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Knee Arthrodesis as Limb Salvage for Complex Failures of Total Knee Arthroplasty

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ABSTRACT

Patients with multiple failures of total knee arthroplasty (TKA) are challenging limb salvage cases. Twenty one patients over the last 10 years were referred to our service for knee fusion by arthroplasty surgeons who felt they were not candidates for revision TKA. Active infection was present in 76.2% and total bone loss averaged 6.6 cm. Lengthening was performed in 7/22 patients. Total time in Ilizarov frames was 9 months, with 93.3% union. Patients treated with IM fusion nails had 100% union. Average LLD increased from 3.6 to 4.5 cm following intervention, while those with concurrent lengthening improved to 1.6 cm. Findings suggest that bone loss and the soft-tissue envelope dictate knee fusion method, and multiple techniques may be needed. A treatment algorithm is presented.

Revision total knee arthroplasty (TKA) has been increasingly utilized in limb salvage for younger patients, particularly after significant trauma, neoplasm resection, or protracted sepsis [1,2]. However, patients with multiple failures of TKA often have significant bone loss, recalcitrant infection, extensor mechanism loss or wound problems that present a complicated surgical picture, making a revision TKA difficult or impossible [3–6]. Further, post-operative infection remains a challenge, commonly requiring multiple procedures to manage [7]. In these cases above-knee amputation has been offered to the patient as a definitive solution. However, knee arthrodesis has been shown to have better outcomes than above-knee amputation with respect to gait, patient satisfaction and overall energy expenditure [8,9].

A myriad of techniques have been proposed for knee arthrodesis in the complicated setting. Ilizarov external fixation, intramedullary fusion nails, internal fixation, or various combinations thereof have all been employed with success [3,5,7,10,11]. While no consensus surgical standard has been established, there appears to be specific indications for one operative technique over another—such as the utility of Ilizarov fixation in patients who would benefit from simultaneous limb lengthening [12]. However, Van Rensch et al conclude in their retrospective analysis that an individualized approach is equally important to proper patient selection [13].

Here we review our experience with knee arthrodesis for limb salvage after failed TKA. In our practice we utilize an individualized approach that has evolved over the last decade, and includes external fixation, intramedullary (IM) nails, antibiotic coated IM nails, bone lengthening, and prophylactic percutaneous plate stabilization. In assessing our outcomes we sought to (1) use our own clinical outcomes to justify knee arthrodesis as a viable limb salvage procedure; and (2) propose an algorithm for managing a failed TKA, particularly in patients with large bone loss, recalcitrant infection or a poor soft-tissue envelope.

Methods and Materials

We performed an institutional review board-approved retrospective cohort analysis of all 21 patients who had undergone knee arthrodesis for failed TKA at our institution from January 2001 to December 2012. Patients who underwent knee arthrodesis for other indications such as post-trauma and arthrofibrosis were excluded. Average patient age was 66.9 years (SD ± 14.6) and BMI was 31.4 (SD ± 7.0). Follow-up was 42 months (range 22–120). All patients were referred to our service by fellowship-trained arthroplasty surgeons who felt that the patient was not a candidate for a revision TKA. Demographics and comorbidities, existence of active infection, limb-length discrepancy (LLD), and bone loss were recorded (Table 1). Ten patients were referred due to a prior explantation, 1 due to arthrofibrosis, 2 for significant skin compromise, and 8 for active infection. Eight patients had undergone arthroplasty revision prior to referral. All surgeries were performed by the senior author (SRR) using Ilizarov and internal fixation techniques. Data were

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Table 1
Demographic and Indications.

Age	66.85 years (±SD 14.59)
Gender	10 M, 11 F
BMI	31.43 (±6.97)
Side	13 R; 8 L
Smoker	2/21
Diabetic (DM1 or DM2)	4/21
Active infection	16/21
Measured bone loss on presentation (anticipated bone defect after explantation)	3.55 cm (±SD 1.71)
Measured LLD on presentation	3.19 cm (±SD 2.83)
Total bone loss (LLD + bone defect after explantation and debridement)	6.6 cm (±SD 2.8)
Prior knee arthroplasties	20/21 (3 with 2nd attempts)
Total number of prior surgeries	2.33 (±SD 0.80)

Table 2
Procedures Performed and Post-Op Ambulation.

Fusion methods	16 Ilizarov (2 later converted to IM Rod) 5 IM Rod
Fusion docking	14 acute, 7 gradual
Lengthening performed	7/21
Fusion position	3.89° flexion (±SD 8.71)
Post-op ambulation	20 WBAT, 1 PWB

prospectively collected but analyzed retrospectively from radiographs, hospital records and office notes. Fusion methods, lengthening procedures, fusion position, and ambulatory status were documented (Table 2).

Surgical methods varied, but all patients underwent explantation of a knee arthroplasty at or prior to the time of fusion. Some patients presented to us with a cement spacer or with a resection arthroplasty. Once explanted, patients were evaluated for soft-tissue compromise, bone loss, and the presence of infection. Bone was recut to create fresh bleeding surfaces and to align the knee to a femorotibial angle of 5° of anatomic valgus in the coronal plane and 10° of flexion. Once the appropriate alignment was obtained the bone surfaces were opposed and held together temporarily with Kirschner wires. Ilizarov external fixation was then used to obtain stabilization of the knee fusions (Fig. 1A,B). If the gap between the femur and tibia was too large, or the soft-tissue envelope would not allow direct bone contact, gradual docking of the surfaces was performed using the Ilizarov method (Fig. 2A,C). The soft tissue envelope is the limiting factor. Acute shortening of a large bone defect can lead to the loss of a palpable pulse and/or distortion of the soft tissue envelope such that primary closure is not possible. A longitudinal incision distorts into the shape of a diamond with acute shortening, making closure difficult. When using a frame, our strategy is to close the wound without shortening and then to acutely shorten as much as is tolerated. We usually can do some acute shortening and the remainder is then done gradually. In a subset of patients, separate bone lengthening procedures were done using Ilizarov frames in the femur, tibia or both (Fig. 3A–E). Indications for use of a frame were an inability to acutely shorten the bone defect, THR above excluding the ability to use an IM nail, or a desire to lengthen the lower extremity during the same treatment.

In some circumstances antibiotic coated locked IM nails were utilized (Fig. 4A,B) [14]. The patients with IM fusion nails had minimal bone loss, a native hip joint and good soft-tissue envelope. Acute shortening of the bone defect was possible while still maintaining the

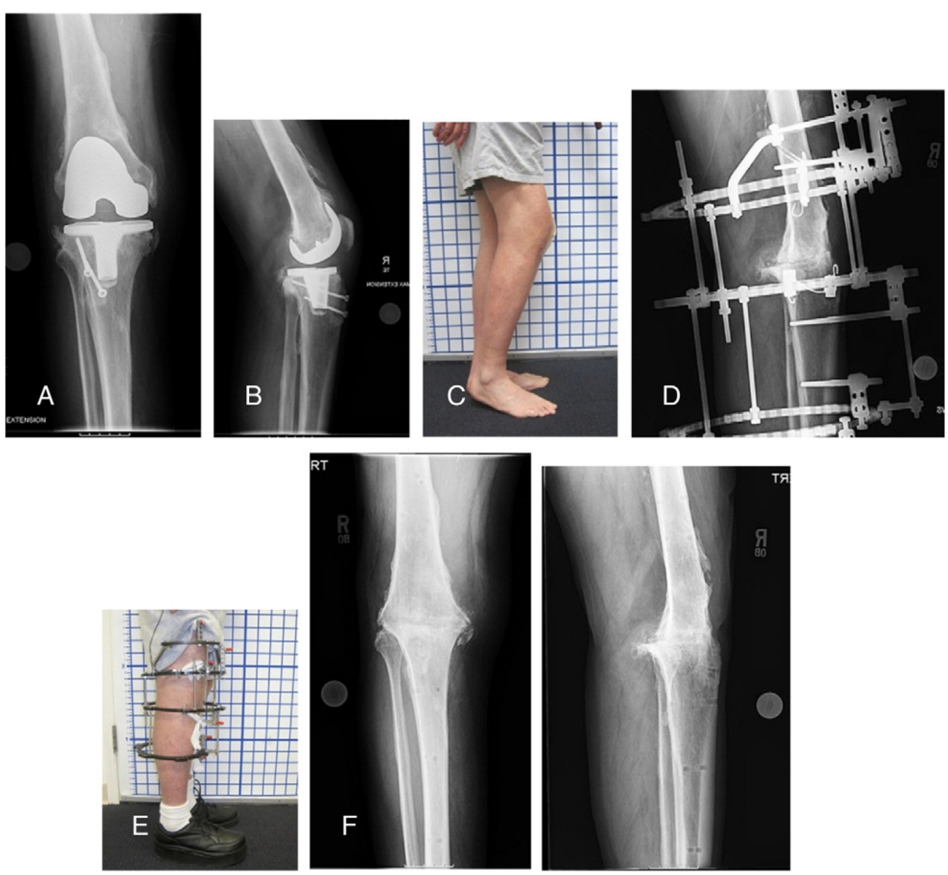

Fig. 1. (A)–(C) 80 year old male with infected TKA, arthrofibrosis, and extensor mechanism insufficiency. (D) and (E) After explantation and fusion in single stage surgery with circular frame. Good bone stock present as no revision TKA done. (F) Healed fusion in 10° flexion at 12 months. LLD managed with 1 inch shoe lift.

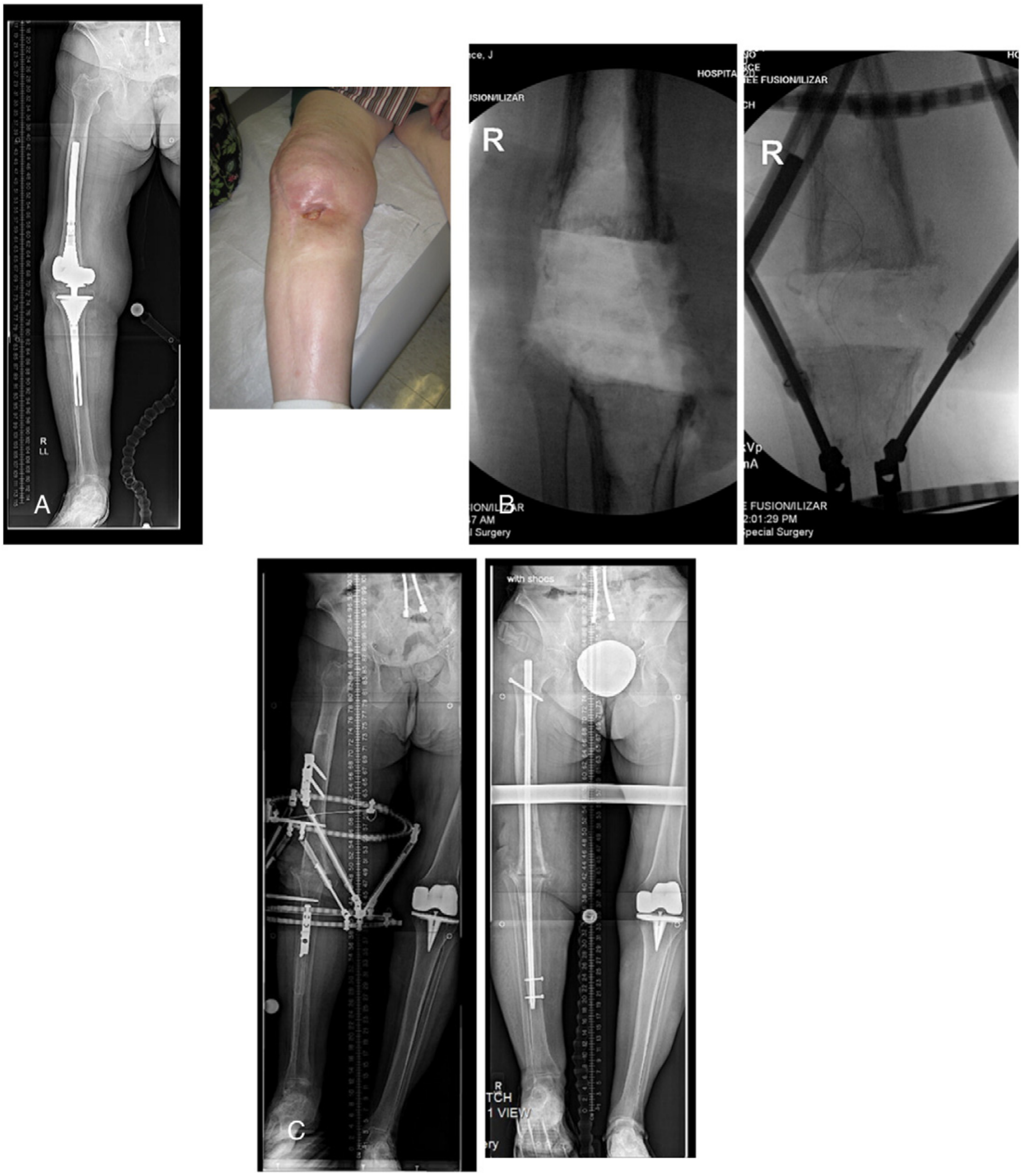

Fig. 2. (A) 85 year old woman with recurrent infection and draining sinus after 3 failed TKAs. (B) Note 6.5 cm defect on left. With skin closed primarily and circular frame applied, acute shortening of half of the defect is possible. (C) Gradual shortening of defect is done over 2 weeks until docking is achieved. A few weeks later, an antibiotic coated IM nail is inserted and frame is removed. Full union is achieved, and the patient walks full weight-bearing without any pain or sign of loosening or hardware failure.

ability to primarily close the wound. In general limb lengthening was not a goal, although it could still be done at a later time after knee fusion bone healing.

In some cases, internal fixation was used in a staged fashion after the use of a frame (Fig. 3D,E). IM nail or percutaneous plating techniques were used after re-fracture of the knee fusion or as a prophylactic measure to prevent fracture. In those patients who required plating, narrow large fragment locking plates with 5 mm locking screws were used in neutral mode. The criss-cross screws were 6.5 mm compression screws and were inserted before the plate.

Post-operatively patients were allowed to bear weight as tolerated after docking of the femorotibial bone defect. Those patients who required a frame presented to the clinic every 2 weeks during docking and then monthly once docking was complete. Infection was assessed with surgical site cultures. Bone docking and fusion progression were assessed with plain film radiographs at each visit.

Ilizarov frames were removed via determination of a healed fusion based upon X-ray evidence of 3 of 4 healed cortices and clinical assessment. Patients were then placed in long-leg casts for 2–6 weeks to avoid re-fracture. Outpatient physical therapy and gait training were provided following cast removal. Shoe lifts were frequently prescribed to accommodate leg length discrepancies in those patients who did not undergo additional bone lengthening. The LLD goal after knee fusion was considered 1.5 cm for optimal gait [15]. All patients were followed for a minimum of 2 years, after which an outcome was considered final.

Statistical analysis was performed using GraphPad Prism 5.0 (LaJolla, CA). As this was a single cohort study, patients were stratified based upon surgical stabilization and the need for concurrent limb lengthening. As the diversity of these groups prevented intragroup testing, only means and standard deviations were calculated for all groups.

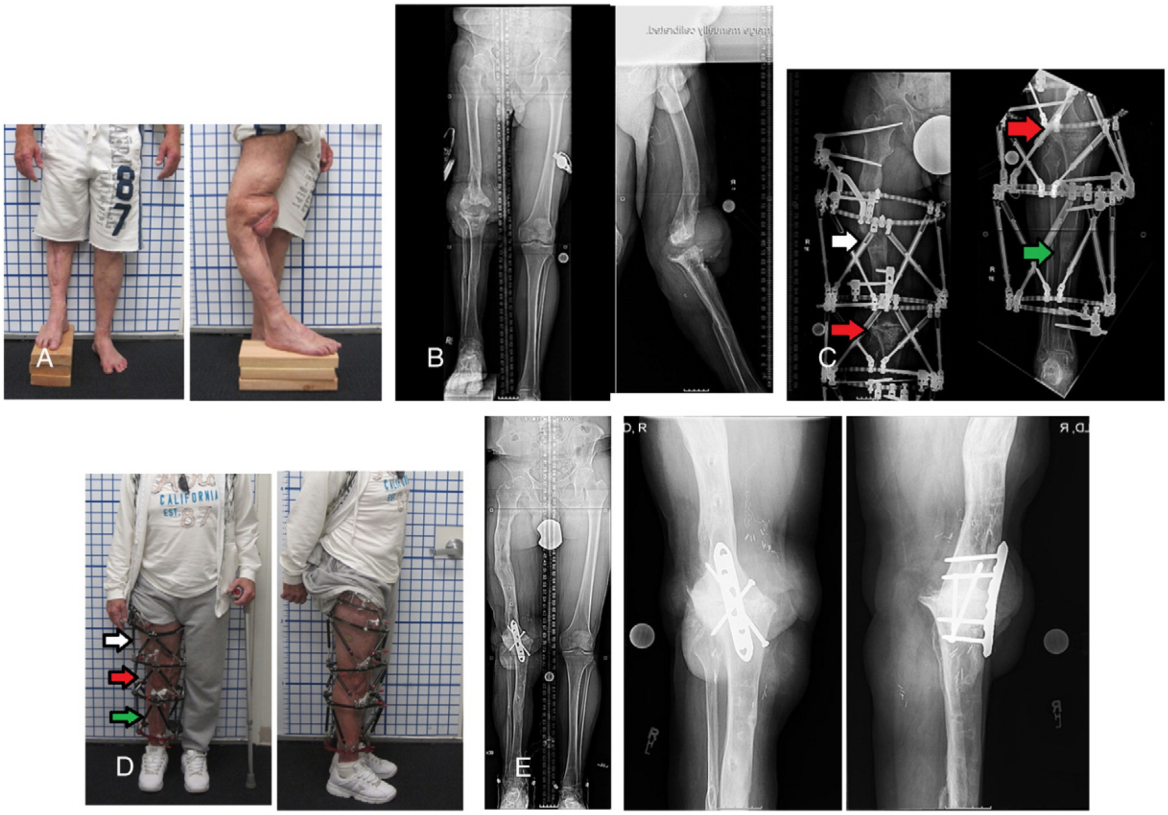

Fig. 3. (A) and (B) 42 year old male after trauma and 3 failed TKAs now with 6 inches of LLD and unstable knee. (C) and (D) Trifocal treatment with knee fusion (red arrow), femur lengthening (white arrow), and tibia lengthening (green arrow). (D) and (E) Successful reconstruction of all three sites. The knee fusion site had a refracture that was managed with percutaneous insertion of anterior plate and screws. This technique is also being used in a prophylactic fashion at the time of frame removal.

Results

Sixteen patients were treated with Ilizarov fusion frames, two of which were converted to intramedullary (IM) nails to prevent refracture at the time of frame removal. Five patients were managed primarily with IM fusion nails. Active infection with a known organism was present in 76.1% (16/21) of patients. Fifteen of these patients underwent explantation and spacer placement prior to presentation, while one patient underwent a single stage explantation and fusion procedure. Among the major procedure groups, the average number of follow-up visits for patients managed with an IM nail was 6.3 (±SD 2.71). Follow-ups for those managed with a frame were 9.67 (±SD 5.12), although two patients' follow-up data were unable to be obtained.

In our series, 7/21 patients underwent bone lengthening procedures and were on average younger than the non-lengthened group (average age 52 vs. 74 years). Femoral lengthening was performed in 4/7 patients, tibial in 2/7 and femorotibial in 1/7. Total lengthening was 6.3 cm (SD ± 2.9), and total time in frame was 13.1 months (SD ± 3.4). The external fixator index (EFI) was 2.0 (SD ± 0.9) and the final LLD was 1.6 cm (SD ± 0.7). This compared favorably with a non-lengthened average of LLD of 5.7 cm (SD ± 1.9). The average time in Ilizarov frames was 9 months (±SD 4.3) with knee fusion union achieved in 15/16 (93.8%) patients. One patient presented with significant knee deformity, which was managed with frame modification and prophylactic percutaneous plating of the fusion site post-frame removal. Union was achieved in 5/5 (100%) of patients treated with IM nailing.

Prior to surgery, bone loss measured pre-operatively via comparison to the unaffected contralateral limb was 3.6 cm (±SD 1.71). Following appropriate resurfacing and surgical intervention, total bone loss increased to 6.6 cm (±SD 2.8) for all patients (Table 1).

Infection history was significant in the non-lengthened group. Of a total of fourteen patients, four patients had primary TKAs, all of which had active infection. Six patients had a single revision with 5/6 actively infected, while four were multiply revised with 2/4 infected prior to presentation on our service. Using an evolving technique previously described, three patients had percutaneous plating/screw fixation after frame removal to protect the fusion site. This allowed for further compression and added stability to the fusion site, which is subjected to long lever-arm forces when the Ilizarov frames are removed [16]. Within the Ilizarov group, virtually 100% of patients experienced at least one superficial pin site infection. These were routine and predictably treated effectively with a 10-day course of oral antibiotic.

Overall, limb salvage was accomplished in 19/21 (93.3%) patients. Two other patients (13.7%) eventually had AKA. The reasons for failure in this group were (1) intractable wound problem, and (2) acute

Table 3
Ilizarov Fixation Vs. IM Nail Outcomes.

Procedure	No. of pts	Union	LLD (cm)	Ambulation	Infection Post-Fusion	Fusion Flexion (°)	Amputation
IM nail	5	5/5	6 ± 1.8	4/5	0/5	6.4 ± 2.2	0
Ilizarov fixation	16	15/16 union 1 malunion	3.88 ± 2.4	15/16	3/16	3 ± 10.3	2

Table 4
Fusion Options based upon Clinical Presentation.

Group	Problem	Fusion Option(s)
TKA with minimal bone loss	Presence of refractory infection	1) Abx coated IM nail* 2) Ilizarov method
TKE with massive bone loss	Unable to acutely oppose bone ends	1) Ilizarov method with use of gradual shortening
TKA with wound problem	Wound closure/soft tissue envelope	1) Ilizarov method with use of gradual shortening for closure
TKA with proximal THR	THR/Less femur to work with	1) Ilizarov method avoiding proximal prosthesis

Table 5
Indications for Surgical Approach.

Technique	Indications	Problems
Circular external fixation	1. Cannot acutely shorten leg 2. Desire for concomitant lengthening	1. Refracture risk if poor bone quality 2. Difficult in patient with wide leg
Antibiotic coated IM nail	1. Can acutely shorten leg 2. Accept LLD	Not possible with THR above
Frame then rod	1. Poor bone stock with refracture risk 2. Cannot acutely shorten defect 3. Accept LLD	Infection risk from pin sites so antibiotic coated nail is good option
Prophylactic stabilization with percutaneous plate at frame removal	1. Poor bone stock and high risk of knee fusion fracture	Anterior soft-tissue must be reasonable.

vascular emboli 1 year after frame removal. The single patient with a fibrous non-union did not undergo an amputation. Outcomes of IM nail and Ilizarov-assisted fusion groups are documented (Table 3).

Discussion

Knee arthrodesis can be successfully accomplished as an alternative to AKA in the multiply failed TKA patient. In an evaluation of all patients on our service, we found that bone loss, infection state and the soft-tissue envelope play the greatest role in dictating the appropriate knee fusion method, and in some cases more than one method is needed.

Single stage reconstruction of infected cases is often possible. In our series we were able to eradicate infection using a thorough debridement followed by the insertion of antibiotic coated nails or application of a circular frame to obtain stability. Bone lengthening via external fixation was effective for managing large bone defects and LLD in our group, and along with active infection appears to be a primary indication for the use of the Ilizarov technique in knee fusions [17]. While our finding that union rates are generally equivalent between both techniques is also reflected in a studies performed by Mabry et al [18] among others, some suggestion of increased deep infection risk with internal fixation persists [7,19,20]. An algorithm for the use of external fixation, IM nailing, and other internal fixation is therefore proposed (Tables 4 and 5).

Patients with a primary TKA with minimal bone loss and the presence of refractory infection are a group that can be treated with multiple methods. One option is to use an antibiotic coated locked IM fusion nail based upon organism sensitivities [21]. This method is likely to be the simplest one to perform and can be done by most surgeons with nailing experience. The patient cannot have a THR and the soft-tissue must allow acute shortening of the femorotibial bone defect while still being able to primarily close the wound. An alternate method is to use the Ilizarov external fixation method to obtain fusion with axial compression [22]. The Ilizarov technique allows the surgeon to acutely appose femur to tibia or gradually shorten the defect after frame application if the soft tissues dictate this. Retained hardware within the knee itself is avoided, and long term infectious complications are less likely than internal fixation [18].

In the setting of massive bone loss, usually after explantation of a revision system, acutely opposing bone ends is difficult or impossible. In our experience, this scenario is best managed via Ilizarov external fixation to gradually shorten the gap between the tibia and femur,

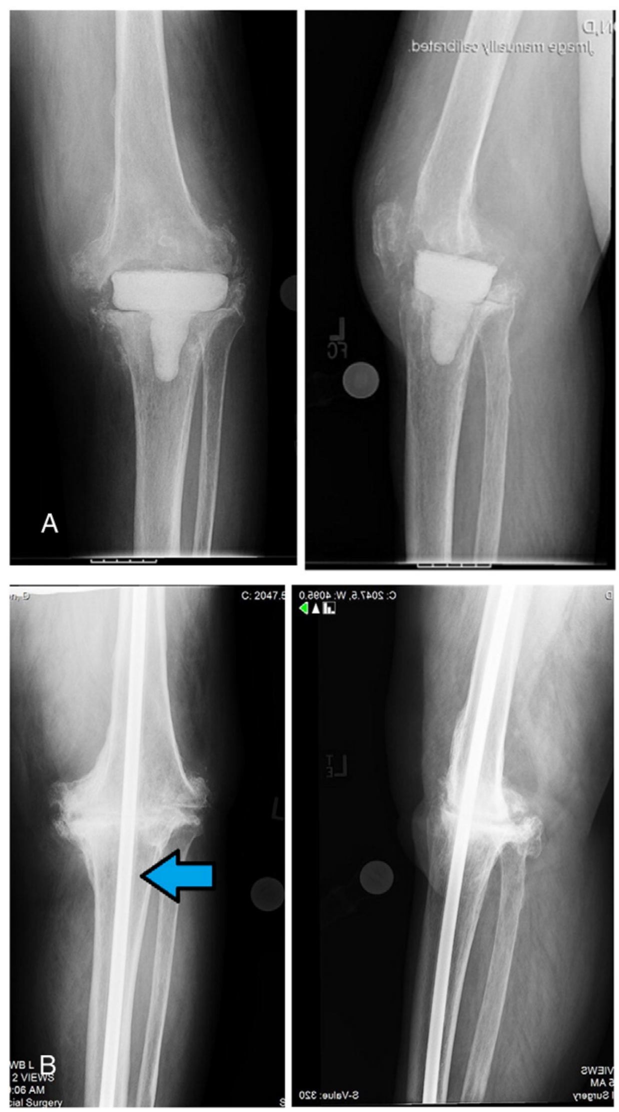

Fig. 4. (A) 75 year old male with persistent infection following explantation and cement spacer insertion. (B) Acute shortening and insertion of antibiotic coated IM nail at 12 months. Note cement around IM nail (blue arrow).

Fig. 5. Knee fusion using a circular frame in the presence of a THA.

which can accomplished at a rate of 1–2 mm per day. This procedure has repeatedly been performed without increased infection risk, provided a well-debrided environment with adequate soft-tissue coverage [21]. These patients will have a significant leg length discrepancy, which can be treated with a shoe-lift or lengthening at a later date. Further, in patients where soft-tissues do not allow for acute closure, or there is a significant wound defect, Ilizarov external fixation can be utilized to gradually dock the bone ends or use temporary intentional deformation to obtain soft-tissue apposition [6].

Lastly, in the common situation of a proximal total hip arthroplasty, we recommend Ilizarov external fixation with multiple wires and half-pins over a short segment. This provides the stability for the fusion construct (Fig. 5). Due to the hip implant, IM nailing in this group is not possible.

In our case series, we often found that supplementation of internal fixation at the fusion site was protective and provided rapid recovery. This was previously described by Stiehl and Hanel as a high union-rate solution to fusing a patient with chronic infection and poor bone stock [23]. This “protection plating” was done using a percutaneous/minimally invasive technique in order to avoid wound problems and disruption of blood supply. In our experience, anterior bone loss is universally present in these cases. After bony union of the posterior, medial, and lateral zones of the fusion, there is risk of refracture. This is related to poor bone stock and a long lever arm of the stiff leg. Refracture typically occurs with flexion instability. The fusion remains stable to extension, varus and valgus stress. The anterior percutaneous plate has been useful to protect against this type of refracture.

Here we summarize the indications for a specific fusion technique as discussed previously (Table 5). In our experience, it is ideal for a patient to undergo explantation and fusion in a single stage procedure. This obviates the need for a cement spacer. Acute shortening and stabilization with an antibiotic coated IM nail or external fixator is our ideal approach.

We have been successful in limb salvage with a relatively low amputation rate in an extremely difficult patient population. A single solution for all patients does not exist, and careful planning and creativity are frequently required to obtain a fusion after an explanted TKA. While Ilizarov methods can be used for most cases, not all patients are candidates and other fusion techniques should be considered. Our algorithm provides some guidance in making pre-operative decisions to best manage these patients.

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