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Clinical Research

What Is the Likelihood of Union After Coronal Limb Realignment Using Revision Osteosynthesis and Concurrent TKA in Patients with Advanced Arthritis and Loss of Fixation After Distal Metaphyseal Femur Fractures?

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Abstract

Background Metaphyseal fracture healing in the distal femur requires a stable biomechanical environment. The presence of arthritis-induced coronal-plane knee deformities can cause deviation of the mechanical axis, which results in asymmetric loading and increased bending forces in fractures of the distal femur metaphysis. This predisposes patients to nonunions or loss of fixation. Concurrent TKA during revision osteosynthesis might facilitate fracture healing, owing to its ability to correct coronal alignment, thereby restoring normal loading patterns at the fracture site, but to our knowledge, this has not been studied.

Questions/purposes (1) Does TKA with concurrent revision internal fixation achieve fracture union in patients with coronal-plane deformity from knee arthritis and nonunion or loss of fixation in distal metaphyseal femoral fractures? (2) What is the survivorship and what are the short-term functional outcomes after these reconstructions? (3) What complications occur after these reconstructions?

Methods Between 2015 and 2018, one surgeon treated 16 patients with a distal metaphyseal femur fracture nonunion and/or loss of fixation using concurrent TKA plus revision internal fixation. Autologous iliac crest bone grafting was performed in five patients with evident gaps at the fracture site. The indications for the procedure included patients older than 55 years of age presenting with a nonunion and/or loss of fixation of a distal metaphyseal femur fracture in the setting of painful Ahlbäck Grade III to V knee arthritis with an associated coronal-plane deformity. All patients meeting these indications were treated with this approach during the study period. Fracture union assessed by radiological bridging of at least three cortices, TKA survival free from revision due to any reason, coronal-plane correction using tibiofemoral angle, and patient mobility status assessed presurgery and at follow-up using the Parker mobility score (scored 0-9 points, with 9 indicating best mobility) were assessed by two surgeons who were not involved in the care of the study patients. Immediate and delayed complications were recorded.

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Patients were followed for a minimum of 24 months. The median (range) follow-up was 38 months (27 to 52 months).

Results All fractures united after concurrent TKA plus revision internal fixation. In all, 14 of 16 fractures healed before 5 months, while the remaining two fractures united by 6 months. Survivorship analysis revealed a TKA component survival of 94% (95% CI 63% to 99%) at 52 months. The median (range) preoperative Parker mobility score of 5 points (3 to 8) improved to 7 points (2 to 9) at 12 months postoperatively and was maintained at last follow-up ($p = 0.001$). Four patients experienced complications; these were (1) prolonged surgical wound drainage resulting in debridement and polyethylene liner exchange, (2) deep knee infection needing a staged revision, (3) popliteal vein thrombosis, and (4) prolonged graft site pain.

Conclusion Concurrent TKA plus revision internal fixation is effective for achieving union in patients with distal metaphyseal femur nonunion and loss of fixation in the setting of coronal-plane deformity induced by knee arthritis. Short-term TKA survival and improvement in patient mobility are excellent, although 4 of 16 patients in this report experienced complications, as one might expect with a procedure of this magnitude. Based on our results, correction of arthritis-induced coronal-plane knee malalignment can be considered part of the surgical strategy when treating such distal metaphyseal femur nonunions. Better preoperative evaluation of the deformity and control-based comparative studies can further validate the utility of this technique.

Level of Evidence Level II, therapeutic study.

Introduction

Infraisthmal femoral fractures, especially those in the distal femoral metaphyseal region, are associated with a higher risk of nonunion after intramedullary nailing [26]. A short and wide distal segment leads to a reduction in the ratio of the nail diameter to intramedullary cavity, which compromises fixation stability in the distal fragment [17]. Knee arthritis can coexist in older patients who sustain such distal femoral shaft fractures. In this setting, mechanical axis deviation that results from the arthritis-induced coronal-plane knee deformity might influence postoperative fracture alignment, construct stability, and subsequent loading patterns at the fracture site. In some instances, severe coronal-plane deformities can make successful intramedullary nailing difficult without deformity correction (Fig. 1). These factors might also compromise fixation and impose eccentric loads at the fracture site, conceivably leading to a higher risk of loss of fixation or nonunion after internal fixation of these distal femur metaphyseal fractures.

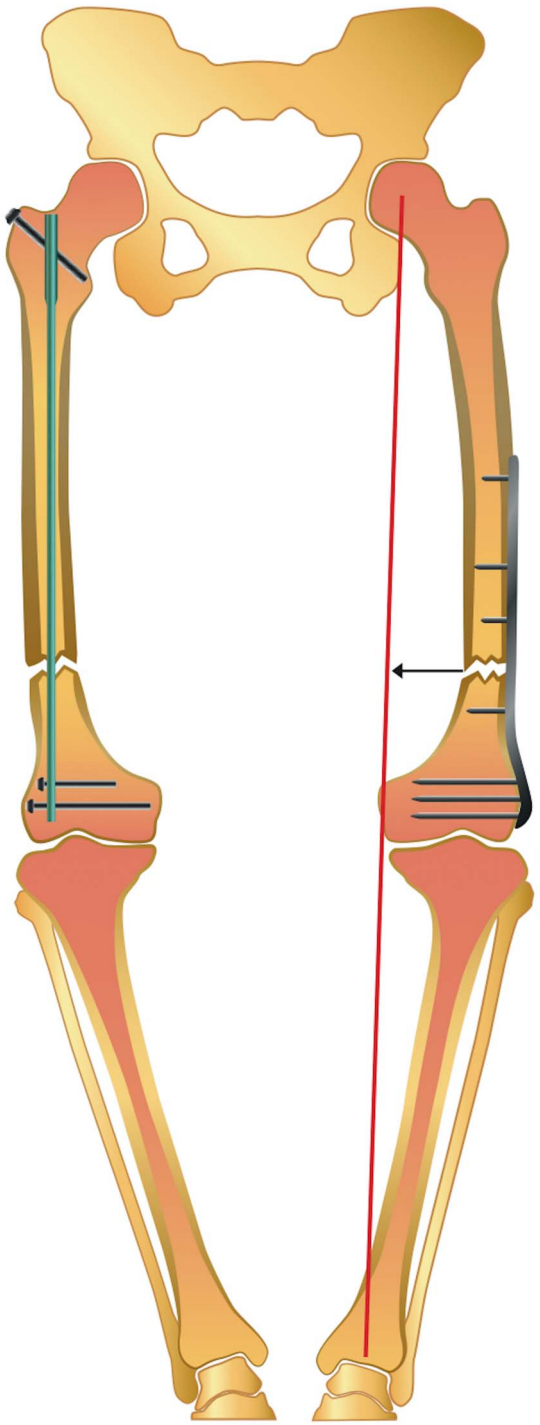

Fig. 1 This diagram shows the effects of a varus arthritic knee on a distal metaphyseal femur fracture. A coronal-plane deformity at the knee can interfere with centering a straight and rigid intramedullary nail, compromising alignment and stability at the fracture site (right femur). In a varus knee with a fracture above, a locked plate positioned on the lateral aspect will be subjected to tremendous bending forces on the medial side and a long lever arm created by the mechanical axis deviation (left femur).

Very distal femoral periarticular nonunions can be successfully treated using endoprosthetic reconstructions in patients with advanced knee arthritis [9, 25]. The technique has been used even in older patients with primary articular fractures of the distal femur without arthritis [5,19] to restore mobility and knee function. But more-proximal metaphyseal nonunions may not be a good indication for endoprosthetic reconstruction. We wondered whether correcting an arthritis-induced coronal knee deformity with concurrent TKA in patients with painful advanced arthritis during revision internal fixation would result in a high likelihood of union, good TKA survivorship, and a low enough complication risk that a surgeon can feel justified offering this option to his or her patients.

We therefore asked: (1) Does TKA with concurrent revision internal fixation achieve fracture union in patients with coronal-plane deformity from knee arthritis and nonunion or loss of fixation in distal metaphyseal femoral fractures? (2) What is the survivorship and what are the short-term functional outcomes after these reconstructions? (3) What complications occur after these reconstructions?

Patients and Methods

Study Design and Setting

This was a prospective study. All procedures were performed by one surgeon (ASG) at three tertiary-care institutions between February 2015 and January 2018. Informed consent was obtained from all patients for their participation.

Participants

During the study period, we treated 16 patients with a distal metaphyseal femur nonunion and/or loss of fixation using a technique of concurrent TKA plus revision internal fixation. During that time, the indications for this procedure were patients older than 55 years presenting with an ununited femur fracture located distal to the middle and distal one-third junction and proximal to the femoral condyles (Fig. 2) in the setting of a coexistent varus or valgus knee deformity due to painful bone-on-bone arthritis classified as Grade III to V according to Ahlbäck grading system [1]. We screened 22 patients during this period for possible inclusion in the study. Six patients were excluded: three for infection at the fracture site, two patients were not willing to participate, and one patient had a pathological fracture due to Paget disease. All 16 patients who met those indications were treated with this approach during the study period, and all were enrolled and followed prospectively in this series. The median (range) age was 64 years (56 to 75 years). There were 11 females and 5 males. The median BMI was 28 kg/m^2 (20 to 36 kg/m^2). The

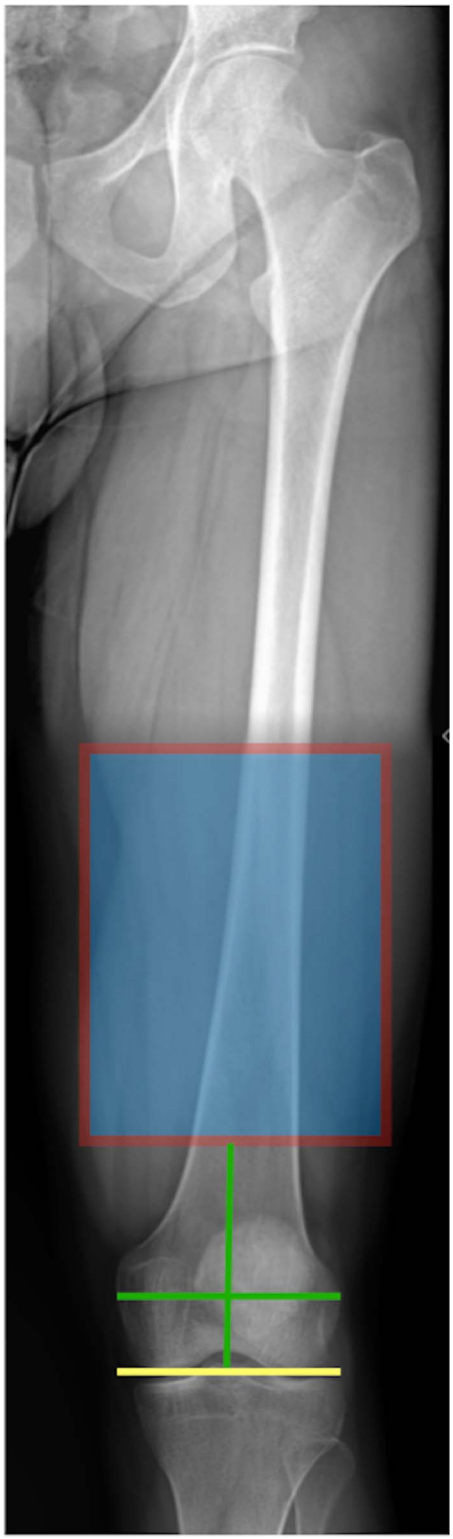

Fig. 2 Fractures included in the study (blue-shaded zone) extend from the infraisthmal region proximally and the distal limit defined by a vertical line subtended from the distal joint line, the length of which equals the width of the widest portion of the femoral condyles.

minimum follow-up was 2 years (median 38 months [27 to 52 months]). Except for one deceased patient, the remaining 15 patients were available for follow-up (Table 1).

Preoperative Evaluation

Standard preoperative AP and lateral radiographs of the femur, including the knee, were obtained. Radiographs were used to document the unhealed fracture with or without implant fracture, location of the fracture, and type of internal fixation used. Arthritic changes in the knee were graded according to the Ahlbäck system, and the tibiofemoral angle was calculated to assess the degree of coronal-plane deformity. As most patients were not able to bear weight during presentation, the tibiofemoral angle was calculated on the AP non-weightbearing knee radiographs using the conventional technique described previously [8, 22]. The midpoint of the tibial spines and points midway between the medial and lateral cortices 10 cm above (femur) and below the tibial spine (tibia) were used as reference points for calculation of the tibiofemoral angle [12]. The preoperative infection work-up included: (1) documenting any history of wound healing problems with the prior fracture surgery; (2) assessing clinical signs such as presence of fever, swelling, redness, or sinus at the fracture site; and (3) obtaining a C-reactive protein value

Table 1. Patient data

Number	Age/sex	ASA grade	Initial failed surgeries	Preoperative TFA	Postoperative TFA	Follow-up in months	Prosthesis	Remarks
1	65/M	II	Antegrade nail	172°	178°	47	CR	Iliac crest bone grafting
2	60/F	III	DFLCP Delayed bone grafting	170°	177°	52	CR	
3	69/F	II	DFLCP	168°	177°	50	CR	Iliac crest bone grafting Donor site pain
4	71/F	II	IMSC nail	170°	179°	47	CR	
5	65/M	I	Antegrade nail Dynamization + bone grafting	165°	180°	45	CS	RIA bone grafting
6	63/F	II	DFLCP	162°	178°	43	CS	
7	75/M	III	Antegrade nail	170°	178°	40	CR	Proximal DVT
8	63/F	I	Antegrade nail Delayed bone grafting	172°	176°	38	CR	
9	68/F	II	DFLCP	168°	177°	38	CR	
10	62/F	II	DFLCP	166°	179°		CS	Iliac crest bone grafting
11	70/M	III	Antegrade nail Dynamization	170°	177°	35	CR	
12	58/F	I	IMSC nail	173°	175°	33	CR	
13	56/F	II	DFLCP revision DFLCP + bone grafting	170°	178°	33	CR	RIA bone grafting Delayed infection Died
14	62/M	II	DFLCP	171°	176°	30	CR	
15	68/F	I	DFLCP	167°	177°	30	CR	Wound drainage underwent DAIR + polyethylene exchange
16	61/F	II	Antegrade nail	192°	184°	27	CS	Rheumatoid; limited assisted mobility

ASA grade = American Society of Anesthesiologist's physical status classification; TFA = tibiofemoral angle; CR = cruciate retaining; CS = cruciate substituting; DFLCP = distal femur locked compression plate; IMSC = intramedullary supracondylar; RIA = Reamer Irrigator Aspirator (Depuy Synthes); DVT = deep vein thrombosis; DAIR = debridement, antibiotics, and implant retention.

(> 10 mg/L was considered abnormal). A preoperative functional assessment was performed to evaluate patient mobility using the validated [16] Parker mobility score, scored from 0 to 9 points, with 9 indicating the best possible mobility [18]. During presentation, 14 patients were unable to bear weight because of loss of fixation; these patients were asked to record their mobility levels before loss of fixation occurred.

Surgical Technique

The surgeon removed the implants using appropriate exposures, and then the surgeon exposed and debrided the fracture site. The knee was exposed through a medial parapatellar arthrotomy in all patients. In select patients, the surgeon exposed the nonunion site through the same incision. The tibia-first hybrid technique [23] was used to perform TKA. A cruciate-retaining femoral component (PFC, DePuy Synthes) was used in all patients. A cruciate-retaining polyethylene insert was used in 12 patients. In the remaining four patients, a cruciate-substituting deep dish ultra-congruent polyethylene insert was used since the PCL was released to balance the flexion and extension gaps. Before making the entry for an intramedullary rod in the femur, the surgeon debrided and reduced the fracture. A guide rod was then passed proximal to the fracture site beyond the isthmus, and alignment at the fracture site was confirmed with fluoroscopy in both coronal and sagittal planes before the distal femur cut was made. The surgeon left an intramedullary guide rod inside just proximal to the cut surface of the distal femur to keep the fracture reduced and help complete the other femoral cuts and ligamentous releases. At this point, the surgeon used fluoroscopy to confirm femoral rotation using the lesser trochanter profile compared with the opposite side. Once confirmed, this was marked using diathermy on the anterior cortex proximal and distal to the nonunion. Femoral component rotation in TKA was then set by using the cut proximal tibial surface as a reference to establish a rectangular flexion gap and was confirmed further with the transepicondylar axis.

Once the cuts were completed and the knee was tested for stability, alignment, and balance, the surgeon reamed the femur and inserted an appropriately sized retrograde femur nail (Trigen, Smith and Nephew) and locked it on both sides. Before inserting the nail, the surgeon ensured that the distal end of the nail was well centered on the central cutout of the femoral component. This makes the proximal nail threads completely accessible for removal if needed in the future, without interference with the femoral component. The knee was brought into hyperflexion, cut surfaces were prepared for cementing, and the final components were cemented in place. During cementing, care was taken to avoid cement intrusion into the nail threads. Bone grafts were used only when there was no circumferential bony contact at the fracture site. For bone grafting, the cancellous bone from the cut surfaces of the knee during TKA was used. Additional grafts (when the surgeon felt more graft material was needed) were harvested either from the iliac crest or the femur using a Reamer Irrigator Aspirator (Depuy Synthes). Five patients underwent bone grafting: three from the iliac crest and two from the femur. The median (range) time between the first surgical procedure and revision open reduction and internal fixation with TKA was 5 months (2 to 11 months).

Rehabilitation and Follow-up Evaluation

Postoperatively, patients were mobilized the day after surgery. Knee ROM, quadriceps exercises, and weight-bearing as tolerated with a walker or crutches were allowed. Pharmacologic prophylaxis for deep vein thrombosis was administered using low-molecular-weight heparin during the hospital stay, followed by oral apixaban for 2 weeks. The length of hospital stay and blood transfusions were recorded. Patients were discharged after effective pain relief was achieved, active limb control was regained, and after they were able to independently walk and perform toilet activities using assistive devices. Patients were weaned from assistive walking devices after radiologic evidence of fracture union was documented. Postoperative outpatient visits were performed at 6 weekly intervals until fracture union, then at 12 months, and then annually thereafter. The tibiofemoral angle was measured on standard AP knee radiographs to measure the coronal-plane alignment postoperatively. Functional evaluations were performed at 3 and 12 months postoperatively and at the final follow-up after a minimum of 2 years using the Parker mobility score.

Ethical Approval

Ethical approval was obtained from Parvathy Hospital, Chennai, India, before the first patient having surgery (ref. ECR/1276/Inst/TN/2015/0037).

Statistical Analysis

We performed the statistical analysis using Statplus pro for Mac (version 5.4, Analystsoft Inc). All data analyzed were continuous and were presented as median (range). We used the Wilcoxon signed-rank test to compare medians of tibiofemoral angle and Parker mobility scores before and after surgery. A p value of 0.05 was considered significant.

A survival analysis of TKA components was performed using a Kaplan-Meier survivorship curve at the time of last follow-up assessment (52 months after the start of the study). Revision due to any reason was the endpoint, with revision defined as removal of all TKA components and implantation of new components.

Results

Fracture Union and Radiographic Findings

ptFracture union was achieved in all patients (Fig. 3). Overall, 14 fractures united before 5 months and the remaining two united by 6 months. No secondary interventions were performed to augment fracture healing. The median (range) preoperative tibiofemoral angle was 170° (162° to 192°), which improved to 177° (175° to 184°) postoperatively (difference of medians, 7°; $p < 0.001$). All TKA components appeared well fixed without any signs of loosening (Fig. 4).

TKA Component Survival and Mobility Scores

The Kaplan-Meier survivorship analysis showed a survivorship of 94% (95% CI 63% to 99%) for the TKA at 52 months, with revision for any reason as the endpoint (Fig. 5). The median (range) Parker mobility score improved from 5 points (3 to 8) preoperatively to 7 points (2 to 9) at 12 months ($p = 0.001$), which was maintained at most recent follow-up (Fig. 6). At the most recent assessment, 14 patients were independent in their activities of daily living; 12 patients could ambulate in the community without any assistive aids, and two patients used a walking stick to ambulate outside the home. One patient with fulminant rheumatoid arthritis was mostly homebound and needed the assistance of another person to ambulate.

Complications

No systemic complications were seen after surgery during the hospital stay. Six of 16 patients had autologous blood transfusions. Four patients had complications, three of which were considered serious. One patient with prolonged wound drainage underwent debridement and polyethylene insert exchange 10 days after surgery, although her intraoperative culture results did not demonstrate any bacterial growth. Her wound healed uneventfully after debridement and cessation of deep vein thrombosis prophylaxis. One patient with uncontrolled diabetes who had two prior attempts at internal fixation experienced delayed deep knee infection after an episode of cellulitis at 14 months postoperatively and planned to undergo two-stage revision arthroplasty. She underwent nail and prosthesis removal and application of an antibiotic-loaded cement spacer. However, she died of pulmonary embolism 9 days after the first stage of the procedure. One patient developed symptomatic popliteal vein deep vein thrombosis at 4 weeks postoperatively, and this patient was treated with long-term anticoagulation

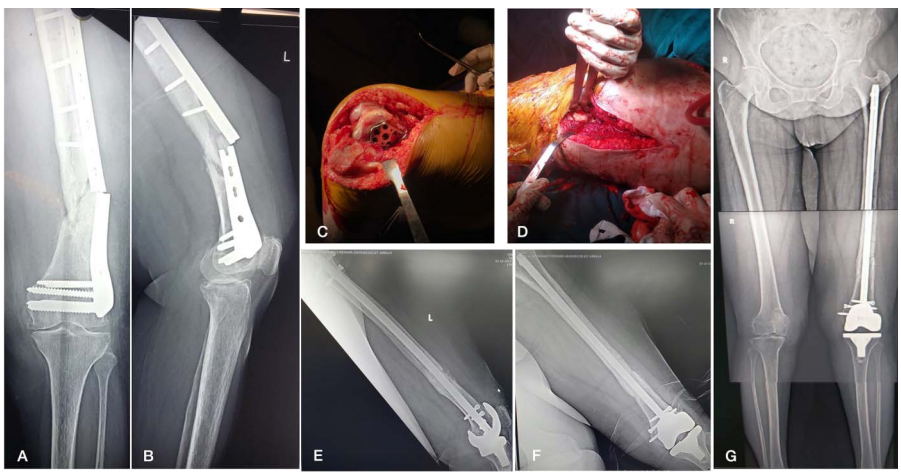

Fig. 3 A-G (**A**) An AP radiograph from a 63-year-old woman with distal femur metaphyseal nonunion and Grade IV medial compartment arthritis. (**B**) Lateral radiograph of the same patient with the broken implant. (**C**) Standard midline exposure for TKA. (**D**) Exposure of the nonunion site through a separate lateral incision. (**E**) Lateral follow-up radiograph showing the healed fracture. (**F**) AP radiograph of the healed fracture and the well-aligned TKA. (**G**) Long leg radiograph showing a healed fracture with restoration of length and alignment.

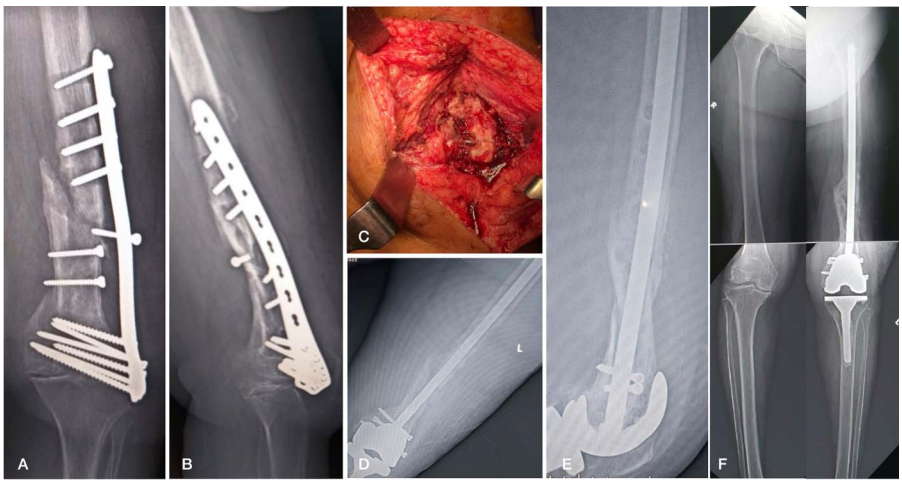

Fig. 4 A-F (**A**) AP radiograph from a 56-year-old woman with loss of fixation after the second attempt at osteosynthesis of a distal metaphyseal femur fracture. (**B**) Lateral radiograph showing the same with advanced arthritic changes at the knee. (**C**) An intraoperative image shows the extent of joint damage and screws in the patellofemoral joint. (**D**) Follow-up AP radiograph shows a well-healed fracture. (**E**) Lateral radiograph after healing. (**F**) Long leg radiograph shows the well-functioning TKA and improved coronal alignment.

therapy. The fourth patient had persistent pain at the iliac crest for up to 9 months after bone grafting. The median (range) length of hospital stay was 7 days (5 to 10).

Discussion

Infraisthmal femur fractures have a higher nonunion risk after conventional intramedullary nailing since the wide flare of the medullary cavity below the isthmus compromises the ability to achieve sufficient control, reduction, and rotational stability of the distal fragment [17, 26]. Presence of a coronal-plane deformity (varus or valgus) because of associated knee arthritis in such patients can accentuate these problems. These deformities result in mechanical axis deviation, which may alter loading patterns at the fracture site and produce increased stresses on the implant, predisposing patients to nonunion and/or loss of fixation [Fig. 7]. Since to our knowledge this has not been studied before, we wanted to determine whether correction of coexistent coronal-plane knee deformities using a TKA during revision osteosynthesis would result in a high likelihood of union in such fractures after initial unsuccessful attempts at internal fixation. In this small series, patients achieved reliable union when the knee deformity was simultaneously corrected during revision internal fixation. We accomplished this in most patients without the use of additional bone grafting and with high short-term survivorship of the TKAs. We note that 4 of 16 patients in this series experienced complications, as one might expect from an intervention of this magnitude.

Limitations

Our study has some limitations. The study had a sample size of only 16 patients spread over 3 years at three centers. With such small numbers, it is likely that other complications can follow this procedure that were not observed here. Also, such a small sample made it impossible to compare patient factors associated with particular endpoints of interest, such as time to union. Still, the main finding here seems robust, which is that this approach yields consistent union and good functional scores in patients who have a problem that is difficult to treat. We had a minimum follow-up duration of only 2 years; it is possible, if not likely, that some of these patients may yet present with serious complications, such as infection. We did not have a control group, which would have allowed us to test the question of whether restoring coronal limb alignment improves the likelihood of fracture healing. Since most patients were unable to bear weight, preoperative tibiofemoral angle measurements were performed on standard nonweightbearing AP knee radiographs. This may not have been entirely accurate and may have underestimated the knee deformity compared with what might have been observed had weightbearing long leg radiographs been obtained [4]. Our protocol also did not evaluate the amount of sagittal plane deformity at the knee and coronal-plane deformity at the fracture site as well as other locations such as the proximal tibia. Although these are serious limitations in our preoperative evaluation, we believe they do not disqualify the main findings of this report.

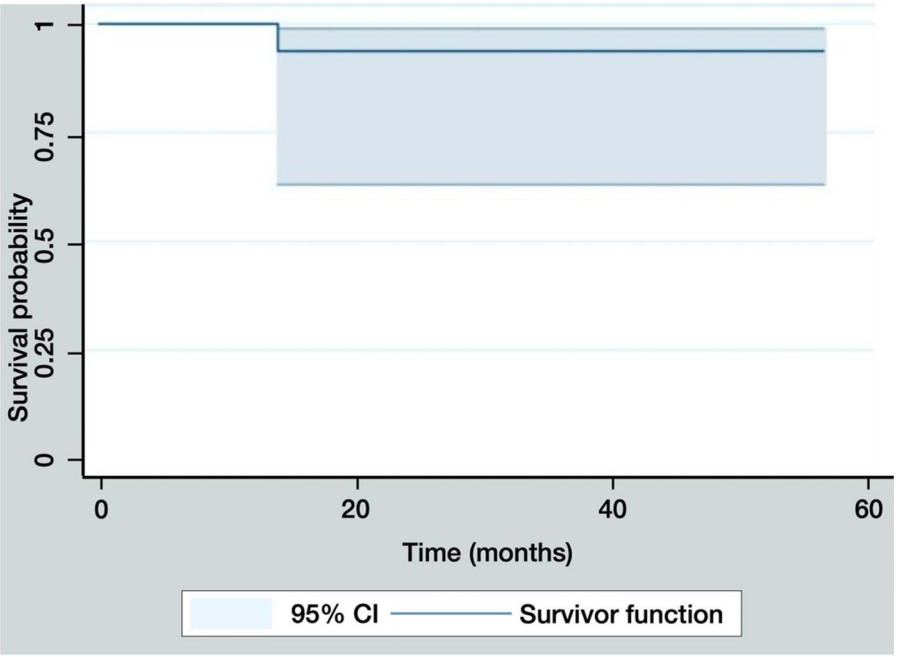

Fig. 5 This Kaplan-Meier survivorship curve for TKA shows one patient who underwent revision at 14 months, with overall survival of 94% (95% CI 63% to 99%) and revision as the endpoint.

Fracture Union and Radiographic Findings

Union was consistently achieved in this small series, and most patients were united by 5 months after the reconstruction. Correcting the coronal-plane knee deformity with TKA and restoration of the anatomical femorotibial alignment moves the mechanical weight transmission axis closer and more axially in line with the fracture. This may help improve loading patterns at the fracture site by subjecting the fracture to more axial loads compared with bending and shearing forces, although our study did not evaluate biomechanics and cannot offer conclusions about the mechanisms behind the observed findings. All patients treated with the approach in our series healed without further interventions, which might emphasize the possible role for improving coronal alignment in treating such nonunions and/or loss of fixation. Even though the location of the deformity was away from the nonunion site, correction of such deformity can help restore the overall limb alignment, which is one of the important facets in treatment of lower limb meta-diaphyseal nonunions. Even with improved coronal limb alignment, it is still imperative to provide sufficient stability at the fracture site for the fracture to heal. Intramedullary nails positioned along the weightbearing axis resist bending loads better compared with an eccentrically located plate [7]. The intramedullary nail used in our study has provision for three angle-stable locking options in the distal fragment located in multiple planes to provide enhanced fixation stability [6, 11].

TKA Component Survival and Mobility Scores

Survivorship in this series was 94% (95% CI 63% to 99%) at 52 months, with revision as the endpoint. Only one prosthesis was scheduled for revision in our series (because of infection). Previous authors have reported TKA with long custom stems to address distal femoral nonunions with adequate bone stock in the distal fragment [10, 15]. Kress et al. [15] reported the technique of TKA using custom long, press-fit stems in nine patients with different indications. Two of their nine patients had supracondylar femur nonunions above an arthritic knee. They reported fracture union in both patients and good knee function at a median (range) follow-up of 3 years (1 to 5 years). However, both patients experienced complications (patella fracture in one patient and superficial wound infection in the other); in addition, there was a delay of 4 weeks to procure the custom stems in that series. Although this technique could have been used in some of our patients, we still believe the approach of using TKA plus a long retrograde intramedullary (IM) nail was more suitable in our patients for several reasons. First, using a long IM nail independent of the prosthesis allows a simpler arthroplasty procedure using a primary (cruciate-retaining or cruciate-substituting) implant. This preserves distal femoral bone stock and avoids constraint, thereby improving component survival; it also allows for easier revision. Second, our approach also

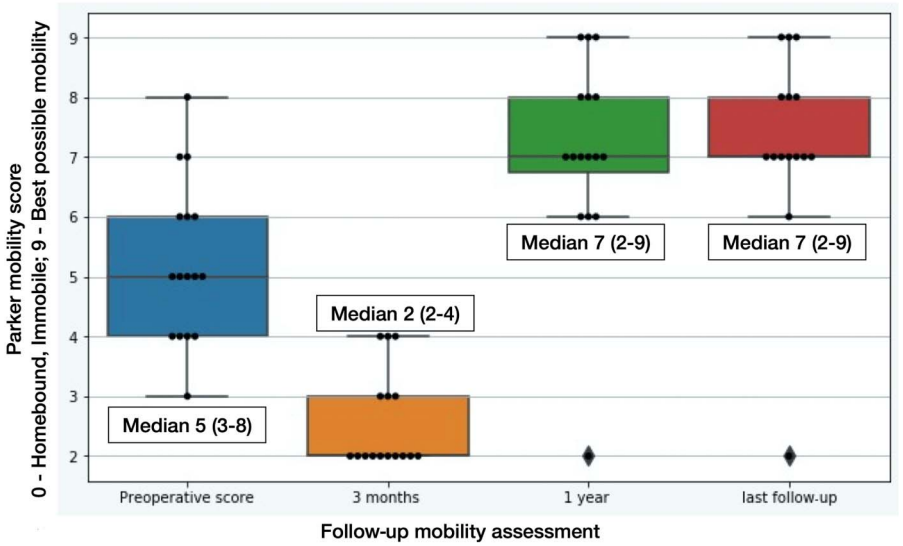

Fig. 6 This graph shows preoperative and postoperative Parker mobility scores. The 12-month follow-up score was improved compared with the preoperative score. This was maintained at the last follow-up visit.

avoids the use of longer custom stems, which add cost, may delay care, and are associated with higher risk of revision than are primary (cruciate-retaining or cruciate-substituting implants [2]. Finally, our approach avoids diaphyseal stress risers with longer stems, which may be an important factor in preventing periprosthetic fractures, especially in osteoporotic patients. The Parker mobility scores at 3 months showed assisted independence in activities of daily living for most patients in this small series. Once fracture union was achieved by 5 to 6 months, improvement in mobility scores were more robust, as evident by scores at 12 months follow-up, which then plateaued. At final follow-up, 14 of 15 patients were able to ambulate in the community, indicating the functional effectiveness of the procedure.

Complications

As one would expect in large reconstructions in older patients who have had prior surgery, major complications were common, occurring in 4 of 16 patients in this series, two of whom underwent repeat surgery. The procedure was generally well tolerated, and patients participated in early rehabilitation, but the median hospital stay, time to independent weightbearing, and transfusion usage were

Fig. 7 A-D (**A**) An AP radiograph showing a nonunion and Grade V arthritic changes at the knee of a female with rheumatoid arthritis. (**B**) AP femur radiograph showing the associated arthritic changes and protrusion at the hip. (**C**) An AP follow-up radiograph showing restoration of alignment and healing after concurrent TKA plus revision open reduction and internal fixation. (**D**) Lateral radiograph showing the healed fracture.

higher in our series compared with published reports of patients who undergo primary TKA alone [3, 13]. Deep infection was observed in 1 of 16 patients, which seems high compared with the frequency of that event reported with primary TKA performed for arthritic conditions [14]. We note, though, that the reported incidence of deep knee infection generally is higher for posttraumatic conditions and in patients with history of previous fracture fixation [23]. Saleh et al. [21] reported that 13.4% of patients developed deep infection in their systematic review from a cohort of 520 patients with posttraumatic arthritis; our findings likely are more in line with that series, as one might expect, rather than those reporting on uncomplicated primary TKA.

Conclusion

We found that in the setting of arthritis-induced coronal-plane deformity at the knee, our approach of treating distal femoral metaphyseal nonunion and loss of fixation with concurrent TKA plus revision internal fixation achieved fracture healing, although 4 of 16 patients in this report experienced complications. Further studies with more patients, a control group, and better preoperative deformity assessment techniques are needed to validate our results.

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