Knee Arthrodesis Outcomes After Infected Total Knee Arthroplasty and Failure of Two-stage Revision With an Antibiotic Cement Spacer

Matthew Robinson, MD
Hristo I. Piponov, MD
Andrew Ormseth, BS
Cory W. Helder, MD
Brian Schwartz, MD
Mark H. Gonzalez, MD, PhD

From the Department of Orthopaedics (Dr. Robinson, Dr. Piponov, Helder, Dr. Schwartz, and Dr. Gonzalez), and the College of Medicine (Mr. Ormseth), the University of Illinois at Chicago, Chicago, IL.

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Abstract

Background: Reinfected total knee arthroplasty can be managed with a second two-stage exchange or a knee arthrodesis procedure.

Methods: Twenty-three patients with knee arthrodesis after failed exchange arthroplasty for infection were reviewed. Patients were managed with a staged protocol of implant extraction, débridement, and implantation of an antibiotic spacer, with subsequent arthrodesis. Follow-up averaged 40.4 months, with a minimum of 1 year.

Results: Bony union with eradication of infection was achieved in 20/23 knees. Sixteen of the 20 patients were able to ambulate with minimal pain. The average time to union was 11.3 months, and the average leg length discrepancy was 4.85 cm. The average Knee Society Score after arthrodesis was 44, and the average visual analog scale pain score was 1.73. Three patients underwent above-knee amputation.

Discussion: Knee arthrodesis performed for persistent periprosthetic infection allowed for eradication of infection and union in 87% of the patients, creating a stable knee fusion.

Total knee arthroplasty (TKA) is the preferred treatment for end-stage debilitating knee pathologies such as osteoarthritis and rheumatoid arthritis. Although failure of TKA is a rare event, TKA infection is a particularly challenging clinical problem associated with increased morbidity and cost. Despite the use of prophylactic antibiotics, between 1% and 2% of all knee replacements are complicated by peri-prosthetic joint infection (PJI). A two-stage revision procedure is considered the benchmark in the treatment of TKA infection. This consists of explantation of the infected implant, complete débridement, and placement of an antibiotic spacer, with at least 6 weeks of systemic antibiotic therapy. Once the infection is eradicated based on clinical examination, aspirate culture, and inflammatory markers, such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) level, revision arthroplasty can be undertaken.
Placement of an antibiotic-impregnated polymethyl methacrylate cement spacer offers multiple advantages in the treatment of PJI. It locally delivers a concentration of antibiotics not otherwise attainable with intravenous administration alone. A spacer also maintains leg length, facilitating reimplantation of a prosthesis. In a two-stage revision without the use of a spacer, patients may have symptomatic joint instability and develop soft-tissue contractures. Reimplantation with contractures, while possible, is technically more difficult. Using an antibiotic-impregnated cement spacer can preserve knee joint mobility and allow for successful revision arthroplasty while delivering antibiotics locally to the site of infection.

There are two types of antibiotic-loaded polymethyl methacrylate cement spacers: nonarticulating (or static) and articulating. Although nonarticulating spacers provide local antibiotics and maintain the joint space for future revision surgeries, they have the disadvantage of a limited range of motion at the knee joint. This can result in quadriiceps or abductor shortening, scar formation, and bone resorption. Articulating cement spacers, like the Prostalac Hip System (DePuy), permit greater joint motion and decrease scar formation to facilitate arthroplasty reimplantation. Emerson et al compared 26 patients treated with nonarticulating spacers with 22 patients treated with articulating spacers. Although they found virtually the same reinfection rate (8% in nonarticulating and 9% in articulating), the range of motion of the knee joint was an average of 14° greater after an articulating knee spacer.

In approximately 9% to 12% of cases, infection can persist, despite explantation of TKA and implantation of antibiotic spacers. In the case of persistent TKA infection, a well-recognized salvage procedure is knee arthrodesis, which can provide a stable, painless joint that allows for an independent lifestyle. Knee arthrodesis can be achieved using an intramedullary (IM) nail, tibiofemoral screw-plate fixation, or an external fixator. Compared to knee arthrodesis with external fixation, knee arthrodesis using an IM nail is reported to provide greater stability, avoid pin-track infection, and allow faster weight-bearing, and is generally more acceptable to patients. However, external fixation arthrodesis remains an attractive option for knee fusion when soft-tissue conditions are poor.

A number of studies have looked at patient outcomes after knee arthrodesis with bone IM nailing and external fixation. Solid bony fusion rates in the literature ranged from 73.7% to 100% in knee arthrodesis with IM nailing and ranged from 68.4% to 100% in knee arthrodesis with external fixation. Reported time to bony fusion ranged from 3.6 to 9.3 months. The reported limb-length discrepancy after arthrodesis ranged from 2.76 to 5.5 cm.

Limited information exists regarding patient outcomes after knee arthrodesis for PJI and failure of two-stage revision. This study retrospectively assessed radiographic bony fusion, clinical eradication of infection, limb-length discrepancy, and patient functional outcomes after knee arthrodesis.

Methods

Patients

Retrospective analysis of 23 consecutive patients by a single surgeon at our institution who underwent knee arthrodesis between 2002 and 2014 was performed. Each patient was diagnosed with PJI that recurred after two-stage reimplantation. Patients were followed until evidence of fusion occurred, or they underwent a salvage above-knee amputation (AKA).

Electronic medical records were queried to also include the date of diagnosis of PJI, ESR, and CRP level at the time of diagnosis, infectious organisms, patient body mass index (BMI), patient comorbidities, number, type, and length of antibiotic-impregnated cement spacer placement, surgical technique, surgical complications, date of radiographic fusion, patient ambulatory status and limb-length discrepancy after arthrodesis, and total duration of follow-up.

Treatment

Before arthrodesis, each patient who developed knee PJI underwent a two-staged revision, consisting of extraction of the implant, débridement, and implantation of either a static or articulating antibiotic-impregnated cement spacer containing tobramycin and vancomycin. Implantation of a static or articulating spacer was at the discretion of the treating surgeon. Treatment was augmented with systemic antibiotics in all patients. Periprosthetic infec-
tion was diagnosed after complete evaluation of clinical findings, including the new onset of joint pain, fever, swelling, effusion, elevated ESR and CRP level, or culture-positive arthrocentesis.

In treating TKA infection before knee arthrodesis, patients had an average of 2.1 procedures for spacer placement and 0.9 irrigation and débridement procedures before fusion. Nine patients received Prostalac articulating cement spacers, and 14 patients had static cement spacers placed.

After a waiting period during which patients were treated with systemic antibiotics, revision arthroplasty was performed if clinical and laboratory markers suggested eradication of infection. If infection had not been cleared, further débridement and exchange of the antibiotic-loaded cement spacer were performed. In patients who did not clear infection after multiple procedures with antibiotic-impregnated cement spacers, knee arthrodesis was the salvage procedure of choice. Knee arthrodesis with IM nailing, external fixation, or tibiofemoral screw-plate fixation was performed only after clinical and laboratory markers favored eradication of infection.

All two-staged revision and knee arthrodesis procedures were performed by one orthopaedic fellowship-trained adult reconstruction surgeon at a single institution. Arthrodesis was performed using an IM nail, external fixation, or tibiofemoral screw-plate fixation. Radiographic examples of fusion of the IM nail or external fixation construct are shown in Figure 1, A and B.

Evaluation

Electronic medical records and serial radiographs of all 23 patients were reviewed to evaluate clinical and radiographic arthrodesis outcomes of the surgeries. If patients did not return to the clinic with signs and symptoms of infection such as joint pain, fever, swelling, or effusion, laboratory markers (ESR and CRP level) were not generally rechecked. Arthrodesis was defined radiographically when a bridge of bone trabeculae could be observed in both AP and lateral radiographs at the knee joint.\textsuperscript{11}

Leg length discrepancy was measured on routine follow-up after arthrodesis. Leg length discrepancy was measured from the surgical side anterior superior iliac spine to the surgical side ankle medial malleolus. This was subsequently compared with the contralateral leg length measurement, and leg length discrepancy was calculated.

Patients subsequently were assessed for functional and pain outcomes using a variety of standardized scoring systems. The Knee Society Score (KSS) and Knee Society Functional Score were used to assess patient knee function and satisfaction after the arthrodesis procedure. The Knee Injury and Osteoarthritis Outcome Score (KOOS) was used to assess patient pain and symptoms, ability to take part in activities of daily living, function in sport and recreation, and knee-related quality of life. The visual analog scale (VAS) was used to assess pain after arthrodesis.

Knee arthrodesis was considered a success if patients achieved a painless, stable radiographically fused joint. The procedure was considered a failure if patients did not achieve solid bony union or required an AKA.

To factor the effect of patient co-morbidities, the subjects in the cohort were stratified by the Charlson Co-morbidity Index Score. This score has been found to be predictive and valid in various outcomes, such as mortality, disability, readmission, and length of stay.\textsuperscript{19}

Results

The arthrodesis procedure was successful in achieving a stable limb with radiographic union in 20 of 23
patients (87%). Of the 20 patients with fusion or delayed union, 16 (80%) ambulated with minimal pain, although 6 required the assistance of a cane or walker. Four patients required a wheelchair for activities of daily living.

Nine male and 14 female patients were included in this study. The mean age at the time of arthrodesis surgery was 63.7 years. Twelve patients had left-sided PJI, and 11 had right-sided infection. The mean follow-up period was 40.4 months (range, 12 to 138 months). Osteoarthritis was the indication for the initial TKA in 19 cases, rheumatoid arthritis in 2 cases, and traumatic arthritis in 2 cases. Nine of the patients had diabetes mellitus, and 11 of the patients had a BMI of >30 kg/m² (average BMI, 33.8 kg/m²).

Most patients (61%) in the study were categorized into a mild severity of the comorbidity group. Stratification by the Charlson Comorbidity Index Score and its age-adjusted version is provided in Table 1.

The average ESR mm/hr and CRP mg/L at the time of diagnosis were 66.9 and 6.4, respectively. Infectious microorganisms varied widely but included six cases of methicillin-resistant *Staphylococcus aureus*, two cases of vancomycin-resistant *Enterococcus*, and two cases of multiorganism infections.

The average length of time between the diagnosis of PJI and knee fusion was 18.2 months. Table 2 details the staged surgical course, outcomes, and complications of the patients undergoing arthrodesis.

The patients were able to be grouped by treatment approaches: IM nail, external fixation device due to a poor soft-tissue envelope, and alternative arthrodesis methods due to anatomic reasons (Figure 2).

Arthrodesis with a long IM nail was the preferred treatment and was attempted in 17 patients (cases 1 through 17) (Table 2). Sixteen of 17 patients (94%) with an IM rod attained a clinical stable fusion, with no clinical and laboratory signs of infection. The infection relapsed in 2 of the original 17 patients (12%) with IM nail placement. One (case 16) was on long-term immunosuppressive therapy after organ transplantation and was effectively managed with removal of the rod, placement of an external fixator.
and wound débridement, and placement of antibiotic beads to clear the infection. The patient, at latest follow-up, remains on oral antibiotic suppressive therapy, despite a radiographically fused painless limb with no clinical signs of infection and a normalized ESR and CRP level. The second was unable to clear the infection, developing abscesses and osteomyelitis for which AKA was performed.

Four patients (cases 18 through 21) at the time of attempted fusion lacked sufficient soft-tissue coverage and were alternatively treated with an external fixator. Three of four cleared the infection and attained

| Table 1 | Patient Demographic Information and Comorbidities and Cultured Infectious Organisms |
|---------|----------------------------------------------------------------------------------|
| Case | Age | Sex | BMI | Primary Diagnosis | Infectious Organism | Comorbidities | Comorbidity Index (Age-factored Score) |
| 1 | 68 | F | 35 | OA | MRSA | DM, CAD, HTN, HL, and OSA | 3 (5) |
| 2 | 73 | M | 29 | OA | Staphylococcus epidermidis | None | 0 (0) |
| 3 | 66 | M | 31 | OA | Unknown | DM, HTN, and DVT | 1 (3) |
| 4 | 53 | M | 52 | OA | GBS | DM, HTN, and HL | 1 (2) |
| 5 | 54 | M | 32 | OA | MRSA | HTN, DVT, and hepatitis B | 2 (3) |
| 6 | 60 | F | 32 | OA | Enterococcus faecalis | HTN and asthma | 0 (0) |
| 7 | 66 | F | 34 | OA | MRSA | HL and hypothyroidism | 0 (0) |
| 8 | 57 | M | 55 | OA | MRSA | DM, HTN, and OSA | 2 (3) |
| 9 | 76 | F | 22 | OA | Diphtheroids | DM, CAD, and CKD | 4 (7) |
| 10 | 79 | F | 25 | OA | Acinetobacter baumannii | DM, HTN, HL, CKD, spinal stenosis, pseudogout, and vascular dementia | 4 (7) |
| 11 | 69 | F | 34 | OA | Klebsiella pneumoniae and Mycobacterium abscessus | DM, HTN, and osteoporosis | 1 (3) |
| 12 | 59 | F | 42 | OA | GBS | DM, HTN, HL, gout, DVT, and GERD | 1 (2) |
| 13 | 59 | F | 33 | OA | S. epidermis | Breast cancer, asthma, and GERD | 2 (3) |
| 14 | 74 | F | 47 | OA | MRSA | CHF, HTN, and HL | 1 (4) |
| 15 | 52 | M | 23 | OA | S. epidermis | HIV, hepatitis B, ITP, BPD, and schizophrenia | 7 (8) |
| 16 | 75 | F | 40 | OA | Aerococcus viridans | HTN, DM, CHF, and CKD | 3 (6) |
| 17 | 55 | M | 38 | OA | Pseudomonas aeruginosa and MRSA | None | 0 (0) |
| 18 | 64 | F | 25 | OA | MRSA | None | 2 (4) |
| 19 | 64 | F | 28 | RA | VRE | Anemia | 0 (0) |
| 20 | 64 | F | 26 | OA | Traumatic arthritis | MSSA | HL and hepatitis C | 3 (5) |
| 21 | 41 | M | 22 | OA | Traumatic arthritis | Corynebacterium amycolatum | None | 0 (0) |
| 22 | 54 | F | 28 | RA | Streptococcus mitis and orales | DM and HTN | 1 (2) |
| 23 | 57 | M | 46 | OA | VRE | Thalassemia, OSA, and HTN | 0 (0) |

**Mean** | 63 | — | 34 | — | — | — | — |

**BMI** = body mass index, **BPD** = borderline personality disorder, **CAD** = coronary artery disease, **CHF** = chronic heart failure, **CKD** = chronic kidney disease, **DM** = diabetes mellitus, **DVT** = deep vein thrombosis, **GBS** = group B Streptococcus, **GERD** = gastroesophageal reflux disease, **HL** = hyperlipidemia, **HTN** = hypertension, **ITP** = idiopathic thrombocytopenic purpura, **MRSA** = methicillin-resistant *Staphylococcus aureus*, **MSSA** = methicillin-sensitive *Staphylococcus aureus*, **OA** = osteoarthritis, **OSA** = obstructive sleep apnea, **RA** = rheumatoid arthritis, **VRE** = vancomycin-resistant *Enterococcus*.
a solid knee fusion. One patient was unable to clear the infection and underwent AKA. The main complications in this group involved pin complications and wound dehiscence at the site of the spacer explantation. Three of the four patients required vacuum-assisted closures (VACs). In addition to VACs, case 20 required a medial gastrocnemius flap and skin graft to cover the defect.

Two patients were treated with alternatives to IM nails because of anatomic reasons. One patient (case 23) was treated with an external fixator because of previous total hip arthroplasty. After developing a

| Case | Age | Sex | Spacer Type | Spacer Placed | Fusion Method | Outcome | Months to Fusion | Complications |
|------|-----|-----|-------------|---------------|---------------|---------|-----------------|---------------|
| 1    | 68  | F   | Articulating | 2             | IM nail       | Fusion   | 2.5             | None          |
| 2    | 73  | M   | Articulating | 2             | IM nail       | Fusion   | 1.6             | None          |
| 3    | 66  | M   | Articulating | 1             | IM nail       | Fusion   | 9.5             | Painful distal tibia screws (removed) |
| 4    | 53  | M   | Articulating | 3             | IM nail       | Fusion   | 8.6             | None          |
| 5    | 54  | M   | Static      | 1             | IM nail       | Fusion   | 5.3             | None          |
| 6    | 60  | F   | Static      | 1             | IM nail       | Fusion   | 5.3             | None          |
| 7    | 66  | F   | Articulating | 3             | IM nail       | Fusion   | 3.2             | Persistent peroneal nerve palsy |
| 8    | 57  | M   | Static      | 2             | IM nail       | AKA      | Nonunion        | Compartment syndrome, persistent infection, and osteomyelitis |
| 9    | 76  | F   | Articulating | 2             | IM nail       | Fusion   | 8.1             | None          |
| 10   | 79  | F   | Static      | 2             | IM nail       | Fusion   | 9.5             | Wound dehiscence |
| 11   | 69  | F   | Static      | 3             | IM nail       | Fusion   | 10.2            | None          |
| 12   | 59  | F   | Static      | 2             | IM nail       | Fusion   | 18.5            | Painful distal tibia screw necessitating removal |
| 13   | 59  | F   | Static      | 3             | IM nail       | Fusion   | 7.5             | Superficial distal tibia infection and screw removal |
| 14   | 74  | F   | Static      | 2             | IM nail       | Fusion   | 12.8            | None          |
| 15   | 52  | M   | Static      | 2             | IM nail       | Fusion   | 15.4            | Painful distal tibia screws necessitating removal |
| 16   | 75  | F   | Static      | 2             | IM nail       | Fusion   | 6.7             | Infection treated with antibiotic bead placement |
| 17   | 55  | M   | Static      | 1             | IM nail and Ilizarov external fixation | Fusion | 60.4            | Anterior thigh and calf abscesses, tibial osteomyelitis, and nonunion requiring three attempts at fusion |
| 18   | 64  | F   | Articulating | 2             | External fixation | Fusion | 9.5             | None          |
| 19   | 64  | F   | Static      | 1             | External fixation | Fusion | 20.1            | Wound dehiscence requiring to medial gastrocnemius and split-thickness skin graft |
| 20   | 64  | F   | Static      | 3             | External fixation | AKA    | Nonunion        | Persistent infection |
| 21   | 41  | M   | Static      | 2             | Ilizarov external fixation | Fusion | 7.0             | Distal pin loosening and pin-tract infection |
| 22   | 54  | F   | Articulating | 2             | Long leg cast | Fusion | 4.4             | Wound dehiscence |
| 23   | 57  | M   | Articulating | 2             | External fixation | AKA    | Nonunion        | Skin impingement and nonunion |
| Mean | 63  |     |             |                |               |         | 11.3            |               |

AKA = above-knee amputation, IM = intramedullary
nonunion, the patient was offered a repeated attempt at fusion but elected for AKA. Case 22 with rheumatoid arthritis had bilateral autofused hips, and preexisting knee deformity was treated with a long leg cast. The patient further developed wound dehiscence at the explant site, necessitating wound VACs. The patient achieved fusion and healing of the fracture in a long leg cast with an angulation of 30°/C176 of procurvatum, which was planned to be corrected during subsequent surgery.

In total, three patients underwent AKA: one because of nonunion and two because of persistent infection. The patient who underwent AKA because of nonunion had a previous articulating antibiotic spacer and an external fixator. The same patient ultimately decided on an amputation 2 years after his original external fixation instead of undergoing another arthrodesis procedure. The patients who underwent AKA because of persistent infection, one of whom had persistent purulent drainage, had previous static cement spacers. The external fixation device was chosen in one of them, and IM nailing was the preferred fusion method in the other.

Of the 23 patients who underwent knee arthrodesis for knee PJI, 8 (35%) had no complications. Complications in those patients with external fixation arthrodesis included distal pin loosening, skin impingement, pin-tract infection, and wound dehiscence. Complications in patients who underwent knee arthrodesis with IM nailing included painful screws, foot drop, anterior thigh abscesses, tibial osteomyelitis, compartment syndrome, and wound dehiscence. Of note, one patient (case 17) (Table 2) had persistent infection and nonunion after knee arthrodesis using an IM nail and required a total of two IM nail procedures separated by placement of an antibiotic rod and an Ilizarov external fixator, after which he achieved fusion and eradication of infection.

The average follow-up time after knee arthrodesis was 40.4 months, with a minimum of 12 months of follow-up. The average time to achieve radiographic bony fusion, defined as the presence of bone trabeculae in both AP and lateral radiographs at the knee joint, for the cohort was 11.3 months (8.2 months for IM nailing alone and 12.2 for external fixation alone).

The average limb-length discrepancy after arthrodesis based on 12 cases was 4.85 cm. Eleven patients participated in KSS, KSS Functional Score, KOOS, and VAS surveys after arthrodesis. The average KSS was 44. The average KSS Functional Score was 27.7. The average KOOS Symptom Score was 73.1. The

### Table 3

| Author                  | Patients Studied | Arthrodesis Method          | Fusion Rate | Mean Time to Fusion (mo) | Mean Limb-length Discrepancy (cm) | Mean Follow-up (mo) |
|-------------------------|------------------|-----------------------------|-------------|--------------------------|-----------------------------------|---------------------|
| De Vil J et al (2008)18 | 19               | Intramedullary nail         | 14/19 (73.7%) | —                        | 4.5                               | 60                  |
| Rammazini-Castro et al (2013)11 | 18               | Intramedullary nail         | 14/18 (77.8%) | 3.6                      | 2.8                               | 75                  |
| Leroux et al (2013)7    | 17               | Intramedullary nail         | 16/17 (94.1%) | 5                        | 2.8                               | 16                  |
| Gore et al9             | 19               | Intramedullary nail         | 18/19 (94.7%) | —                        | —                                 | 54                  |
| Incavo et al10          | 22               | Intramedullary nail         | 22/22 (100%) | 7                        | —                                 | —                   |
| Bargiotas et al8        | 12               | Intramedullary nail         | 10/12 (83.3%) | 5.5                      | 5.5                               | 49                  |
| Watanebe et al1         | 8                | External fixation           | 7/8 (87.5%)  | —                        | 5.4                               | —                   |
| Johannsen et al (2005)12| 8                | Ilizarov external fixation  | 6/8 (75%)    | 3.5                      | 3.5                               | 10                  |
| Manzotti et al (2001)13 | 6                | Ilizarov external fixation  | 5/6 (83%)    | 6.8                      | —                                 | 34.2                |
| Garberina et al (2001)14| 19               | Ilizarov external fixation  | 13/19 (68.4%)| 4.6                      | —                                 | 32                  |
| Oostenbroek et al (2001)15 | 15              | Ilizarov external fixation  | 14/15 (93.3%)| 12                      | 4.0                               | 52                  |
| David et al (2001)16    | 13               | Ilizarov external fixation  | 13/13 (100%) | 6.4                      | 3.7                               | 40.8                |
| Spina et al (2010)17    | 17               | Ilizarov external fixation  | 13/17 (76.5%)| 9.3                      | 3.8                               | 30                  |
average KOOS Pain Score was 85.4. The average KOOS Activities of Daily Living Score was 56.2. The average KOOS Sports and Recreation Score was 4.5. The average KOOS Knee-related Quality of Life Score was 25.0. Finally, the average VAS pain score was 1.73.

Discussion

Knee arthrodesis is a well-recognized salvage procedure in the challenging treatment of persistent PJI. After multiple failed surgical interventions, including placement of a static or articulating antibiotic-loaded cement spacer, knee arthrodesis can provide a painless, stable joint and eliminate infection.4 Options for knee arthrodesis include internal fixation with IM nailing, external fixation, and tibiofemoral screw-plate fixation.4 IM nailing was the preferred treatment in our series. Of these options, IM nails are reported to provide greater stability, avoid pin-tract infection, and allow faster weight-bearing, and several authors have reported good results with internal fixation arthrodesis with IM nailing.1,4,7–11,18,20 However, fusion with an external fixator is a reasonable option when dictated by patient circumstances, such as a poor soft-tissue envelope or anatomy.4

Achievement of bony fusion in the literature ranges from 73.7% to 100%.1,7–17 Our group achieved bony fusion and eradication of infection in 20 of 23 patients (87%), well within the range of studies in the literature, many of which are small studies to which our study size compares favorably.1,7–17 Three patients in our study underwent AKA due to non-union or persistent infection. Much like previous studies, active infections are the primary cause of failed arthrodesis necessitating AKA, emphasizing the importance of maximizing therapy against the infectious organism. Along the same lines, those treated with external fixation constructs tended to have high incidence of pin-tract infections and recurrent infections. The exception in our series is that one of the patients preferred AKA rather than a second attempt at fusion with external fixator arthrodesis augmented with bone graft after tolerating his previous external fixation device for 2 years. One patient in the series did require multiple arthrodesis procedures to achieve bony fusion.

The mean time to achieve radiographic bony fusion was 11.3 months, slightly more than the range of 3.6 to 9.3 months reported in the literature.1,7,8,10,15–17 However, with the exclusion of an outlier that necessitated 60.4 months to fusion and resolution of infection due to osteomyelitis, our mean falls within the range reported by the literature. This patient’s course was repeatedly complicated by multiple infectious organisms and difficulty eradicating the osteomyelitis.

The mean limb-length discrepancy was 4.85 cm. The limb-length discrepancy after knee arthrodesis in the literature ranges from 2.76 to 5.5 cm.1,7,8,10,12,15–18 Table 3 outlines other authors’ results with knee arthrodesis procedures. Each patient with limb-length shortening was offered a shoe lift, and 16 of 20 patients with successful arthrodesis were able to ambulate after the procedure.

Fifteen of 23 (65%) patients who underwent knee arthrodesis had some complications after the procedure. In tibiofemoral screw-plate fixation arthrodesis, complications were limited to hardware failure. In external fixation, arthrodesis complications overwhelmingly involved the pins and included skin impingement, pin-tract infection, pin loosening, fracture through pin site, and wound dehiscence. Furthermore, in these patients adjunctive methods were often used to assist in wound closure. In IM nail arthrodesis, complications included foot drop, painful devices, compartment syndrome, osteomyelitis, and wound dehiscence. These types of complications are consistent with reported outcomes in other studies.1,7–18

All patients were assessed for physical function, pain, and stiffness in the clinic. Sixteen of the 20 successful patients with arthrodesis are able to ambulate and perform their activities of daily living with minimal pain, although 6 required a walker or cane to ambulate. Based on the review of patient KSS, KSS Functional Scores, KOOS, and VAS pain scores, patients were largely pain-free but did have significant functional limitations. Arthrodesis is a salvage procedure useful to prevent limb amputation in very challenging cases, and these reported functional outcomes seem to be within an acceptable range.

We suggest that knee arthrodesis can provide a functional, painless, stable knee joint and is a good option for patients who have failed two-stage revision with an antibiotic-loaded cement spacer. In our group, 20 of 23 patients showed clearance of the infection clinically and achieved clinical and radiographic knee fusion. Although persistent TKA infection is a devastating problem for patients and clinicians, knee arthrodesis is a salvage procedure, which, despite complications, provided our group with consistent results.

References

1. Watanabe K, Minowa T, Takeda S, et al: Outcomes of knee arthrodesis following infected total knee arthroplasty: A retrospective analysis of 8 cases. Mod Rheumatol 2014;24:243-249.

2. Gooding CR, Masri BA, Duncan CP, Greidanus NV, Garbuz DS: Durable infection control and function with the PROSTALAC spacer in two-stage revision for infected knee arthroplasty. Clin Orthop Relat Res 2011;469:985.
3. Cui Q, Mihalko WM, Shields JS, Ries M, Saleh KJ: Antibiotic-impregnated cement spacers for the treatment of infection associated with total hip or knee arthroplasty. *J Bone Joint Surg Am* 2007; 89:871.

4. Emerson RH Jr, Muncie M, Tarbox TR, Higgins LL: Comparison of a static with a mobile spacer in total knee infection. *Clin Orthop Relat Res* 2002;404:132-138.

5. Haddad FS, Masri BA, Campbell D, McGraw RW, Beauchamp CP, Duncan CP: The PROSTALAC functional spacer in two-stage revision for infected knee replacements: Prosthesis of antibiotic-loaded acrylic cement. *J Bone Joint Surg Br* 2000;82:807.

6. Renovell P, Silvestre A, Vaamonde O: The role of knee arthrodesis after TKA infection. In: Kinov P, ed: *Arthroplasty—Update*. Rijeka, InTech, 2013, pp Ch. 26.

7. Leroux B, Aparicio G, Fontanin N, et al: Arthrodesis in septic knees using a long intramedullary nail: 17 consecutive cases. *Orthop Traumatol Surg Res* 2013;99:399.

8. Bargiotas K, Wohlrab D, Sewecke JJ, Lavinge G, Demeo PJ, Sotereanos NG: Arthrodesis of the knee with a long intramedullary nail following the failure of a total knee arthroplasty as the result of infection. *J Bone Joint Surg Am* 2006;88:553.

9. Gore DR, Gassner K: Use of an intramedullary rod in knee arthrodesis following failed total knee arthroplasty. *J Knee Surg* 2003;16:165.

10. Incavo SJ, Lilly JW, Bartlett CS, Churchill DL: Arthrodesis of the knee: Experience with intramedullary nailing. *J Arthroplasty* 2000;15:871.

11. Ramazzini-Castro R, Pons-Cabrafiga M: Knee arthrodesis in rescue surgery: A study of 18 cases [in Spanish]. *Rev Esp Cir Ortop Traumatol* 2013;77:45.

12. Johannsen HG, Skov O, Weeth ER: Knee arthrodesis with external ring fixator after infected knee arthroplasty [in Danish]. *Ugeskr Laeger* 2005;167:3295.

13. Manzotti A, Pullen C, Deromedis B, Catagni MA: Knee arthrodesis after infected total knee arthroplasty using the Ilizarov method. *Clin Orthop Relat Res* 2001;389:143-149.

14. Garberina MJ, Fitch RD, Hoffmann ED, Hardacker WT, Vail TP, Scully SP: Knee arthrodesis with circular external fixation. *Clin Orthop Relat Res* 2001;382:168-178.

15. Oostenbroek HJ, van Roermund PM: Arthrodesis of the knee after an infected arthroplasty using the Ilizarov method. *J Bone Joint Surg Br* 2001;83:30.

16. David R, Shtarker H, Horesh Z, Tsaur A, Soudry M: Arthrodesis with the Ilizarov device after failed knee arthroplasty. *Orthopedics* 2001;24:33.

17. Spina M, Gualdrini G, Fosco M, Giunti A: Knee arthrodesis with the Ilizarov external fixator as treatment for septic failure of knee arthroplasty. *J Orthop Traumatol* 2010;11:81.

18. De Vil J, Almqvist KF, Vanheeren P, Boone B, Verdonk R: Knee arthrodesis with an intramedullary nail: A retrospective study. *Knee Surg Sports Traumatol Arthrosc* 2008;16:645.

19. de Groot V, Beckerman H, Lankhorst GJ, Bouter LM: How to measure comorbidity: A critical review of available methods. *J Clin Epidemiol* 2003;56:221.

20. Rand JA, Bryan RS: The outcome of failed knee arthrodesis following total knee arthroplasty. *Clin Orthop Relat Res* 1986; 205:86-92.

21. Ramazzini-Castro R, Pons-Cabrafiga M: Knee arthrodesis in rescue surgery: A study of 18 cases. *Rev Esp Cir Ortop Traumatol* 2013;77:45-52.