheral vascular disease and questionable clinical vascular exam [69].

The choice of donor sites for free flaps continues to grow as does the popularity of newer fasciocutaneous perforator flaps. Historically,

depending on the size of the defect, muscle flaps such as the rectus abdominis, latissimus dorsi, or gracilis have been advocated given the ease of harvest, ability of muscle to contour to the defect and fill dead space, as well as the robust vascularity of these flaps which has been thought to improve antibiotic delivery and wound healing in the setting of infection. Patient positioning or need for intraoperative repositioning should be considered when deciding on a donor site as should the size of the defect and donor site morbidity. The rectus and gracilis muscle flaps are readily accessible in the supine position; however, abdominal weakness, bulge, or hernia should be a serious consideration when choosing the rectus flap. Even though the gracilis has minimal thigh donor site morbidity, it is significantly smaller and has a much shorter pedicle. The latissimus flap is ideal for larger defects but requires more complicated positioning for harvest from the back.

Free fasciocutaneous flaps offer a viable alternative for large and small defects and avoid the morbidity associated with muscle harvest. The workhorse fasciocutaneous flap for many microsurgeons has become the ALT flap which is highly versatile. Its proximity to the knee obviates any position changes and keeps the morbidity limited to the affected limb. It has a long pedicle which can overcome the need for a vein graft and can be designed for both small and very large knee defects (Fig. 21.30). A fasciocutaneous flap, unlike a muscle flap, does not atrophy over time but can be thinned in the acute or delayed fashion to provide a pliable and aesthetic wound coverage. Additionally, a fasciocutaneous flap allows for greater tendon or patella gliding under its deep surface than does a muscle flap which scars down, and it can be re-elevated with ease in the future in case revision or reoperation is necessary. Other examples of fasciocutaneous flaps include the thoracodorsal artery perforator (TDAP) flap and superficial circumflex iliac (SCIP) perforator flap [70, 71]. In addition, if the wound is contaminated or greater bulk is required, the underlying muscle (e.g., vastus lateralis with ALT flap and latissimus dorsi with TDAP flap) can be included in a chimeric fashion [72].



Fig. 21.30 (a) An extensive full-thickness soft tissue necrosis overlying right total knee arthroplasty. (b) Reconstruction with microvascular fasciocutaneous

anterolateral thigh (ALT) flap from left thigh. Satisfactory coverage and contour achieved (Photos courtesy of Dr. Oren Lerman)

Post-op management of patients with free flap reconstruction requires close monitoring with serial flap assessments to detect signs of vascular compromise and prevent flap failure, which typically occurs within the first 24–48 h [73]. Patient positioning, hydration, and leg elevation are critical aspects of postoperative management for microvascular free flaps as well as most pedicled flaps, which can be equally susceptible to venous congestion and vascular compromise.

Key Points

- Expedited debridement, washout, and coverage with well-vascularized, stable soft tissue are necessary for the salvage of the threatened or exposed prosthesis.
- Traditional pedicled muscle flaps such as the gastrocnemius are the tried and true method but have limitations.

- It is necessary to consider both the defect and donor site when determining a course of treatment.
- Newer techniques such as pedicled fasciocutaneous and freestyle perforator flaps offer viable solutions to the limitations of pedicled muscle flaps. Often the combination of one or more of these techniques is necessary.
- Microvascular free tissue transfer should be considered when local options are unavailable, but do not hesitate to take the reconstructive escalator directly to the top.

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Index

A

- Achilles tendon allograft, 290, 308, 321
- Acute delayed infections, 181
- Acute hematogenous infection, 181
- Acute postoperative infections, 181
- Anterior cruciate ligament (ACL), 10, 385
- Anterior inferior iliac spine (AIIS), 373, 374
- Anterior tibial artery perforator flaps, 405
- Anterolateral thigh (ALT) flap, 405
- Anteromedial thigh perforator flaps, 405

B

- Bicompartamental UKA (bi-UKA), 347

C

- Cement and screws technique, 387
- Cement dowels, 197, 198
- Chronic periprosthetic joint infections, 182
- Chronic suppressive antibiotic therapy, 183
- Circular hexapod external fixator (CHEF), 162
- Closed incision negative-pressure therapy (ciNPT), 395, 399
- Closed incision negative-pressure therapy dressing, 397
- Computer-assisted surgery (CAS), 157
- Constrained condylar knee (CCK), 206, 260
- Continuous passive motion (CPM), 231

D

- Deep medial collateral ligament (dMCL), 8, 14
- Deep vein thrombosis (DVT), 122, 123
- Diabetes mellitus, 389
- Distal femoral periprosthetic fractures, 333
- Distal femoral prosthesis
 - clinical results, 281–282
 - patients history, 279
 - physical examination, 279
 - postoperative results, 280
 - radiographs and advanced imaging, 279
 - surgical approach, 279–280
- Distal quadricepsplasty, 373

E

- Extra-articular deformity, 149
 - femoral extra-articular deformity correction with implant
 - clinical results, 168
 - highly constrained TKA, 168
 - intraoperative techniques, 167, 168
 - patient's history, 166
 - physical examination, 166
 - postoperative results, 168
 - preoperative evaluation, 166, 167
 - radiographic evaluation, 166
 - femoral osteotomy and TKA
 - clinical results, 171–173
 - patient history, 169
 - physical examination, 169, 170
 - postoperative results, 171
 - surgical approach, 170–171
 - X-ray, 170
 - implant, correction with, 152–154
 - clinical results, 156, 157
 - full-length standing radiographs, 151, 152
 - implant choice, 154
 - patient's history, 150
 - physical examination, 151
 - postoperative results, 155, 156
 - preoperative planning, 154
 - procedure, 155
 - tricompartmental arthrosis, 151
 - valgus deformity, 151, 153
 - intra-articular correction, 150
 - tibial osteotomy and TKA
 - AP hip to ankle radiograph, 159, 160
 - circular hexapod external fixation, 161–163
 - clinical results, 164
 - knee and ankle radiographs, 159–161
 - patient history, 158
 - physical examination, 158–159
 - postoperative results, 163, 164
 - preoperative problem list, 159, 160

F

Failed patellofemoral arthroplasty, management of
 clinical results, 362–364
 patient's history, 360
 physical examination, 360
 postoperative results, 362
 radiographs and advanced imaging, 360
 surgical approach, 360–363

Failed unicondylar arthroplasty

- lateral unicondylar arthroplasty
 - common failure mechanisms, 355
 - edge loading, 355
 - IT band pain, 356
 - lateral failure modes, 356
 - lateral UKAs, 355
 - maltracking of implants, 355
 - medial compartment osteoarthritis, 355
 - patient's history, 349, 350
 - physical examination, 350
 - popliteus tendonitis, 355
 - postoperative results, 354
 - radiograph and advanced imaging, 350
 - surgical approach, 350, 352, 353
 - tibial/femoral loosening, 355
 - UKAs, outcomes of, 355
 - unicompartmental candidates, 354

medial UNI

- careful cementation, 346
- clinical results, 347–349
- femoral condyle preparation, 346
- femoral drill guide, 346
- femoral preparation, 346
- final tibial preparation, 346
- lateral parapatellar arthrotomy incision, 345
- patient's history, 344
- physical examination, 344
- postoperative results, 347
- radiographs and advanced imaging, 344
- tibial plateau, 345

Fasciocutaneous flaps, 384

Femoral bone grafting

- clinical results, 271, 273
- patient history, 265
- physical examination, 266
- postoperative results, 270
- radiographs and advanced imaging, 266
- surgical technique
 - operative procedure, 268–270
 - preoperative considerations, 266–268

Femoral component removal, 195

Femoral loosening, 343, 355

Fibular osteotomy, 161

First-generation implants, 88

Fixed flexion contracture, 67–68

- cruciate-retaining femoral component
 - clinical results, 72
 - patient history, 68, 70
 - physical examination, 68, 70
 - postoperative care, 70, 72

radiographs and advanced imaging, 68, 70
 surgical approach, 69, 70

posterior stabilized TKA

- clinical results, 77, 78
- patient history, 73
- physical examination, 73
- postoperative rehabilitation, 77
- radiographs and advanced imaging, 74
- surgical approach, 74–77

Fixed flexion contracture (FFC), 77–79

Fixed valgus knee

- lateral femoral epicondylar osteotomy
 - clinical results, 38, 41–43
 - patient's history, 37
 - physical examination, 38
 - postoperative results, 38
 - radiograph and advanced imaging, 38
 - surgical approach, 38

lateral parapatellar approach (*see* Lateral parapatellar approach (LPA))

medial parapatellar approach

- bone resection, 43–45
- clinical results, 54–56
- ligament assessment and balancing, 45–47, 50–54
- patient's history, 43
- physical examination, 43
- poetoperative results, 54
- radiograph and advanced imaging, 43

pie-crust technique

- clinical results, 34–37
- patient's history, 27
- physical examination, 27
- postoperative photograph, 33
- radiographs and advanced imaging, 28
- surgical technique, 28–36

Flexion instability

complete revision

- clinical results, 212–213
- diagnosis, 209–210
- patient's history, 208
- physical examination, 208, 209
- postoperative results, 211
- surgical approach, 210–211

etiology of, 203

management of, 203

tibial component revision

- clinical results, 206–207
- patient's history, 204
- physical examination, 204, 205
- postoperative results, 206
- radiographs and advanced imaging, 205
- surgical approach, 205–206

Free flaps, 406, 407

Freestyle perforator flaps, 405

G

Gastrocnemius muscle flap, 403

Gentamycin, 322

- Gerdy tubercle (GT) osteotomy, 57–60
Gigli saw, 369, 370
Global instability
 complete revision
 clinical results, 224–225
 implant choice, 223, 224
 patients history, 222
 physical examination, 222
 pneumatic tourniquet, 223
 polyethylene insertion, 223
 postoperative results, 224
 radiographs, 222
 tibial component revision
 clinical results, 219–221
 patients history, 215
 physical examinations, 216
 postoperative results, 218
 radiographs and advanced imaging, 217
 surgical approach, 217, 218
Gracilis muscle flaps, 403
Gullwing patellar osteotomy for osteolytic deformity
 clinical results, 301–304
 everted patella, articular side of, 299, 300
 patient's history, 298
 physical examination, 299
 radiograph and advanced imaging, 299
 surgical technique
 decision-making, 300
 mediolateral stability, 301
 osteotomy, 300
 postoperative management, 300
 tibial-first technique, 299
- H**
Heterotopic ossification (HO), 382
- I**
Iliotibial band (ITB), 30, 39, 45, 49, 50, 52, 55, 57, 356, 373
Indirect reduction technique, 332
Infected total knee arthroplasty (TKA)
 irrigation and debridement
 clinical results, 181–183
 dilute betadine and chlorhexidine gluconate, 177
 equipment, 177
 patient history, 175
 physical examination, 176
 postoperative rehabilitation protocol, 181
 postoperative results, 181
 surgical technique, 177–181
 two-stage procedure, 177
 vancomycin pending culture results, 177
 X-rays, 176
one-stage revision arthroplasty
 hardware, removal of, 184
 patient's history, 183
 physical examination, 183
 postoperative course, 187
 preoperative planning and surgical approach, 183
 radical debridement, 184–187
 reimplantation, 187
 two-stage exchange arthroplasty (*see* Two-stage exchange arthroplasty)
Interpositional arthroplasty, 289
Intramedullary nailing fixation, 332, 333
Isolated tibial polyethylene insert exchange (ITPIE), 217, 220, 221
- K**
Knee sepsis. *See* Sepsis
Knitted polypropylene graft
 clinical results, 321
 patients history, 316
 physical examination, 316
 postoperative results, 320
 radiograph and advanced imaging, 317
 surgical approach, 317–320
- L**
Lateral collateral ligament (LCL) complex, 30, 45, 47, 49, 51, 54, 56, 205, 206, 222–224
Lateral distal quadricepsplasty, 373
Lateral gastrocnemius rotational flap, 384
Lateral parapatellar approach (LPA)
 clinical results, 62, 63
 patient's history, 56
 physical examination, 56
 postoperative results, 62
 radiographs, 56
 surgical approach
 arthrotomy and wound closure, 61, 62
 distal femur and proximal tibia cuts, 60, 61
 femoral rotation, 61
 flexion gap balancing, 61
 GT osteotomy and lateral retinaculum, Z-plasty of, 57–60
 preoperative planning, 57
Lateral posterior capsule (LPC), 46, 52
Lateral unicompartmental knee arthroplasty (UKA), 344, 350, 355, 356
Latissimus flap, 406
LCL. *See* Lateral collateral ligament (LCL) complex
Local fasciocutaneous flaps, 404–406
Local wound care
 distal femoral bone, 385, 386
 final X-rays, 387, 390
 multimodal periprosthetic injection, 387, 389
 OrthAlign® device, 385
 patella tracking, 387, 388
 patient's history, 384
 physical examination, 384
 postoperative wound complications, 388
 preoperative management

- L**
- Local wound care (*cont.*)
 - intraoperative, 391
 - midline skin incision, 391
 - minor superficial wound complications, 392
 - NPWT, 392
 - plastic surgery, 389
 - polydioxanone bidirectional barbed suture wound closure, 391
 - prophylactic flap coverage, 391
 - subcutaneous flaps, 391
 - transverse skin incisions, 391
 - wound dressings, 392
 - Prineo® skin closure system, 387, 389
 - proximal tibial dissection, 387, 388
 - radiographs and advanced imaging, 385
 - spacer block and drop rod, 386, 387
 - tibia component, 388
 - tibial component, 387
 - Locked plating techniques, 333
- M**
- Macrostrain, 393
 - Medial collateral ligament (MCL), 7, 8, 10, 13, 14, 205, 206, 281, 373, 387
 - Medial compartment osteoarthritis, 355
 - Medial gastrocnemius muscle flap, 401
 - Medial gastrocnemius rotational flap, 384
 - Medial parapatellar approach, 184, 195
 - bone resection, 43–45
 - clinical results, 54–56
 - ligament assessment and balancing, 45–47, 50–54
 - patient's history, 43
 - physical examination, 43
 - postoperative results, 54
 - radiograph and advanced imaging, 43
 - varus knee, 8
 - Medial quadricepsplasty, 373
 - Medial unicompartmental knee arthroplasty (UKA), 345, 356
 - Metaphyseal bone loss, 259
 - Methicillin-resistant *Staphylococcus aureus* (MRSA), 189
 - Microstrain, 393
 - Microvascular free flap, 406
 - Mid-vastus approach, 16
- N**
- Negative-pressure dressing therapy (NPT)
 - macrostrain, 393
 - microstrain, 393
 - patient's history, 393
 - physical examination, 393, 394
 - postoperative radiographs, 397–399
 - radiographs and laboratory data, 394
 - surgical approach, 394–397
 - Negative-pressure therapy with instillation (NPTi), 395, 398
 - Negative-pressure wound therapy (NPWT), 383, 391, 392
- O**
- OA. *See* Osteoarthritis (OA)
 - Obesity. *See* Super obese knee
 - One-stage exchange arthroplasty, 142
 - Open reduction internal fixation (ORIF)
 - clinical results, 332–334
 - distal femoral replacement, 339
 - patient's history, 329–330
 - physical examination, 330
 - postoperative results, 331
 - radiograph and advanced imaging, 330
 - surgical approach, 330, 331
 - OrthAlign navigation system, 353
 - Osteoarthritis (OA), 1, 344, 345, 347–349, 354, 356
 - Osteolytic deformity, gullwing patellar osteotomy for articular side of everted patella, 299, 300
 - clinical results, 301–304
 - patient's history, 298
 - physical examination, 299
 - radiograph and advanced imaging, 299
 - surgical technique
 - decision-making, 300
 - mediolateral stability, 301
 - osteotomy, 300
 - postoperative management, 300
 - tibial-first technique, 299
 - Oxford Knee Score (OKS), 344, 347
- P**
- Parallel to tibial cut technique, 4, 6
 - Partial knee arthroplasty, 343, 344
 - Patella bone loss, 285, 286
 - Patella tendon ruptures
 - allograft survival rate, 326
 - AORI type 3 defect, 326
 - complication, 308
 - extensor mechanism allograft
 - allograft preparation, 311
 - clinical results, 314, 315
 - freeze-dried allografts, 310
 - host distal quadriceps preparation, 313, 314
 - knee, exposure of, 310, 311
 - patient's history, 308
 - physical examination, 308, 309
 - postoperative protocol and rehabilitation, 314
 - proximal tibial trough preparation, 311–313
 - radiographs and advanced imaging, 309, 310
 - specimen, 310
 - tensioning and closure, 313, 314
 - TKA component revision, 311
 - knitted polypropylene graft, extensor mechanism deficiency
 - clinical results, 321
 - patients history, 316
 - physical examination, 316
 - postoperative results, 320
 - radiograph and advanced imaging, 317
 - surgical approach, 317–320
 - structural allograft reconstruction, 326

- structural proximal tibia and patellar tendon
patient's history, 321, 322
physical examination, 321, 322
postoperative results, 324
radiograph and advanced imaging, 322
surgical exposure, 322–324
tibial fixation, 326
- Patellar augments
prior patellectomy
clinical results, 297, 298
patient's history, 295
postoperative results, 296
radiographs and advanced imaging, 296
surgical approach, 296
- TM implant
clinical results, 295
patient's history, 291
postoperative results, 295
radiographs and advanced imaging, 291
surgical approach, 291–293
- Patellar bone grafting
clinical results, 289, 290
patient's history, 286
physical examination, 287
postoperative results, 288
radiographs and advanced imaging, 287
surgical approach, 287, 288
- Patellar component removal, 196
- Patellar tracking, 87, 287
- Patellofemoral arthritis (PFOA), 362
failed metal patella replacement with erosion, 82, 83
PFA
clinical results, 88–91
magnetic resonance imaging, 85
patient history, 83
physical examination, 83
postoperative results, 88
preoperative radiographs, 83
surgical approach, 85–88
surgical treatment, 81
for symptomatic patient, 81
- TKA
clinical results, 93–97
patient's history, 91
physical examination, 91
postoperative results, 93
radiograph, 91
surgical approach, 91–94
- Patellofemoral arthroplasty (PFA), 81, 82, 96, 97, 359, 363, 364
clinical results, 88–91
magnetic resonance imaging, 85
patient history, 83
physical examination, 83
postoperative results, 88
preoperative radiographs, 83
surgical approach, 85–88
- Patellofemoral instability, 219
- PCL. *See* Posterior cruciate ligament (PCL)
- Pedicled hemi-soleus muscle flap, 401
- Pedicled muscle flaps, 402–404
- Pedicled vastus lateralis myocutaneous flap, 404
- Perforator-based propeller flap, 405
- Periprosthetic femur fractures, 329
distal femoral replacement
clinical results, 337–339
patient's history, 335
physical examination, 335
postoperative results, 337
radiograph and advanced imaging, 335
surgical approach, 335–337
- ORIF
clinical results, 332–334
patient, 330
physical examination, 330
postoperative results, 331
radiograph and advanced imaging, 330
surgical approach, 330, 331
- Periprosthetic infections, 181
- Periprosthetic joint infection (PJI), 142, 144, 145, 181–183, 194, 394
- Peroneal artery perforator flaps, 404
- PFA. *See* Patellofemoral arthroplasty (PFA)
- PFC SIGMA posterior-stabilized (PS) implant, 3
- Polyethylene (PE) exchange, 213
- Popliteus tendonitis, 355
- Posterior cruciate ligament (PCL), 10, 14, 16, 21, 51, 53, 68, 69, 209, 210, 212, 218, 231, 386
- Posterior stabilized (PS) implants, 207, 209, 212, 213
- Prineo® skin closure system, 387, 389, 391
- Prior knee fusion, management of
AIIS, rectus femoris off of, 373
clinical results, 379, 380, 382
closure, 378
collateral ligaments repair, 378
distal quadricepsplasty, 373
general anesthesia, 368, 370, 374
incision, 368
insert drains, 378
ITB release, 373
knee replacement, 378
lateral collateral ligament, 378
lateral distal quadricepsplasty, 373
MCL release, 373
medial quadricepsplasty, 373
osteotomy of, 369
patella and patellar tendon, 378
patient's history, 367
physical examination, 367, 368
posterior release, 378
postoperative care, 378, 379
postoperative results, 379, 380
proximal medial quadricepsplasty, 378
proximal quadriceps, release of, 373
radiographs and advanced imaging, 368, 369
retinaculoplasty with ITB, 378
second incision, 373
- Proximal medial quadricepsplasty, 378

R

- Radical debridement, 184
- Reconstructive ladder, 401, 403
- Reduction osteotomy, 387, 388
- Retained hardware
 - complexed TKA, partial removal in
 - clinical results, 103–106
 - patient history, 102
 - physical examination, 102
 - postoperative results, 103
 - preoperative radiographs, 102
 - surgical approach, 102, 103
 - hardware removal
 - clinical results, 111–112
 - patient's history, 106, 107
 - physical examination, 107, 108
 - postoperative results, 111
 - surgical approach, 108–111
 - patient's history, 101
 - preoperative planning, 101
 - PSI, 101, 102
- Robotic technology, 344

S

- Sartorius muscle flaps, 403
- Second-generation patellofemoral arthroplasty implants, 89–90
- Segmental proximal tibial allograft, 326
- Semitendinosus tendon, 307
- Sepsis, 133
 - IV antibiotics, course of, 134
 - one-stage procedure
 - AP radiographs, 135, 136
 - clinical results, 140, 141
 - lateral radiographs, 135, 136
 - patient's history, 134
 - physical examination, 134
 - postoperative results, 140
 - preoperative planning, 135, 136
 - surgical approach, 136–140
 - two-stage revision arthroplasty
 - clinical results, 144–146
 - knee amputation, 143
 - modular components, exchange of, 142
 - one-stage exchange arthroplasty, 142
 - patient's history, 141
 - physical examination, 142
 - postoperative results, 144
 - radiograph and advanced imaging, 142
 - recurrent aspiration and antibiotic suppression, 142
 - stage 1 postoperative radiographs, 143, 144
 - stage 2 postoperative radiographs, 144, 145
 - two-stage exchange arthroplasty, 142
- Severe femoral bone loss
 - Anderson Orthopaedic Research Institute classification, 265, 266
 - distal femoral prosthesis (*see* Distal femoral prosthesis)
- femoral augments and cones
 - clinical results, 277–278
 - patient's history, 273
 - physical examination, 273
 - postoperative results, 276, 277
 - radiograph and advanced imaging, 273
 - surgical approach, 273–276
- femoral bone grafting (*see* Femoral bone grafting)
- sMCL. *See* Superficial medial collateral ligament (sMCL)
- Soft tissue defects management, 392
 - fasciocutaneous flaps, 384
 - flap reconstruction
 - free flaps, 406, 407
 - local fasciocutaneous flaps, 404–406
 - new flap options, 403
 - patient's history, 400
 - pedicled muscle flaps, 403, 404
 - physical examination, 400
 - postoperative results, 401, 402
 - radiographs and advanced imaging, 400
 - reconstructive escalator, 402
 - surgical approach, 400, 401
 - treatment algorithm, 401–403
 - lateral gastrocnemius rotational flap, 384
- local wound care
 - distal femoral bone, 385, 386
 - final X-rays, 387, 390
 - multimodal periaricular injection, 387, 389
 - OrthAlign® device, 385
 - patella tracking, 387, 388
 - patient's history, 384
 - physical examination, 384
 - postoperative wound complications, 388
 - preoperative management, 389, 391, 392
 - Prineo® skin closure system, 387, 389
 - proximal tibial dissection, 387, 388
 - radiographs and advanced imaging, 385
 - spacer block and drop rod, 386, 387
 - tibia component, 388
 - tibial component, 387
- medial gastrocnemius rotational flap, 384
- NPT (*see* Negative-pressure dressing therapy (NPT))
- proximal wound dehiscence and delayed healing, 383, 384
- split-thickness skin grafts, 384
- Split-thickness skin grafts, 384, 405
- Stiff knees, 238
 - dynamic splinting, 228
 - ROM, 227, 228
- stiff total knee arthroplasty
 - clinical results, 236, 238
 - patient's history, 233, 234
 - physical examination, 234
 - postoperative results, 236
 - radiographs and advanced imaging, 235
 - surgical approach, 235, 236
- tibial component revision
 - AP radiograph, 228
 - clinical results, 232, 233

- lateral radiograph, 228
merchant patellar radiographs, 229
patient's history, 228
physical examination, 228
postoperative radiographs, 232
surgical approach, 229–232
- Structural allograft reconstruction, 244
- Subcutaneous flaps, 391
- Sub-meniscal arthrotomy, 107
- Super obese knee
conventional instrumentation, surgical technique with
AP radiograph of left knee, 126
clinical results, 129–130
left knee, lateral radiograph of, 126
patient's history, 124–125
physical examination, 125
postoperative radiographs, 129, 130
surgical technique, 126–130
- specific instrumentation, surgical technique with
clinical results, 119–124
magnetic resonance image, 116
patient's history, 115
patient-specific instrumentation, 117–119
physical examination, 116
postoperative results, 119, 122
preoperative plan, 117
surgical technique, 117–121
X-ray, 116, 117
- Superficial medial collateral ligament (sMCL), 3, 5, 7, 11, 14
- Superior lateral genicular artery (SLGA) perforator flap, 405
- Supracondylar periprosthetic fractures, 332, 333
- T**
- Thoracodorsal artery perforator (TDAP) flap, 406
- Tibial bone loss, management of
Anderson Orthopaedic Research Institute
classification, 241, 242
- proximal tibial prosthesis
clinical results, 258–260
patient's history, 255
physical examination, 256
postoperative results, 258
radiograph, 256
surgical approach, 256–258
- tibial augments and cones
clinical outcomes, 251
clinical results, 252–255
physical examination, 250
postoperative results, 251, 252
radiograph and advanced imaging, 250
surgical approach, 251
- tibial bone graft
clinical results, 247–250
CT scan, 242
patient's history, 242
physical examination, 242
postoperative results, 246, 247
radiographs, 242
- surgical approach, 242–246
- Tibial component revision
for flexion instability
clinical results, 206–207
patient's history, 204
physical examination, 204, 205
postoperative results, 206
radiographs and advanced imaging, 205
surgical approach, 205–206
- global instability
clinical results, 219–221
patient's history, 215
physical examinations, 216
postoperative results, 218
radiographs and advanced imaging, 217
surgical approach, 217, 218
- stiff knees
AP radiograph, 228
clinical results, 232, 233
lateral radiograph, 228
merchant patellar radiographs, 229
patient's history, 228
physical examination, 228
postoperative radiographs, 232
surgical approach, 229–232
- Tibial loosening, 355
- Tibial polyethylene trial, 197
- Tibial tubercle avulsion, 307
- Tibial tubercle osteotomy (TTO), 62, 63
- Tobramycin, 197
- Total knee replacement (TKR), 142, 204, 353
- Total knee revisions (TKRs), 389
- Trabecular metal (TM) cone, 258, 292, 296, 323
clinical results, 295
components, 297
patients history, 291
patellar components, 291, 293–295
patellar reconstruction, 297
postoperative results, 295
radiographs and advanced imaging, 291
surgical approach, 291–293
- Two-stage exchange arthroplasty, 142, 187, 188
with mobile spacer
bone loss and articulating spacer construction, 196, 197
cement dowels, 197
clinical results, 199, 200
closure, 199
debridement, 196
diagnostic evaluation, 193
femoral component removal, 195
implantation, 197
median parapatellar approach, 195
patellar component removal, 196
patient's history, 193
physical examination, 193
polyethylene insert removal, 195
postoperative protocols and rehabilitation, 199
radiograph, 193–195
tibial component removal, 196

Two-stage exchange arthroplasty (*cont.*)

- sepsis, 146
- static spacer
 - clinical results, 191–192
 - first-stage spacer insertion, 190–191
 - patient's history, 189
 - physical examination, 189
 - postoperative outcomes, 191
 - radiographs and advanced imaging, 189

U

- Ultra-high-molecular-weight polyethylene (UHMWPE) component, 292, 293
- Unicompartmental knee arthroplasty (UKA), 249, 250, 256, 344, 347, 348, 355

V

- Vacuum-assisted closure (VAC) therapy, 402
- Valgus deformity, 67, 151, 153, 159
- Vancomycin, 197, 322
- Varus knee
 - flexion contracture to native alignment
 - clinical results, 23
 - patient's history, 14, 15
 - physical examination, 15
 - postoperative results, 21, 23
 - radiograph and imaging, 15
 - surgical approach, 16–21
 - medial collateral ligament pie crusting
 - clinical results, 5–7
 - electrocautery, 3
 - extension gap, 3, 4

- intramedullary femoral alignment guide, 3
- parallel to tibial cut technique, 4, 6
- patient's history, 2
- pes anserinus insertion, 3
- PFC SIGMA posterior-stabilized implant, 3
- physical examination, 2
- postoperative results, 5
- radiographs, 2
- Ran-sall maneuver, 3
- sMCL, 3, 5
- spinal anesthesia, 3
- thick tibial cut, 3
- medial release of
 - clinical results, 12–14
 - curved osteotome, 8
 - distal femur, 10
 - extramedullary guide, 10
 - final implants, cementing of, 12, 13
 - gap-balance device, 11
 - medial parapatellar approach, 8
 - patient's history, 8
 - physical examination, 8
 - posterior Meckel retractor, 10
 - postoperative results, 12
 - radiographs and imaging, 8
 - spacer block, 10–12
 - trial implants, 12
- Varus-valgus constrained (VVC) trial, 224
- Vastus sparing approach, 369

W

- Wound complications, 383, 384