

Chapter

Management of Distal Femoral Fractures

Luis Bahamonde and Alvaro Zamorano

Abstract

Operative treatment of distal femoral fractures has evolved significantly in terms of strategy and implants available for fracture fixation. Major advances include improvements in fixation devices, as well as the understanding of the pathomechanics of fixation failures. As the complexity of the fracture increases, and in conjunction with considerations of the general status and functionality of the patient, judicious planning, surgical approach and choice of implants can be undertaken, in order to obtain optimal functional restoration. This goes along tightly with the capability of a given construct to withstand deforming forces, while early mobilization and weight bearing take place, and ultimately bone healing occurs. Minimizing the risk of complications, such as hardware failure and nonunion, depend closely on proper planning and execution. Factors inherent to the patient and the fracture itself are beyond the surgeon's control. But taking these in mind, allows the surgeon to select properly the timing, surgical approach and choice of implant—or combination of implants—, best suited for a given patient.

Keywords: distal femoral fractures, mechanical failure, nail, plate fixation, surgical technique

1. Introduction

Fractures of the distal part of the femur, whether extra articular or intra articular, have a bimodal distribution. At younger ages, high-energy trauma is the main cause, whereas in the elderly, low energy trauma results in a fracture due to osteopenia [1, 2]. In any case, the fracture pattern varies in terms of comminution, site of the fracture (articular and/or extraarticular), quality of bone and general condition of the patient. The high loads and bending forces affecting this anatomical area contribute to the complexity of the problem on a given patient. Hardware failure and nonunion are major concerns, and occur irrespective of the fixation method in nearly one of five patients. Proper understanding of the biomechanics of different fracture patterns, assessment of bone quality, physiological needs of the patient and the capability of different implants available for surgical treatment, are essential for the selection of the surgical approach, type and fixation strategy. Ultimately, judicious planning is probably the most important factor influencing the outcome of treatment, in which fracture healing, maintenance of proper reduction and swift restoration of function are altogether the goals.

2. Pathomechanics of distal femoral fractures

The most frequent mechanical complication of distal femoral fractures (DFF) is nonunion, reported in up to 19% of patients [3, 4]. Along with nonunion, varus collapse and hardware failure come together. This continues to occur despite advances in fracture fixation implants for this injury, reflecting the need for better understanding of different factors that influence the outcome. Modern implants include those advocated by the AO Foundation decades ago, such as the 95 degree blade-plate and the Dynamic Condylar Screw (DCS) [5–8]. Such devices are seldom used nowadays for acute fracture treatment. Being made of stainless steel, they provided strong fixation and resistance to fatigue, improving dramatically the quality of fixation and ultimately the results. However, their inherent stiffness was still a cause for atrophic nonunions (**Figure 1**). Advances in the knowledge of concepts such as stress and strain highlighted the importance of the mechanical environment in the process of bone healing [9–11]. Application of these concepts by the surgeon is the basis for the construction of biomechanically sound osteosynthesis, in which highly rigid constructs are being replaced by others allowing controlled micromotion, and subsequent stimulus for callus formation.

In more recent years, both anatomical, locked plates (LP), and retrograde interlocking intramedullary nails (RIMN) became the standard for operative management [4, 12]. Both types of fixation show similar rates of bone healing and functional outcome, despite dissimilarities. In some studies, intramedullary devices perform better than plates in terms of axial stiffness, whilst in others side plates were superior [13, 14]. Nonetheless, both methods are also associated with a high

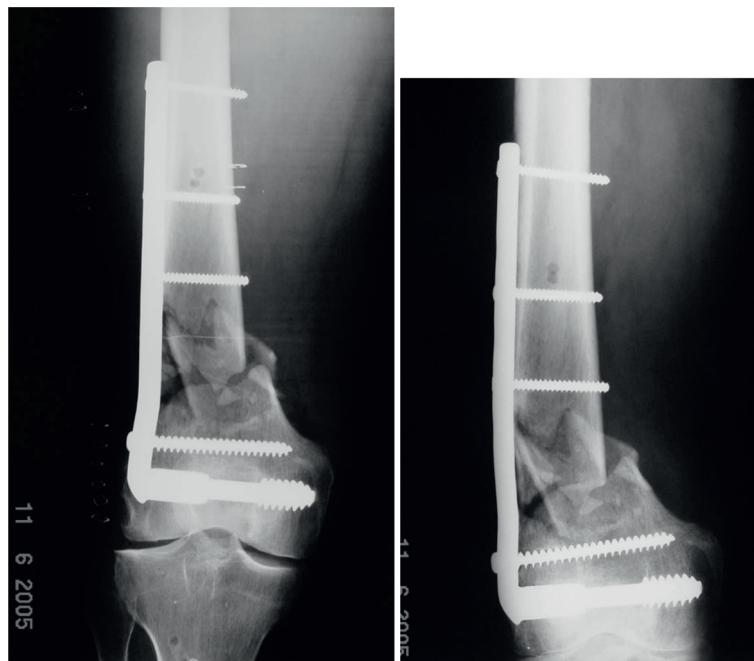


Figure 1.

Extraarticular distal femoral fracture, treated with a short Dynamic Condylar Screw (DCS). At follow up, nonunion and failure in varus occurred. Metaphyseal comminution and a short side plate and working length are considerations to be taken into account to explain the result.

incidence of mechanical failures [4, 15–18]. Although having improved mechanical capabilities compared to previous implants, improper use, or unawareness of the importance of the balance between rigidity, stability and bone healing promotion, can lead to failure (**Figure 2**) [19].

Numerous in vitro reports have been published in recent years, showing improved mechanical capabilities with fixation techniques that combine lateral locking plates and medially placed additional plates, as well as the combination of lateral locking plates and locked intramedullary retrograde nails (“augmented RIMN”) [20–25]. These studies report a significant increase in resistance to axial, rotational and bending forces, along with increased stiffness of such constructs, which has led to their application for clinical use, in pursuit of minimizing complications derived from implant failure. Several mechanical stress studies, as well as clinical studies, focus on fractures with bone defects and/or comminution, including fractures in osteoporotic patients, because they have high risk for failure. Ricci et al. published an analysis of the factors that may influence failure of fixation in distal femoral fractures, treated with laterally placed locked plates [26]. Various types of fractures were included: 64%

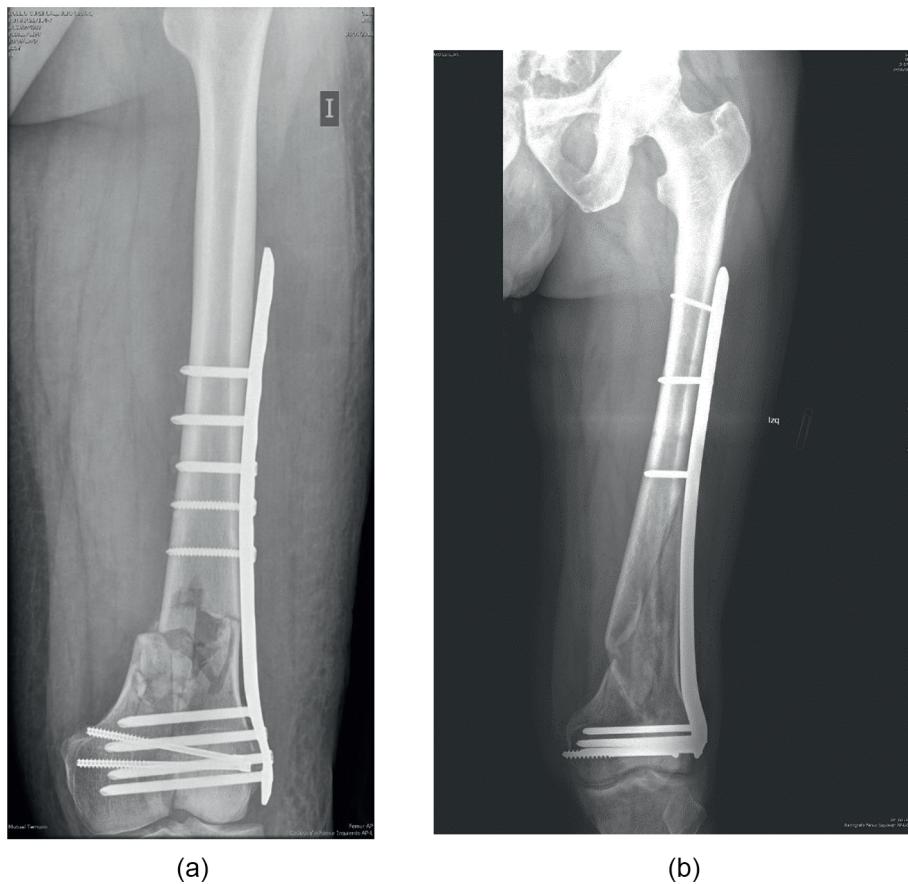


Figure 2.
(a) A3 closed fracture in a 50 year-old patient, treated with anatomical locking plate. AP x-ray at follow up shows atrophic nonunion. Selection of the length of the plate, together with the distribution of screws, may have played a role in the outcome. (b) Same fracture pattern in a 44 year-old patient, with more extended working length and less screw density. Uneventful consolidation has occurred after 6 months.

of 335 fractures were simple metaphyseal (A1 and A2), or simple articular (C1 or C2). They found that there were factors out of reach from the surgeon, such as severity of the injury (high energy, open fractures), young age (with more severe injuries), comorbidities such as diabetes, and smoking. Plate length, on the other hand, was also a contributing factor: shorter plates were associated with failures more frequently than long plates. The surgeon must therefore balance what is inherent to the fracture and the patient, with the available implants, elaborating a strategy that will ultimately lead to a construct design capable of minimizing the risk of failure.

In our opinion, DFF differ in the pathomechanical analysis that can be made whether they are simple extraarticular, comminuted extraarticular, or intraarticular, as well as if present in young or older (osteopenic) patients. Older patients with poor

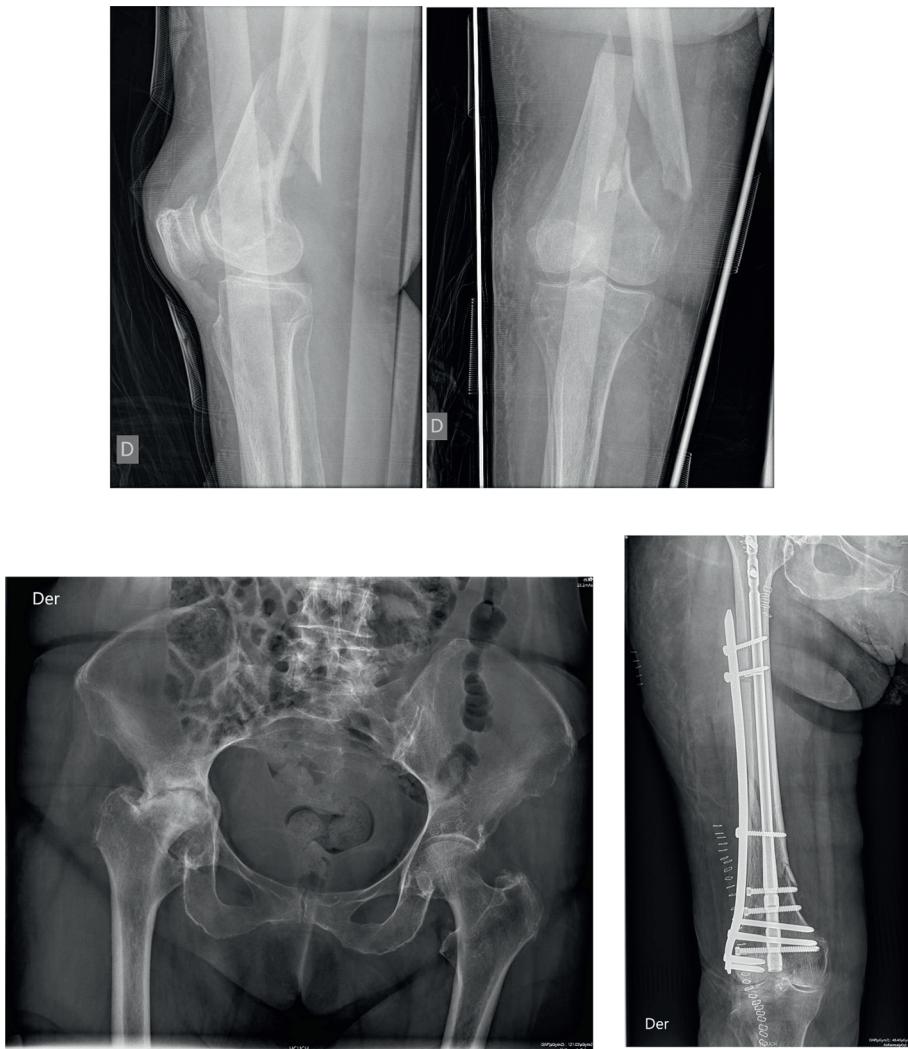


Figure 3.
Distal extraarticular fracture in a 75 year old patient with concomitant severe ipsilateral hip arthritis and rigidity. Despite absence of comminution, fixation was done with RIMN, augmented with a locking plate. This was decided in consideration of the age of the patient, and the increased torsional stresses that the construct will withstand throughout the healing process, due to hip stiffness.

bone quality present inherent difficulties in obtaining stable internal fixation. There is data underlying the difficulties to accomplish “limited” weight-bearing in patients of advanced age, so it should be assumed that patients of a certain age will submit the construct to high forces from the early postoperative period [27, 28]. These considerations have decisive influence on the selection of the operative method.

Of note is the fact that advances in implant stability and rigidity may also present concerns about delayed healing. There is the need to balance the overall strength/stiffness of the construct and the appropriate micromotion that promotes callus formation. With patients of advanced age, however, the benefits of construct stability and endurance may outweigh the achievement of fracture healing, at least initially [28–31]. Postoperative compliance with controlled or “limited” weight bearing is very difficult to achieve in geriatric patients, as mentioned above. Therefore, implant stability and strength is of primary importance (**Figure 3**). These considerations do not apply, nonetheless, in the young patient with similar fractures. In this setting, promotion of bone healing is paramount for long term success and functional restoration. Therefore, careful and judicious application of any fixation method or technique should balance the maintenance of proper reduction while favoring bone healing, the latter by the means of providing a mechanical environment with adequate strain.

As aforementioned, a sound mechanical construct should take into consideration the quality of bone, the general status and age of the patient, and also the type of fracture. We consider it appropriate to analyze distal femoral fractures broadly distinguishing between those with and without articular involvement. Articular involvement has requirements for adequate fixation that differ from extraarticular fractures, whether comminuted or not. Anatomic articular reduction and rigid fixation is a principle that remains unchanged since first advocated by the AO [32]. This requires the use of individual screws for fragment fixation and articular restoration, which is most often followed by implantation of plates and/or intramedullary nails to unite the articular segment to the diaphysis. Within these two main categories, management decisions can be

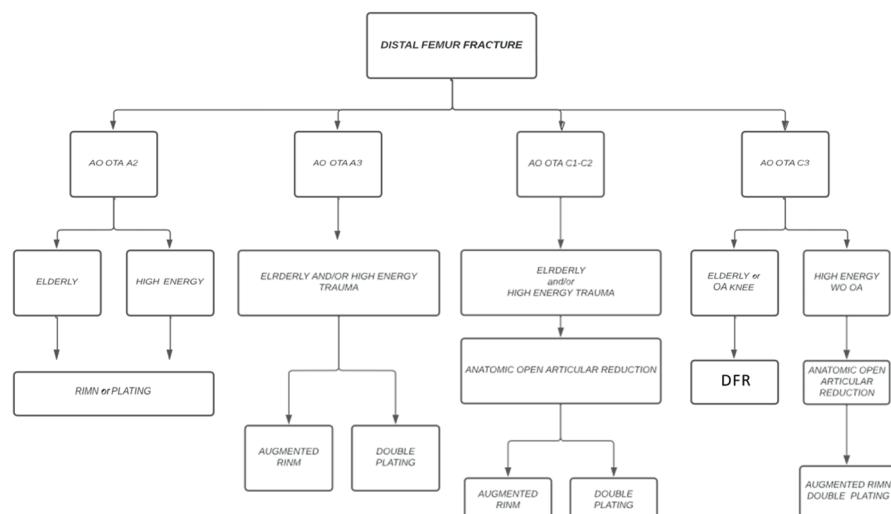


Figure 4.
Flowchart as a proposal for the management of distal femoral fractures. DFR: distal femoral replacement.

made when we include other components in the analysis (those inherent to the fracture and the patient) pertinent to the treatment plan. This could work as an algorithm for proper selection of surgical approach, implants and design of the construct (**Figure 4**).

3. Management of extraarticular fractures of the distal femur

Extraarticular fractures involving the metaphysis, and without comminution (type A1 and A2 fractures, according to AO/OTA), can be addressed efficiently with



Figure 5.
Type A3 high-energy fracture, managed with RIMN and three distal locking screws.

either LP or RIMN (**Figure 5**) [33–37]. The presence of metaphyseal comminution and/or osteopenic bone involves a high risk of varus collapse and hardware failure [38] (type A3 fractures). For these fractures numerous biomechanical studies have been published, as mentioned before, in bone models with finite element analysis and in cadaver studies, in search for stronger fixation methods [38–41]. DeKeyser et al. reported a literature review on what has been investigated in terms of mechanical fixation of distal femoral fractures with a metaphyseal defect. As a summary, medial and lateral plate fixation (dual plating of the distal femur) and the combination of IMN and LP, showed greater strength and resistance to axial, torsional and bending forces, than conventional LP or INM fixation alone. Lodde et al. published a literature review on the clinical results of double plating, that included femoral shaft fractures in polytrauma patients, femoral nonunions, proximal femoral pathological fractures, periprosthetic fractures, and distal femoral fractures. They concluded that double plating is a valid alternative for management of the latter, with high union rates (88%), but also with a 33% complication rate. Steinberg et al. reported on clinical results in double plating for acute distal femoral fractures (intra and extraarticular), nonunions and periprosthetic fractures. Only one of 32 patients developed nonunion that required bone grafting, and one had a femoral shaft fracture proximal to the hardware, requiring lateral plate exchange. Bologna et al. published on a comparative cohort of patients treated either with single or double plating with C2 and C3 (AO-OTA) distal femoral and periprosthetic fractures. A statistically significant difference was found between the two groups in terms of nonunion and time to healing, in favor of dual plating. It is clear that increasing the strength and rigidity of the construct by adding a parallel medial plate has a correlation with better clinical results and fewer mechanical failures. However, there is still lack of definitive clinical evidence whether this augmentation -which leads to increased stiffness- ultimately allows proper bone healing. In cases of poor bone quality, a stronger construct may well withstand forces irrespective of fracture consolidation. It can be difficult to interpret and clearly define the presence of bone bridging in the fracture zone on plain X-rays. To our knowledge, no large scale study has been presented assessing bone healing with a more sensitive exam, such as multiplanar CT.

A few cases reporting on the advantages of the combination of LP- RIMN in fractures in osteopenic bone have been published, as well as femoral nonunions [29, 30, 42, 43]. It seems that this method allows for earlier weight bearing and functional recovery in older patients, due to the increased strength of the construct. Engaging both the plate and the nail with screws that interlock both implants may increase even further the resistance of the system.

In our experience, the combination of IMN and LP (“augmented RIMN”) in the management of fractures with metaphyseal comminution results in a construct which combines the benefits of both implants (**Figure 6**). It has been argued that it results in a more even distribution of forces, which allow for earlier weight bearing, while minimizing the risk of hardware failure [29, 44]. From the mechanical standpoint, a long lateral locking plate with far-proximal cortical screws tangential to the nail, provides a longer working length and higher resistance to cantilever forces towards varus at the proximal end of the plate (which is acting as a true tension band), in an attempt to minimize proximal screw loosening and pull-out (**Figure 7**). In our initial experience with shorter plates, however, toggling and loosening of these screws was not followed by progressive deformity in varus. We believe that the presence of a long, locked intramedullary device helps in maintaining alignment.

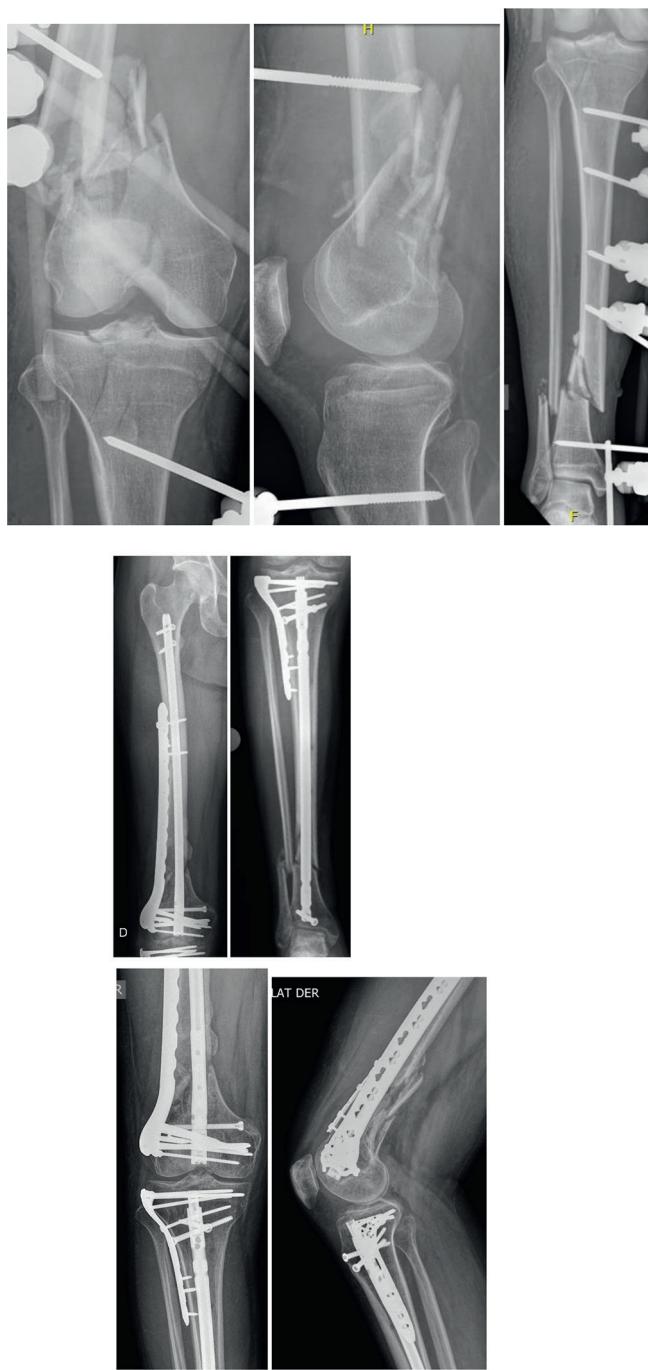


Figure 6.

High-energy floating knee injury (Fraser type IIC), with open segmental tibial fracture. After damage-control orthopaedic management, definitive fixation was performed with a nail and plate combination for the femur and tibia. Reduction of the articular femoral fracture was done with 3.5 mm. cortical screws, and additional 3.5 mm. one-third tubular plate. No other procedures were needed until healing.

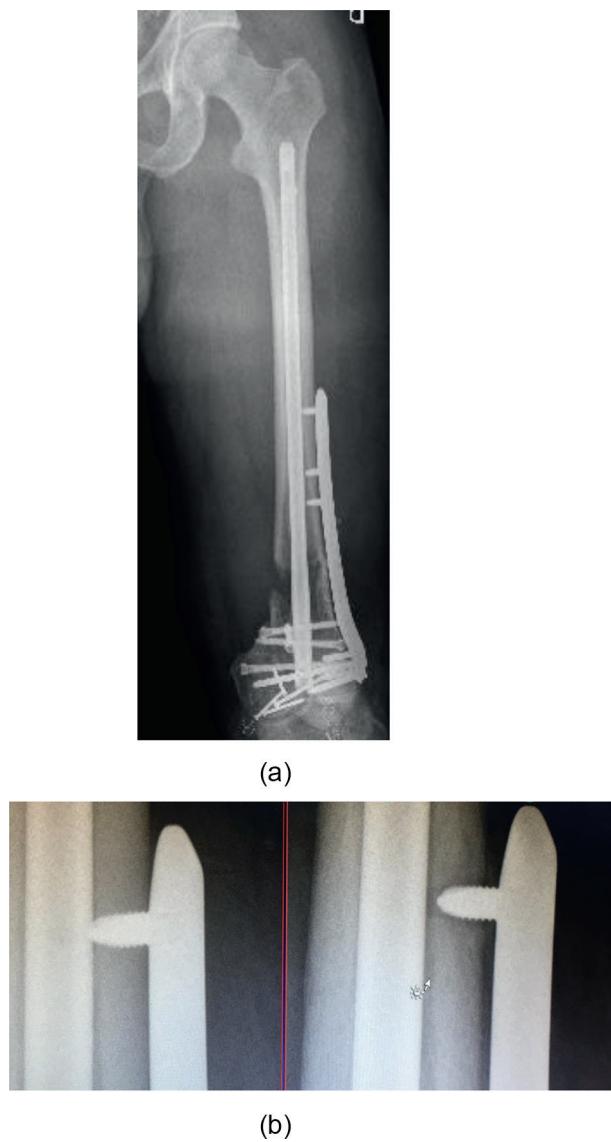


Figure 7.
(a) AP X-ray showing fixation of a A3 distal femoral fracture with nail and plate combination. A short lateral locking plate and proximal monocortical locked screws were used. (b) After 5 months, loosening of most proximal locked screw is seen, due to toggling. To prevent this, extended length of the plate proximally, and proximal bicortical screws, would have been appropriate.

Recent advances in design have brought into market extraosseous devices that engage to a RIMN through screws, adding significant stability to conventional nail interlocking screws [45]. This locked “washer” gets “unitized” to the intramedullary nail, which in mechanical testing -together with still limited clinical experience- has shown significant improvement in endurance and strength. The combination of RIMN plus a lateral locking plate acts using the same principle. This “washer”,

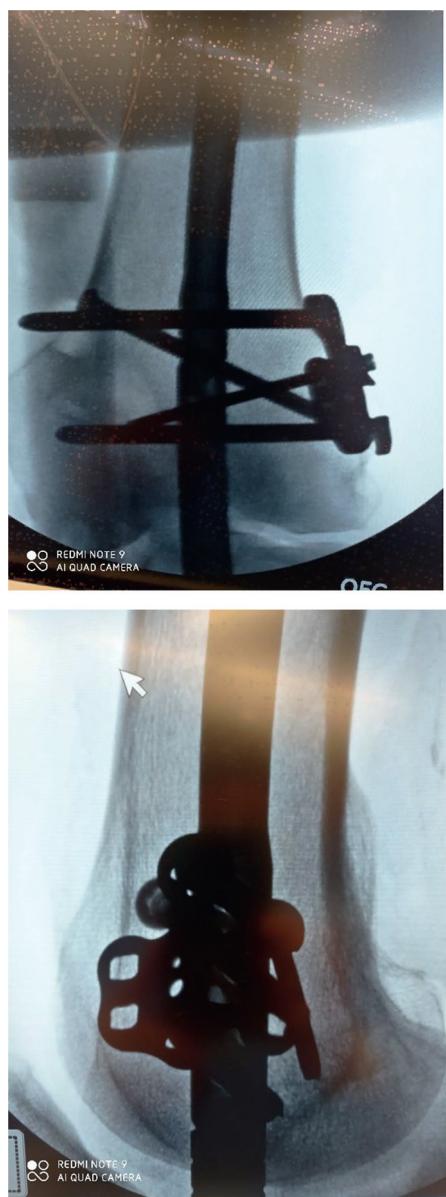


Figure 8.

AP and lateral view of the “locking washer” in place, which engages two locking holes of a retrograde nail with screws that are locked to the external device, providing significant increase in stability over interlocking screws alone.

moreover, could have the additional advantage of avoiding submuscular dissection for placing a long lateral plate (**Figure 8**).

4. Management of intraarticular fractures

Articular involvement should be addressed with anatomical restoration of the joint as a prime objective. Open reduction is often required. Additional fixation of

the articular segment to the femoral diaphysis can be achieved by different methods, either “minimally invasive” or open. As mentioned previously, considerations for the planning of the approach and the selection of implants shall consider the amount of fracture comminution, the quality of the bone, the age and physiological needs of the patient, and -for articular fractures- whether there is previous joint arthritis.

Currently, with modern RIMN and anatomical locking plates, either simple or complex articular fractures can be properly managed in terms of initial fixation and alignment (**Figure 9**) [46–50]. However, comminuted articular fractures -as well as those with metaphyseal comminution, as mentioned before-, together with other specific fracture patterns, have been associated with a high rate of nonunion and hardware failure [15, 26, 51, 52]. Recently, Nino et al. published on 16 patients with articular comminution, that were treated with articular screw fixation and RIMN, with a high degree of success in terms of fracture healing, without the need of additional procedures to promote union [53]. However, 38% of patients had a complication, most commonly knee stiffness. To minimize the risk of fixation failure and nonunion in cases of comminution and/or poor bone quality, and as mentioned before, the advent of techniques such as coupling intramedullary devices to laterally placed plates or locked “washers”, as well as the addition of medial plates as a supporting medial strut, have come into play, with clinical evidence supporting their use (**Figure 10**).

Articular involvement—even with comminution—is not an impediment for the use of RIMN. Proper articular reduction and fixation can be undertaken with small-diameter screws (2.7 or 3.5 mm. cortical screws), which provide sound fixation of articular fragments, and leave space for the insertion of a nail. RIMN becomes a supporting column placed in the mechanical axis of the femur, therefore resisting axial and bending forces, acting as a load-sharing device. “Augmentation”, by the addition of a lateral locking plate—or an interlocking “washer”—adds significant resistance to mechanical failure, with a higher endurance of the construct until bone healing occurs.

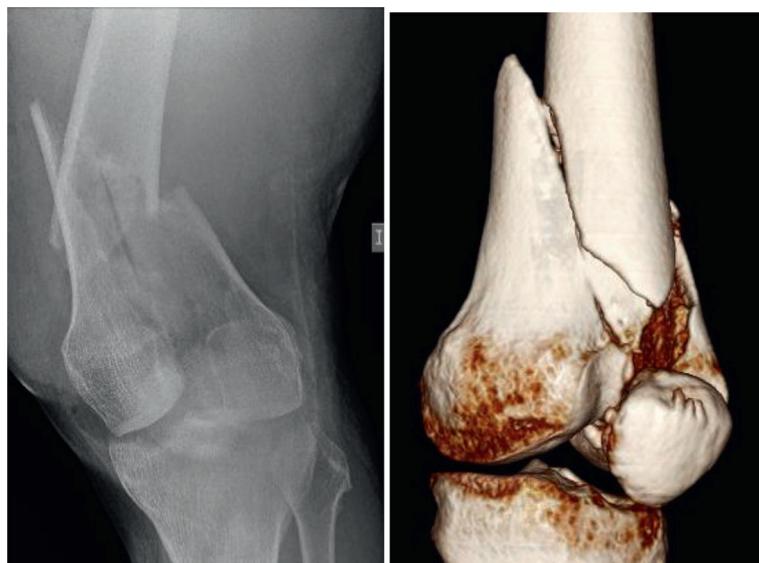


Figure 9.
C₁ fracture, treated with open parapatellar approach, reduction and fixation of the condyles with 3.5 mm. cortical screws, and RIMN as definitive fixation. Callus formation and healing is seen after 6 months.



Figure 10.

High-energy floating knee (Fraser type IIB) in a patient with a previously healed tibial fracture, and an osteoarticular defect of the lateral femoral condyle, due to trauma 9 years before the actual scenario. The articular distal femoral fracture was managed with 3.5 mm. cortical screws, and a 3.5 mm. wrist T plate for reduction to the diaphysis, followed by nail and plate combination. The tibial fracture was fixed with a percutaneous plate, due to absence of displacement, and because the tibial canal was assumed to be occluded by the previous fracture.

The presence of joint arthritis, especially in older patients, should be a main consideration when planning surgical treatment. In such patients, distal femoral replacement with a distal femoral megaprosthesis and a rotating hinge, has been advocated as an excellent treatment method, allowing for swift functional recovery [54–58]. Internal fixation—whichever the method—is subjected to high rotational and bending forces due to joint stiffness, which is often aggravated by poor bone quality, as well as the difficulty (as previously mentioned) in restricting function postoperatively in order to decrease the risk of hardware failure. In addition, older patients with distal femoral fractures share similar epidemiological characteristics with those having proximal femoral fractures, including mortality rates [59], so



Figure 11.
C3 distal femoral fracture in a 70 year-old patient. X-rays and CT show extensive articular comminution, and signs of knee arthritis. A resection of the distal femur and reconstruction with a modular tumor endoprosthesis and rotating hinge was done. Swift postoperative recovery and return to function was possible.

considerations for operative treatment and early return to function should be the same. As such, primary treatment with distal femoral resection and replacement by a rotating hinged prosthetic knee is a very valuable alternative (**Figure 11**). Aside from the aforementioned advantages, complications or re-interventions in distal femoral replacements are not higher than those reported with fracture fixation techniques.

5. Essentials of surgical technique

Our preference for all cases requiring internal fixation, is positioning in supine. A sterile and discardable tourniquet is a useful adjunct which can be used to facilitate exposure, and can be later removed if needed, so it does not interfere with insertion of plates and/or retrograde nails. Whenever RIMN becomes part of the fixation method, we advocate the use of long nails, extending proximally to the metaphysis, in between the two trochanters. This may provide protection of the entire bone segment, therefore minimizing the risk of periprosthetic fractures.

If open reduction is indicated, whether the fracture is intraarticular or extraarticular, we have progressively shifted our choice to a lateral para-quadriceps approach. It was originally described as a trans-articular approach for fracture fixation with plates [60]. This allows excellent exposure of both femoral condyles, facilitating direct visualization and reduction of articular fragments, if present. Deep flexion of the knee allows for the whole contour of the articular surface to be assessed. At times, in cases of metaphyseal comminution (A3 or C2/C3 fractures), this approach allows the surgeon to directly reduce the condyles to the diaphysis, and use small plates or K wires for provisional fixation. Access to the femoral diaphysis can be undertaken by dividing longitudinally the quadriceps between the rectus anterior and vastus lateralis very proximally, to expose the intact proximal diaphysis. Direct assessment -and/or indirect assessment with fluoroscopy- of overall alignment can be done. The same approach allows for placement of a lateral locking plate onto the condyles, which is then slid proximally in a closed manner, to be finally attached to the proximal diaphysis with percutaneous screws.

For the combined use of RIMN and locking plates (“augmented RIMN”), and depending on the details of the fracture pattern as seen during exposure, at times the first implant to be used is the plate, which is fixed to bone with short (usually 30 or 32 mm long) locking screws distally and monocortical (14 mm long) locked screws to the diaphysis (**Figure 12**), in order to allow unobstructed insertion of a RIMN. Whenever possible, we attempt to have at least one locking screw inserted from the plate engaging one of the interlocking holes of the nail. This results in a much stronger construct distally. We should outline that, at the end of the procedure, and in light that proximal monocortical screws might toggle and loosen due to repetitive cantilever forces towards varus, the two most proximal screws in the plate are replaced with bicortical 4.5 large fragment screws. These usually have a trajectory tangential to the intramedullary nail, which enhances their resistance to pull out. Closure of the longitudinal quadriceps split is done with non-absorbable suture in order to restore continuity of the muscular unit, and to allow prompt full passive range of motion and active isometric muscle contraction.

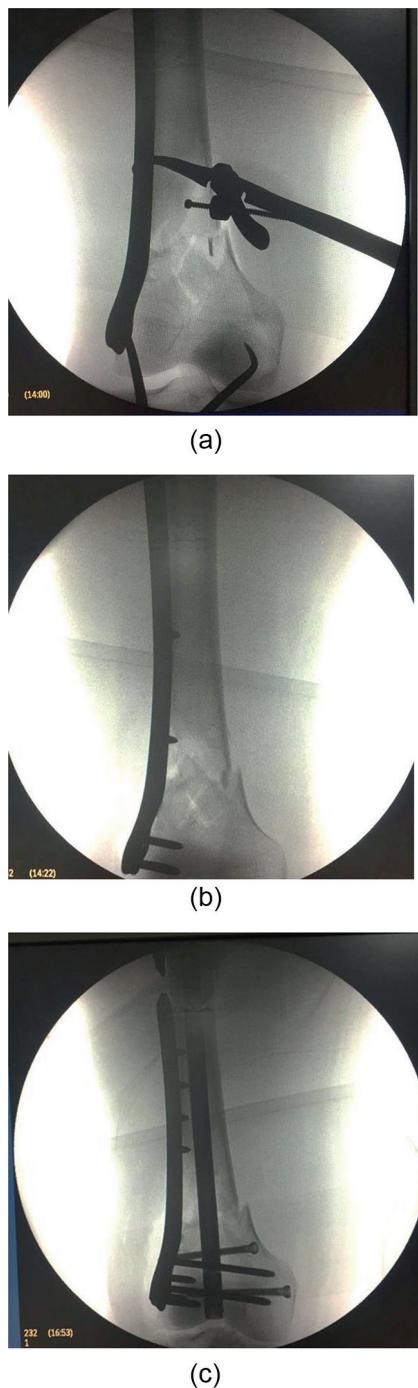


Figure 12.
(a-c) Direct approach and reduction of the fracture by means of a lateral locking plate. Monocortical locked screws proximally and 30 mm-long locked screws distally were used for reduction and provisional fixation, allowing unobstructed insertion of a RIMN.

6. Summary

Distal femoral fracture management illustrates the evolution in the treatment of fractures that have significant impact on function and quality of life. New developments in fixation techniques, together with an increased understanding of the influence of mechanics in the process of fracture healing (the balance between stress and strain) has led to constant evolution in the design and selection of implants for these injuries (and combination of implants when needed). Together with a careful evaluation of the fracture pattern and the condition of the patient, the surgeon can wisely plan the best fixation method.

Distal femoral fractures, whether extra or intraarticular, with or without comminution, presenting in young, active patients (high-energy fractures and/or polytrauma) or in older patients with osteoporosis and/or knee arthritis, should be evaluated taking into account all these considerations. Selection of the surgical approach is also part of preoperative planning. Our preference for anterior, para-quadriceps approach is based on the excellent visualization of femoral condyles, metaphyseal area and proximal femoral diaphysis. In addition, it does not impede standard submuscular sliding of a lateral plate proximally and percutaneous screw fixation. Availability of diverse implants, experience of the surgical team, and dedicated, multidisciplinary care for appropriate postoperative rehabilitation, are additional important factors for successful treatment of these complex injuries.

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