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Cementless Total Knee Arthroplasty Using an Ultraconforming Tibial Bearing: Outcomes at Minimum 5-Year Follow-Up

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ABSTRACT

Background: Cementless fixation for primary total knee arthroplasty (TKA) continues to increase in the United States. However, compared to cemented TKA, reports on revision rates have been mixed. A confounding variable may include the tibial insert design. This study aimed to assess the minimum 5-year survivorship and outcomes of a cementless TKA using an ultracongruent (UC) articulation.
Methods: A consecutive series of 242 cementless TKAs were implanted at two institutions between 2017 and 2019 using an UC kinematic tibial insert. Of the patients, 56% were men. The average age was 60 years. Patients were followed using Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR) and Knee Society clinical and radiographic scores. Preoperative and postoperative radiographs were classified according to the Coronal Plane Alignment of the Knee (CPAK) type. The average follow-up was 5.6 years (range, five to 7.5).
Results: At the final follow-up, KOOS-JR scores averaged 84.0. Knee Society scores averaged 94. Flexion averaged 116°. There were seven manipulations (2.9%), one patella fracture, and no deep infections. There were seven knees (2.9%) revised (three for flexion instability, one for pain, one for femoral fibrous ingrowth, one for distal femur fracture, and one for arthrofibrosis). At 5 years, survivorship free from aseptic loosening was 99.6%. Change in CPAK type did not correlate with final KOOS-JR, pain, University of California Los Angeles activity score, or satisfaction scores.
Conclusions: Cementless TKA using this conforming design has provided excellent clinical results out to 5 years. Once initial component stability is achieved, the UC nature of this articulation does not appear to adversely influence the durability of implant fixation, regardless of whether the CPAK type was changed.

Cementless fixation in primary total knee arthroplasty (TKA) continues to increase steadily in the United States, accounting for 21.8% of all primary TKA in 2023 [1]. This renewed interest in cementless fixation may be due to a variety of factors, including a desire to achieve long-term biologic fixation, especially in younger patients [2–7]. Yet, when comparing cementless fixation to cemented fixation, the results for longevity and revision rates have been mixed in both clinical studies [8–10] and registry data [1,11–13]. Some studies have demonstrated greater survivorship with cementless fixation in primary TKA [8–10], while other comparisons have shown equivocal results [14,15], and still other studies have favored cemented fixation [6].

Variables that may account for these mixed results may include the tibial insert design and/or the congruency of the femoral-tibial articulation. Highly congruent tibial inserts can theoretically influence knee kinematics [3,4,16,17]. Ultracongruent (UC) articulations have been used in an attempt to reproduce normal knee kinematics in TKA [17]. Currently, asymmetric tibiofemoral articulations account for 38% of all primary TKAs in the United States [1]. On the one hand, replicating normal knee kinematics has been

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associated with greater patient satisfaction after TKA [17–21]. However, increasing femoral-tibial articular constraint increases forces transmitted to the bone–implant interface and may increase initial implant micromotion and potentially compromise bone–implant ingrowth [3,22]. Despite these factors, there are relatively few publications reporting results of primary cementless TKA using an asymmetric articulation [2–4,23,24].

The purpose of this study was to determine clinical outcomes, radiographic results, including coronal plane alignment (CPAK), and implant survivorship at a minimum 5-year follow-up for a cementless TKA design using an UC kinematic tibial insert. The secondary goal was to ascertain what patient demographic characteristics, including changes in CPAK type, influence patient-reported outcomes (PROMs). The hypothesis of the study was that excellent survivorship would be observed and changes to CPAK classification would not affect PROMs after primary cementless TKA.

Methods

Between October 1, 2017, and August 31, 2019, a consecutive series of 249 cementless EMPOWR 3D TKAs (Enovis, Wilmington, Delaware) were implanted by two surgeons at two institutions. There were five patients who died of unrelated causes before their 5-year follow-up and two patients were lost to follow-up. At the time of the most recent follow-up, the TKAs in these seven patients were all functioning well. This left a cohort of 242 TKAs in 139 patients for inclusion in the study. Of the surgeons, one contributed 75.2% of cases (182 TKAs) and the other surgeon contributed the remaining 24.8% of cases (60 TKAs). During the same study time period, surgeons A and B performed 506 and 518 cemented TKAs, respectively. There were no other primary cementless TKAs implanted during this time. The indications for using an uncemented tibial and femoral component were adequate bone quality for a press-fit application, according to surgeon discretion, and assessed on the preoperative radiograph and at the time of the operation, and valgus deformity no greater than 20° [3]. Similar to Meding et al. [4], if the degree of osteoporosis on the preoperative radiograph was felt to potentially require a cemented implant, the patient was excluded. Similarly, if the coronal deformity was 20° or greater, the patient was excluded because of the potential need for a more coronal constraint at the time of operation [4]. In this cohort of patients, the decision on the type of fixation did not change during the operation. There were 88 patients (36%) who underwent simultaneous bilateral TKA and 15 patients (6%) had staged bilateral TKAs. Of the bilateral patients, 78 were men (56%) and 61 were women (44%). The diagnosis was osteoarthritis in 95% (230 TKAs). The average body mass index was 37.0 (range, 19.6 to 66.8). The average age of the entire group was 60 years (range, 32 to 91). Of the group, 48% was classified with The American Society of Anesthesiologistsi [25] physical status classification 2. The average Charlson Comorbidity Index [26] was 1.5 (Table 1). There were 31 patients (22.3%) who presented with a diagnosis of depression, and 13 patients (9.5%) had fibromyalgia, as documented in the medical record. There were 16 patients (6.6%) who were regularly taking opioids before the operation.

The study was approved by our institutional review board (ID #218567-1). All data were collected prospectively and then retrospectively reviewed.

Surgical Technique

All TKAs were performed via a medial parapatellar approach using mechanical alignment techniques. A tourniquet was used in 90 knees (37.2%). An intramedullary femoral alignment guide set at 5° was used in 181 knees (74.8%), and femoral navigation was used in 61 knees (25.2%). With both techniques, the initial goal was neutral mechanical alignment. This alignment was then adjusted, as needed, to allow for slight variations in any individual constitutional deformity (i.e., adjusted mechanical alignment). An extramedullary tibial alignment guide set at neutral in the coronal plane was used in all cases. The tibial sagittal plane cut was set to estimate the patient's anatomic posterior slope. Tibial resection was positioned to resect at least 10 mm from the less affected compartment while attempting to maintain as much proximal tibial bone as possible. The posterior cruciate ligament was completely released from its posterior tibial insertion to avoid any potential kinematic conflict. The collateral ligaments were balanced with the goal of achieving equal or symmetrical gaps. However, During the period of this study, the patella was left unresurfaced only if minimal to no chondromalacia was present. Thus, in 48 TKAs, the patella was left unresurfaced (19.8%). In 10 knees (4.1%), a cemented patella (EMPOWR 3D, Envois, Wilmington, Delaware) was used for resurfacing, and in 184 knees (76%), a press-fit patella was used (Triathlon, Stryker, Mahwah, New Jersey). The design of the TKA implant used in the study has been described in detail [3,4,21]. Briefly, the femoral component is designed with a single radius of curvature up to 70° of flexion to allow for consistent soft-tissue tensioning. The medial condyle is relatively wider to allow for femoral external rotation. On the tibial side, the lateral articulation is designed with an 8-mm anterior lip with a conforming single radius of curvature from −10 to 65° of flexion (lateral pivot) and then lesser conformity at higher flexion angles allowing more posterior femoral translation. The medial compartment is more

Table 1
Demographic Data.

TKAs (Patients)	242 (139)
Age (years)	
Average	60
Range	32 to 91
Standard Deviation	8.5
Sex (%)	
Men	56
Women	44
Diagnosis (%)	
Osteoarthritis	95
Osteonecrosis	4.5
Rheumatoid Arthritis	0.5
Body Mass Index	
Average	37.0
Range	19.6 to 66.8
Standard Deviation	8.2
Underweight	-
Normal (%)	6 (2.4)
Overweight (%)	43 (17.8)
Class I (%)	59 (24.4)
Class II (%)	61 (25.2)
Class III (%)	73 (30.2)
Superobese (%)	19 (7.8)
ASA Class[a] (%)	
I	19
II	48
III	33
CCI	
Average	1.5
Range	0 to 7
Standard Deviation	1.6
Bilateral TKA (%)	88 (36.4)
Follow-up (years)	
Average	5.6
Range	5 to 7.5

TKA, total knee arthroplasty; CCI, Charlson Comorbidity Index; ASA, American Society of Anesthesiologists.
[a] The American Society of Anesthesiologists physical status classification.

conforming in 90 to 120° of flexion (medial pivot (MP)), allowing for less femoral translation. The cementless TKA uses a titanium alloy porous metal tibia with interbead pore sizes of between 200 and 525 microns and intrabead pore sizes between 25 and 65 microns for an average porosity of 60%. The tibial keel and cruciform pegs are grit blasted. The cobalt-chrome femoral component uses a sprayed sintered bead 3-dimensional matrix with tapered pegs [3].

The perioperative protocols, including physical therapy, deep vein thrombosis prophylaxis, and prophylactic antibiotics, were the same.

Outcomes

Patients were followed at 6 to 8 weeks, 6 months, 1 year, and every 2 to 3 years thereafter. The Knee Society clinical [27] and radiographic [28] analysis, including the knee score (KS), function score (FS), pain score (PS), stair score, and walking score, was obtained at each follow-up office visit along with the PROMs, including Knee Society Short Form walking pain, stair pain, patient satisfaction, normality [29], the Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR) score [30], and the University of California, Los Angeles (UCLA) activity score [31]. The raw KOOS-JR score (zero to 28 points) for each knee was converted to an interval score [30]. The minimal clinically important difference (MCID) was set at 7.2 points for the KS and 9.7 points for the KS function score [32]. The MCID threshold for the KOOS-JR score was set at six points [33], two points for walking and stair pain [34–36], and 0.9 points for the UCLA score [36,37].

Complications, including manipulations, revisions, periprosthetic fractures, and superficial and deep wound infections were recorded at each follow-up. All radiographs were reviewed and measured at each follow-up by the attending surgeon. Standardized fluoroscopic positioning was not used. The radiographic criteria used to judge fixation and determine the likelihood of component bone ingrowth and fixation have been previously described in detail [3,28,38]. All knees were classified using the CPAK classification [39] preoperatively and postoperatively with standardized short-leg radiographs using a 5° adjustment for the lateral distal femoral angle [40–46].

All patients were followed for at least 5 years. The average follow-up was 5.6 years (range, 5 to 7.5 years). Radiographic and clinical follow-up was the same.

Data Analyses

Minitab 22.2 statistical software (State College, Pennsylvania) was used for all data analyses. Student's 2-sample *t*-tests were used to evaluate continuous variables, and the *Chi*-square tests were used to compare proportions among categorical variables. When determining associations between patient demographics, including CPAK change and patellar resurfacing versus PROMs, linear regression was used for continuous outcomes, and binary logistic regression was used for binary outcomes with significance set at $P < 0.05$. Right-censored Kaplan-Meier analysis of survivorship [47] was determined at 5 and 7 years. Failure was defined as loosening or revision for loosening. All data was collected prospectively and then retrospectively reviewed. Continuous data are presented as statistical means (averages) with associated ranges and 95% confidence intervals and categorical data are presented as proportions (%).

Results

At the final follow-up, the average KS improved to 93.9 points from a preoperative average of 36.7 points. The PS averaged 45.4 points at the final follow-up. The average preoperative FS was 25.2 points and improved to 84.1 points postoperatively. The walking score averaged 41.4 points, and stair score averaged 43.0 points at the most recent follow-up. There were two patients who reported moderate to severe knee pain with stair climbing. At final follow-up, KOOS-JR scores averaged 84.5 points, walking pain averaged 0.7 points (0 = no pain), stair pain averaged 1.1 points, and UCLA activity score averaged 6.7 points. With all scores, the average postoperative score was significantly improved from the average preoperative score at $P < 0.001$ (Table 2). Furthermore, all TKAs achieved the MCID of 7.2 points for the KS and the MCID of 9.7 points for the FS. There were 98.3% (238 of 242 TKAs) that achieved the MCID of six points for the KOOS-JR score. There were 98.8% (239 TKAs) that achieved the MCID of two points for the walking PS. There were 97.5% (236 TKAs) that achieved an MCID of two points for the stair PS. There were 92.5% (224 TKAs) that achieved the MCID of 0.9 points for the UCLA activity score.

Preoperatively, 80% of patients noted that their knee never felt normal and 20% of patients noted that their knee sometimes felt normal. Postoperatively, 34.3% of patients noted that their knee always felt normal and 56.6% of patients stated that their knee sometimes felt normal. This difference was significant ($P < 0.001$). At the most recent follow-up, 91.3% of patients (221 of 242 TKAs) were either very satisfied (52.98%) or satisfied (38.4%) with their TKA. Of the patients, 3.3% were neutral and 5.4% were either dissatisfied or very dissatisfied. Objectively, postoperative knee flexion averaged 115.8° (range, 85 to 135), which improved from a preoperative average of 108.5° (range, 85 to 125). Postoperative terminal knee extension averaged 1° (range, 0 to 3) (Table 3). These improvements were also significant ($P < 0.001$).

Concerning alignment, preoperatively, 94 knees (38.3%) were classified as CPAK II, 73 knees (30.2%) as CPAK III, and 44 knees (18.2%) as CPAK I. Postoperatively, the greatest number of knees

Table 2
Preoperative and Postoperative Patient-Reported Outcome Measures and Clinical Scores.

Score	Average	Range	Standard Deviation
Knee Society Total Score			
Preoperative	36.7	14 to 68	13.8
Final Postoperative[a]	93.9	60 to 100	6.2
Knee Society Pain Score			
Preoperative	6.8	0 to 20	7.1
Final Postoperative[a]	45.4	10 to 50	5.7
Knee Society Function Score			
Preoperative	25.2	0 to 70	15.8
Final Postoperative[a]	84.1	40 to 100	16.2
Knee Society Walking Score			
Preoperative	11.7	0 to 40	8.0
Final Postoperative[a]	41.4	20 to 50	10.5
Knee Society Stair Score			
Preoperative	15.6	0 to 30	11.8
Final Postoperative[a]	43.0	20 to 50	8.3
KOOS-JR			
Preoperative	34.2	0 to 84.6	13.6
Final Postoperative[a]	84.5	42.3 to 100	13.0
Walking Pain			
Preoperative	7.7	1 to 10	1.8
Final Postoperative[a]	0.7	0 to 8	1.5
Stair Pain			
Preoperative	8.3	1 to 10	1.8
Final Postoperative[a]	1.1	0 to 8	1.5
UCLA Activity			
Preoperative	3.3	1 to 6	13.6
Final Postoperative[a]	6.7	2 to 10	1.6

KOOS-JR, knee injury and osteoarthritis outcome score for joint replacement; UCLA, University of California, Los Angeles.
[a] Significantly improved from average Preoperative score at $P < 0.001$.

Table 3
Preoperative and Postoperative Motion.

Variable	Average (°)	Range	Standard Deviation
Extension			
Preoperative	2.8	+5 to 15	2.6
Final Postoperative[a]	1	0 to 10	1.6
Flexion			
Preoperative	108.5	85 to 125	9.3
Final Postoperative[a]	115.8	85 to 135	8.6
Range of Motion			
Preoperative	105.6	75 to 131	10.1
Final Postoperative[a]	115.6	80 to 132	8.9

[a] Significantly improved from average preoperative measurement at $P < 0.001$.

Table 4
Coronal Plane Alignment Classification.

Type	Preoperative (%)	Postoperative (%)	% Change
I	44 (18.2)	12 (5.0)	−13.2
II	94 (38.3)	84 (34.7)	−1.4
III	73 (30.2)	64 (26.4)	−3.8
IV	5 (2.1)	15 (6.2)	+4.1
V	11 (4.5)	38 (15.7)	+2.5
VI	15 (6.2)	21 (8.7)	+11.2
VII	-	3 (1.2)	+1.2
VIII	-	4 (1.7)	+1.7
IX	-	1 (0.4)	+0.4

were still classified as CPAK II (34.7%) and CPAK III (26.4%). However, the number of CPAK I knees diminished to only 12 (5%) postoperatively, and the number of CPAK V knees increased to 15.7% (Table 4). In all, only 36.6% of knees had the same CPAK classification before and after the operation. Radiographically, radiolucent lines were rare but when they were observed on the most recent radiograph, they were most common on the anterior femur (Zone 1, 5.2% and Zone 2, 0.8%), the medial tibial plateau (zone 1, 5.2% and zone 2, 0.8%), and the posterior tibial plateau (zone 2, 0.8%). All radiolucent lines were less than 1 mm and nonprogressive.

A total of 5 TKAs (2.1%) were diagnosed with a superficial infection. All were treated with local wound care and oral antibiotics. There were no deep infections. There were seven TKAs (2.9%) that required manipulation under general anesthesia. There was one patellar fracture, and this was treated nonoperatively. A total of seven knees were revised (2.9%). Of these, four involved a polyethylene exchange only, two for flexion instability, one for arthrofibrosis, and one for pain. At operation, both femoral and tibial components were found to be well-fixed. There were three knees that were revised to a constrained prosthesis secondary to a late distal femur fracture (one knee), global instability (one knee), and a loose femoral component (one knee). No other loose components were identified radiographically (Table 5). Kaplan-Meier survivorship free from all-cause revision at 5 and 7 years was 96.9% [94.7 to 96.7] each. Survivorship free from revision due to aseptic loosening at 5 and 7 years was 99.6% [98.7 to 100] each.

Patient age, sex, Charlson Comorbidity Index, fibromyalgia diagnosis, preoperative opioid use, and CPAK change were not associated with any PROM that was measured. Additionally, there was no difference in any PROM based on whether navigation or an intramedullary technique was used. However, a higher American Society of Anesthesiologists was associated with more walking pain ($P = 0.0001$). A higher body mass index was associated with more patient satisfaction ($P = 0.048$). Patients who had a diagnosis of depression had lower KOOS-JR scores ($P = 0.010$). Resurfacing the patella was associated with great patient satisfaction (i.e., very satisfied or satisfied) ($P = 0.028$), but lower UCLA activity scores ($P = 0.001$) (Table 6).

Discussion

To our knowledge, this current study represents the longest follow-up of any primary cementless TKA that incorporates an asymmetric tibio-femoral articulation. Kaplan-Meier survivorship free from all-cause revision at 7 years was 96.9% and survivorship free from revision due to aseptic loosening at 7 years was 99.6%. These results are consistent with previous reports using this same prosthesis [2–4,24]. Meding et al. [3] reviewed 232 TKAs followed for 2 to 3.5 years. There were no cases of aseptic loosening with an average KOOS-JR score of 84.6. In a later report from that same institution [4], comparing cementless and cemented TKAs, there were no cases of aseptic loosening in 171 cementless TKAs followed for 2 to 5 years. The average KOOS-JR score was 85.6. Helvie et al. [2] reported on a subset of 134 cementless TKAs of this design followed from 1 to 7 years and noted one case of femoral component loosening (0.4%) with 90% patient satisfaction. Also, Patel et al. [24] in a study including cemented and cementless primary TKAs, noted two cases of femoral component loosening (1%) in the subgroup of 196 cementless TKAs and 93% patient satisfaction (Table 7). The implant survivorship reported in these studies, including the current study, shows that using this asymmetric UC tibial insert in this knee design does not seem to adversely influence component fixation, affording a high degree of patient satisfaction. Based on the clinical and radiographic results presented here, the use of this medial and lateral pivot knee design did not adversely influence tibial or femoral component fixation. Additionally, a recent publication compared cementless cruciate-retaining TKA to cementless MP TKA (EVOLUTION, Microport Orthopaedics Inc., Arlington, Tennessee) with follow-up from 3 to 24 months [23]. There were no cases of aseptic loosening in the MP group. Furthermore, the MP cohort had lower PSs (less pain) at 1 and 2 years, a statistically greater range of motion at one year, and higher KOOS-JR scores at one and 2 years.

The growth trend of using cementless fixation in the primary TKA is supported by recent literature regarding implant longevity and clinical outcomes [48]. Contemporary cementless TKA designs have demonstrated survivorship up to 15 years between 97 and 99% [49]. Clearly, the design improvements that have led to enhanced bone ingrowth and initial implant stability have made the likelihood of long-term biologic fixation much more predictable [5]. It is recognized, however, that the success or failure of one cementless implant design may not apply to all cementless TKAs. Increasing conformity and/or constraint in the tibiofemoral articulation can

Table 5
Complications.

Complication	n	%
Superficial Infection	5	2.1
Deep Infection	0	-
Manipulation	7	2.9
Quad Tendon Repair	1	0.4
Patella Fracture	1	0.4
Prepatellar Hematoma	1	0.4
Poly Insert Exchange	4	1.7
Flexion Instability	(2)	
Arthrofibrosis	(1)	
Pain	(1)	
Revision Femur Fracture	1	0.4
Revision Instability	1	0.4
Revision Loose Femur	1	0.4

Table 6
Multivariate Analysis: Patient Characteristics Versus Patient-Reported Outcome Measures.

PROM	Age	Sex	ASA	CCI	BMI	Depression	Fibromyalgia	Preoperative Opioid Use	Δ CPAK	Resurfaced Patella	IM Versus Navigation
KOOS-JR	No	No	No	No	No	$P = 0.010$[c]	No	No	No	No	No
Knee Society pain with level walking	No	No	$P = 0.0001$[a]	No	No	No	No	No	No	No	No
Knee Society pain with climbing stairs	No	No	No	No	No	No	No	No	No	No	No
Knee Society 'Knee Normal'	No	No	No	No	No	No	No	No	No	No	No
Satisfaction	No	No	No	No	$P = 0.048$[b]	No	No	No	No	$P = 0.028$[d]	No
UCLA	No	No	No	No	No	No	No	No	No	$P = 0.001$[e]	No

IM versus Navigation, Intramedullary versus Navigated distal femoral cut.
ASA, American Society of Anesthesiologists physical status classification; CCI, Charlson Comorbidity Index; BMI, body mass index; CPAK, coronal plane alignment of the knee; KOOS-JR, knee injury and osteoarthritis outcome score for joint replacement; UCLA, University of California Los Angeles Activity Level scale; Δ, delta (i.e. change from preoperative baseline).
[a] Higher ASA associated with more walking pain.
[b] Higher BMI associated with more satisfaction.
[c] Depression associated with a lower KOOS-JR score.
[d] Resurfaced patella associated with more satisfaction.
[e] Resurfaced patella associated with lower UCLA score.

potentially influence implant stability and bone ingrowth in cementless TKA. The current study intended to determine implant survivorship using an asymmetric UC kinematic tibial insert. At a minimum 5-year follow-up, it is evident that stable cementless fixation does occur even when this type of articulation is used.

Approaches to improve patient satisfaction after TKA are becoming increasingly important. The Patient Reported Outcome-Based Performance Measure program is now being mandated by the Centers for Medicare and Medicaid Services [50]. The measure of success of a TKA will now include whether the patient meets or exceeds the so-called subjective "substantial clinical benefit." The UC articulations have been developed to reproduce normal knee kinematics in TKA [17], and replicating normal knee kinematics has been associated with greater patient satisfaction after TKA [17,21]. In the current study, patient satisfaction was 91%, and 98.3% of cases achieved the MCID threshold of 6 points for the KOOS-JR score.

The CPAK classification has been used to measure and predict individual variations in lower-extremity alignment [39]. Notably, in the current study, only 36.6% of knees had the same CPAK phenotype before and after the operation. Multivariate regression analysis also demonstrated that CPAK change after TKA was not associated with the measured PROMs including KOOS-JR, patient satisfaction, and UCLA activity score. In contradistinction, Konishi et al. [51] reported that an alteration in CPAK phenotype did have a negative influence on PROMs, including the KOOS-12 and the Forgotten Joint Score-12. These conflicting results are most likely attributed to the multiple factors associated with patient satisfaction, including patient expectations, function, pain, prosthesis design, and social determinants [52].

The study does have potential limitations. This is a retrospective review of two institutional registries with no control group. However, the data were collected prospectively. A randomized trial, or a patient-matched comparison similar to Meding et al. [4], evaluating the same implant using this highly congruent tibial insert versus a conventional cruciate-retaining insert, would prove useful. In addition, because the follow-up in this study is only between 5 and 7 years, further follow-up is needed to determine if this type of UC adversely influences long-term fixation. It is well-established, however, that once initial implant migration and subsequent osseointegration occur, further implant migration is unlikely with cementless fixation [3,53,54]. Also, migration was not measured. The authors do recognize that some early migration of either the femoral or tibial component did, most likely, occur before implant stabilization. Moreover, fluoroscopy was not used for patient positioning when obtaining radiographs at follow-up. However, the study involved high-volume joint arthroplasty centers where the X-rays were standardized by experienced technicians. Furthermore, established radiographic criteria were used for determining both implant fixation and the significance of radiolucent lines [4,28,38]. All radiographic measurements were done by the attending physician. Thus, bias may have been introduced. Additionally, interobserver and intraobserver error was not measured. Also, all TKAs were implanted by high-volume fellowship-trained total joint arthroplasty surgeons. Because cementless TKA may be considered to be more technically demanding [9] these results may not apply to surgeons who do not routinely use cementless TKAs and all surgeon practices. Furthermore, surgeon selection bias for cementless fixation may have influenced the results of this study.

Table 7
Cementless EMPOWR 3D Total Knee Arthroplasty Studies.

Author	Year	# TKAs	Follow-Up	Aseptic Revisions (%)	Aseptic Loosening (%)	Outcomes
Meding et al.[3]	2022	232	2 to 3.5 years	3 (1.2)	-	KOOS-JR 84.6[a]
Meding et al.[4]	2023	171	2 to 5 years	2 (1.2)	-	KOOS-JR 85.6[a]
Helvie et al.[2]	2023	134	1 to 7 years	2 (1.5)	1 (0.4) femoral	90% Satisfaction[b]
Patel et al.[24]	2024	196	1 to 7 years	5 (2.6)	2 (1) femoral	93% Satisfaction[b]
Current Study	2024	242	5 to 7.5 years	7 (2.5)	1 (0.4) femoral	91% Satisfaction[b]

TKA, total knee arthroplasty; KOOS-JR, knee injury and osteoarthritis outcome score for joint replacement.
[a] The average Knee Injury and Osteoarthritis Outcome Score for Joint Replacement score.
[b] Knee Society Satisfaction Score of Very Satisfied and Satisfied.

Historically, cementless TKA has been reserved for younger, more active patients who have adequate bone quality [2,48]. The authors recognize that indications for cementless TKA may be different among arthroplasty surgeons. Nevertheless, in this study, the decision to use cementless fixation was ultimately based on surgeon discretion and not a standardized protocol, which could have introduced preselection bias. Another potential limitation is that almost 20% of the patellae in this group of cementless TKAs were not resurfaced, and both cemented and cementless patella components were used. While only two extensor mechanism complications occurred in the study, both in patients who have resurfaced patellae, further follow-up is needed to determine whether those knees with unresurfaced patellae will eventually require resurfacing or whether further extensor mechanism complications will occur in TKAs with resurfaced patellae. In this study, resurfacing the patella was associated with greater patient satisfaction but lower UCLA activity scores. In a pooled analysis of 11 studies, patellar resurfacing reduced the risk of patellar dislocation and crepitation [55]. This finding may account for the difference in patient satisfaction between the two groups. Furthermore, in a case-controlled matching study comparing 166 TKAs performed without patellar resurfacing to 166 TKAs with patellar resurfacing, Schmidt et al. also found that the mean UCLA activity score was statistically lower in the resurfaced group at a mean of 2.1 years of follow-up [56]. Similar to Schmidt et al. [56], the decision to leave the patella unresurfaced was determined intraoperatively by the attending surgeon. Because the decision to resurface the patella was not standardized, this could have introduced bias as well. It is altogether possible that other patient variables explain the difference in the UCLA score. Finally, long-leg radiographs were not used to measure knee alignment and determine CPAK class. Rather, a 5° adjustment for the lateral distal femoral angle [40–46] was used. It is unknown whether these results would be the same if long-leg radiographs were used. However, because the same technique was used preoperatively and postoperatively, any potential difference in radiographic measurement between these 2 methods (long-leg or short-leg) would be the same, and mathematically, the percentage change in CPAK phenotype would be the same as well.

In conclusion, using this cementless conforming TKA design has provided excellent clinical results, including patient satisfaction, at a minimum of 5-year follow-up. The UC nature of this articulation does not appear to adversely influence initial component stability and the durability of implant fixation, regardless of whether the CPAK type was changed or not.

CRediT authorship contribution statement

John B. Meding: Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **R. Michael Meneghini:** Writing – review & editing, Supervision, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Lindsey K. Meding:** Writing – original draft, Resources, Methodology, Data curation. **Evan R. Deckard:** Writing – review & editing, Resources, Methodology, Investigation, Formal analysis. **Leonard T. Buller:** Writing – review & editing, Validation, Methodology, Formal analysis.

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