The Stavros Niarchos Foundation Complex Joint Reconstruction Center (SNF CJRC) was created to provide specialized care to patients with the most difficult joint problems, primarily in failed joint replacements. The SNF CJRC has an active educational component, with a clinical and research fellowship, and research at the SNF CJRC has been awarded over $225,000 in grants this year. In addition, more than 1200 patients have been entered into a prospective registry that will provide outcomes data to improve techniques for the treatment of patients with these complex conditions. The SNF CJRC will host two international symposia in 2019, one on acetabular bone loss in revision total hip replacement and another on the difficult challenge of bacterial biofilms in the treatment of periprosthetic joint infection.

In this issue, 3 cases are presented involving revision total knee arthroplasty (TKA). Many of our patients have undergone revision TKA elsewhere, presenting to us with often debilitating complications such as chronic periprosthetic joint infection, soft-tissue defects, bone loss, and damaged implants. In Case 1, authors Shawn S. Richardson, MD, and Thomas P. Sculco, MD, discuss a severe adverse outcome of TKA, chronic extensor mechanism disruption with global knee instability, which required an extensor allograft and hinge prosthesis to improve patient function and restore knee extensor power. In Case 2, authors Jason L. Blevins, MD, Victoria Tam, and Michael B. Cross, MD, highlight the successful treatment of a patient with long-term periprosthetic joint infection who had severely compromised bone and soft tissue. In Case 3, authors Ivan De Martino, MD, Michael-Alexander Malahias, MD, PhD, and Peter K. Sculco, MD, describe the complex treatment course for a patient with massive metaphyseal bone deficits requiring prosthetic and bone augmentation.

All three cases illustrate the need for a multidisciplinary approach to management of complex cases—including collaboration among experts in infectious disease, specialized imaging, biomechanics, and surgical treatment. The SNF CJRC is committed to caring for patients with these most challenging conditions and strives through clinical and basic science research to provide the most innovative and evidence-based treatment to alleviate the major dysfunction caused by these failures.

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Additional information about the SNF CJRC can be found at hss.edu/complex-joint-reconstruction-center.asp. You may view our archives at hss.edu/complexcases. And we welcome your feedback at complexcases@hss.edu.
**Case Report**

A 66-year-old man presented to our institution complaining of 2 years of bilateral knee pain. He had previously undergone bilateral total knee arthroplasty (TKA) at another facility. The surgeries had been a success initially, but 7 years later the patient underwent revision of the right TKA for anterior dislocation of his tibial polyethylene liner and rupture of the patellar tendon (Fig. 1). The tibial liner was restored and the patellar tendon repaired and augmented with an Achilles tendon allograft. Postoperatively, he developed an infected hematoma requiring irrigation and debridement. Ultimately, the patellar tendon repair failed. About 1 year later the patient fell, resulting in rupture of the left quadriceps tendon. This was repaired, but it ruptured again 1 month later and required revision left quadriceps tendon repair and augmentation with an Achilles tendon allograft. After this left knee procedure, the patient developed another hematoma and infection.

On presentation to our facility, the patient complained of pain and weakness in both lower extremities and could not actively extend either knee. He occasionally used bilateral hinged knee braces locked in extension for ambulation but was not reliably able to walk across short distances, and was unable to reciprocate stairs. Despite these limitations, the patient continued to work as a schoolteacher. He had been off antibiotics for several weeks and had no signs or symptoms of infection.

On examination, he could ambulate with the aid of a walker and exhibited an antalgic gait pattern. There was a palpable deficiency in the left quadriceps tendon. Both knees had moderate effusions, with range of motion from 25° of hyperextension to 120° of flexion; he could extend neither leg against resistance. Radiographs demonstrated well fixed TKAs with patella alta on the left and patella baja on the right. White blood cell count, erythrocyte sedimentation rate, and C-reactive protein levels were within normal limits, and bilateral knee aspirations showed no evidence of prosthetic joint infection.

We decided to approach the case in a staged fashion, and the patient opted to address the right knee first. Given the significant hyperextension of both knees, we opted to revise the TKAs to hinged prostheses with femoral and tibial cemented diaphyseal stems. During exposure, the deficient extensor mechanism was excised from the tibial tubercle to the proximal pole of the patella, leaving the maximum amount of quadriceps tendon to aid in reconstruction. The same procedure was used for both knees.

Once the revision knee implant had been cemented in place, a trough was made in the anterior tibia in the location of the native tibial tubercle. A ledge of bone was left at the proximal aspect of the tibia to improve graft resistance to tension. A fresh frozen allograft extensor mechanism, including the tibial tubercle, patellar tendon, patella, and quadriceps tendon, was used to reconstruct the extensor mechanism. The tibial tubercle bone fragment was contoured to fit in the trough of the native tibia and was impacted into the bone in a press-fit fashion. Two 3.5-mm screws were used to augment the fixation. With the knee in maximal extension, #5 ethibond sutures were placed in Krackow pattern in both the native and allograft quadriceps tendon. With an assistant applying maximal tension, the 2 quadriceps tendons were repaired to each other in a layered fashion (Fig. 2A and 2B).

Postoperatively, a clamshell splint in maximal extension was applied until postoperative day 2, when the patient was converted to a cylinder cast. He was allowed to be toe-touch weight bearing while the cast was in place for 8 weeks; he then advanced weight bearing and began structured therapy, with a gradual increase in knee flexion. By 3 months postoperatively, he had no pain and no significant extensor lag and 90° of flexion in both knees (Fig. 3A and 3B).

**Discussion**

Although uncommon, chronic extensor mechanism disruption after TKA is an extremely debilitating complication, as this case demonstrates. Multiple reconstruction techniques have been described in the literature, including the use of an allograft extensor mechanism [2, 4] and a synthetic graft [1, 7]. Appropriate tensioning of the graft and native muscle is critical to avoiding extensor lag; a study comparing minimal to maximal graft tensioning is needed.

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**Fig. 1:** Lateral view of the right knee prior to the patient’s initial revision TKA, showing anterior dissociation of the polyethylene liner.

**Fig. 2:** Intraoperative images showing (A) the extensor mechanism allograft overlaying the revision total knee replacement and (B) the fully repaired extensor mechanism.

**Fig. 3:** Postoperative lateral images of (A) the right knee and (B) the left knee.
Case 2
Case presented by Jason L. Blevins, MD, Victoria Tam, and Michael B. Cross, MD

Chronic Periprosthetic Joint Infection: Treatment With Repeat 2-Stage Static Spacer Followed by Distal Femoral Replacement

Case Report A 63-year-old man presented at our institution with 3 years of right knee pain after primary total knee arthroplasty (TKA) performed in 2010 at another institution. The TKA had been complicated 2 years postoperatively by a periprosthetic joint infection (PJI) caused by methicillin-sensitive Staphylococcus aureus (MSSA) and treated with 6 revision surgeries (including placement of a static antibiotic spacer for 2-stage revision) and 6 courses of IV antibiotics. On presentation to HSS, the patient had draining sinuses at both ends of the incision for several months after his most recent revision. This drainage had been treated with serial vacuum dressings and then daily wet-to-dry dressings. The patient sought evaluation at the Stavros Niarchos Foundation Complex Joint Reconstruction Center for the recurrent PJI with a chronically draining sinus.

On examination, the patient had a moderate effusion, range of motion (ROM) of 15° to 90°, and good stability on varus and valgus stress. A 2-cm chronic wound at the distal aspect of the previous incision had active drainage, communication with the joint, and granulation tissue at its base. The incision was inflamed, and the surrounding skin was of poor quality due to maceration from chronic drainage and multiple surgeries. Right knee radiographs revealed a cemented stemmed femoral component and an all-polyethylene tibial component with significant femoral and tibial bone loss (Fig. 1). Laboratory results included a white blood cell (WBC) count of 5.9/nL, erythrocyte sedimentation rate of 37 mm/hr, and C-reactive protein of 6.4 mg/dL. Preoperative aspiration of synovial fluid showed a WBC count of 16,000 cells/mm³, and synovial fluid cultures grew MSSA, thus confirming a chronic infection of the multiply revised TKA.

Our initial surgical procedure consisted of implant removal and thorough canal and bony surface debridement. Due to the poor quality of the soft-tissue envelope, the draining sinus tract was excised and a static antibiotic spacer with high doses of antibiotic cement was inserted. The spacer consisted of 2 fully cement-coated rush rods using 5 bags of Simplex® P cement (Stryker, Mahwah, NJ), with vancomycin 2 g and tobramycin 1.2 g added to each 40-g bag of cement (Fig. 2). The skin was closed primarily and treated with an incisional wound vacuum dressing postoperatively. The postoperative course was complicated by prolonged wound healing and a deep vein thrombosis at 2 weeks postoperatively, which was treated with rivaroxaban. The patient also received IV cefazolin for 6 weeks from the infectious disease team. Three weeks after completion of antibiotic therapy, aspiration of the knee revealed no bacterial growth or indication of infection.

At 3 months after explantation, the patient underwent reimplantation TKA using a distal femoral replacement with tibial metaphyseal sleeve and stems. Tobramycin-and-gentamicin-impregnated cement was used for this procedure (Fig. 3). The incision was closed primarily with the use of an incisional vacuum dressing. At 2 weeks postoperatively the patient developed wound drainage and medial skin breakdown that required open irrigation and debridement and exchange of bearing and hinge components with placement of Stimulan® (Biocomposites, Inc., Wilmington, NC) dissolvable vancomycin antibiotic beads (Fig. 4). Intraoperative cultures grew Enterococcus faecalis, and the patient is now on long-term amoxicillin–clavulanate oral suppression.

At most recent follow-up (11 months after reimplantation), the patient walks without a limp; uses a cane only for long distances; and has a healed incision with no effusion, ROM of 0° to 90°, no extensor lag, and no instability on examination (Fig. 5).

Continued on page 4
Case Report A 66-year-old woman who had undergone right total knee arthroplasty (TKA) in 2006 at an outside institution recently underwent revision spine surgery at HSS. She subsequently developed a methicillin-sensitive *Staphylococcus aureus* (MSSA) infection that led to bacteremia and infection of the right TKA. She was seen for evaluation at the Stavros Niarchos Foundation Complex Joint Reconstruction Center for the acute periprosthetic joint infection (PJI) and underwent irrigation and debridement of her right TKA, which was treated with polyethylene insert exchange and 6 courses of IV antibiotics. She then was transitioned to oral suppression. Six months after the irrigation and debridement she noted increasing swelling and pain in her right knee without any trauma. Laboratory work-up was significant for a white blood cell (WBC) count of 10.3/μL, erythrocyte sedimentation rate of 35 mm/hr, and C-reactive protein level of 83.9 mg/dL. The WBC count of preoperative joint aspirate was 53,750 cells/mm³, and synovial fluid cultures grew MSSA, confirming a diagnosis of recurrent PJI.

At HSS, the patient underwent 2-stage revision TKA with an antibiotic spacer (Fig. 1). The first stage consisted of a thorough debridement of infected tissue with components and cement removal. An articulating antibiotic spacer with high doses of antibiotic cement was inserted. The spacer was fashioned intraoperatively using silicone molds (Stage One™, Zimmer Biomet, Warsaw, IN). Four bags of Simplex® P cement (Stryker, Mahwah, NJ), with vancomycin 2 g and tobramycin 1.2 g added to each 40-g bag of cement, were inserted into the femoral and tibial molds and allowed to harden. Once the cement spacers had fully hardened, one additional package of antibiotic-loaded cement was used to cement the components in place. The skin was closed primarily. The patient also received IV antibiotics for 6 weeks according to the infectious disease specialist; 3 weeks after completion of antibiotic therapy, a knee aspiration of synovial fluid revealed no bacterial growth and no indication of infection.

At 3 months after explantation, the patient underwent reimplantation TKA using a stemmed, constrained condylar knee implant. Femoral and tibial metaphyseal cones were needed to reconstruct metaphyseal defects (Figs. 2 and 3). Tobramycin-and-gentamicin-impregnated cement was used for this procedure. The incision was closed primarily with the use of an incisional vacuum dressing.

At her most recent follow-up visit (4 months after reimplantation), the patient walked without any assisting device and had a healed incision with no effusion, range of motion of 0° to 130°, no extensor lag, and no instability or signs of infection on examination (Fig. 4).

Discussion The management of metaphyseal bone defects during revision TKA is crucial to achieving durable implant fixation. Defects classified as Anderson Orthopaedic Research Institute (AORI) types 2B and 3 were historically addressed with a combination of epiphyseal and diaphyseal fixation (metallic augments and cemented or uncemented stems); other reconstruction techniques included impaction grafting, structural allograft, custom implants, and segmental mega-prosthesis [2]. Over the past decade biologic metaphyseal fixation has gained in popularity with the use of porous-coated titanium sleeves (DePuy Synthes, Warsaw, IN) and highly porous tantalum or titanium cones, which represent alternatives for reconstructing large metaphyseal bone defects [1, 4]. Osseointegration of the metaphyseal implant results in reduced stress at the implant–bone interface [3]. These implants provide excellent structural support for a wide range of bone defects [1, 4].

Continued on page 4
Case 1 Continued
tensioning at the time of repair showed an average postoperative extensor lag of 59° in minimally tensioned grafts and 4° in maximally tensioned grafts [3].

When successful, these reconstruction techniques can significantly improve a patient’s function and comfort and overall knee range of motion, as well as reduce extensor lag [1, 4]. A systematic review showed no difference between patient-reported outcome scores, range of motion, or complication rates between reconstructions with allograft or synthetic graft [6].

Despite appropriate technique, patients undergoing extensor mechanism reconstruction are at high risk of postoperative complications. Failure rates have been reported to be as high as 56 to 58% at 10 years, due to a combination of allograft failure, deep infection, persistent extensor lag greater than 30°, and symptomatic graft lengthening [1, 2, 5]. Younger age at the time of reconstruction may predict subsequent graft failure [5].

REFERENCES:

Case 2 Continued
Discussion Revision TKA in the setting of recurrent PJI presents a challenge for infection eradication and joint reconstruction, requiring aggressive debridement of bone, including intramedullary canals, and soft tissues. It is critical to optimize the soft-tissue envelope for adequate coverage. In this case, the skin was in poor condition due to chronic drainage from PJI and 7 surgeries. Rotational flap coverage should be considered when the skin cannot be closed primarily. A static antibiotic cement spacer was used in our patient to treat infection and allow the tissues to recover after debridement and excision of the draining sinus tract [2]. A systematic review by Pivec et al. found that static spacers were associated with decreased ROM compared to articulating spacers (92° versus 100°) [4], but both types of 2-stage revisions had similar improvements in Knee Society Score and no difference in re-infection, complication, or revision rate [4]. A failed 2-stage revision for recalcitrant PJI poses significant risk for another failure if the host is not optimized and there is a resistant organism [5]. Vadiee et al. reported success in eradicating infection in 74% of 148 cases after repeat 2-stage revision at a mean of 4 years [5]. Our patient had extensive bone loss requiring the use of a distal femoral replacement and tibial metaphyseal sleeve for fixation. The use of a tumor type of prosthesis reconstruction in non-oncologic revision TKA is associated with a 28% PJI rate and up to 37% complication rate [1, 3]. It is important to counsel patients on the risk of complications in repeat 2-stage revision, including refractory infection and bone loss requiring prosthesis reconstruction. Nonetheless, acceptable outcomes can be achieved with optimization of host-related risk factors, careful soft-tissue management, and identification of a susceptible organism.

REFERENCES:

Case 3 Continued
In recent years, studies have shown promising early and mid-term survivorship of metaphyseal sleeves and cones in revision TKA, even in cases of infection. A systematic review by Divano et al. found that metal cones used in revision TKA showed good clinical and functional outcomes, with an implant and cone survival rate of 95% and an infection rate of 7.1% with a mean follow-up of 3.65 years [1]. A systematic review by Zanirato et al. found a metaphyseal sleeve survival rate of 97% with a mean follow-up of 4 years [4]. Our patient had metaphyseal bone loss requiring the use of a stemmed condylar-constrained knee implant with femoral and tibial titanium cones for fixation that allowed for immediate weight bearing and a reconstruction that should be durable for decades.

REFERENCES:
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**Fig 1:** Lateral view of the right knee prior to the patient's initial revision TKA, showing anterior dissociation of the polyethylene liner.
**Fig 2:** Intraoperative images showing (A) the extensor mechanism allograft overlying the revision total knee replacement and (B) the fully repaired extensor mechanism.
Fig 3: Postoperative lateral images of (A) the right knee and (B) the left knee.
**Fig 1:** Anteroposterior (A) and lateral (B) radiographs of the right knee of a patient who had undergone TKA and 6 revision procedures for PJI.
Fig 2: Anteroposterior (A) and lateral (B) radiographs of the right knee after explantation and insertion of a static antibiotic cement spacer.
Fig 3: Anteroposterior (A) and lateral (B) radiographs of the right knee after reimplantation using distal femoral replacement and tibial metaphyseal sleeve with stems.
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**Fig 4:** Anteroposterior radiograph of the right knee after irrigation and debridement and placement of dissolvable antibiotic beads.
**Fig 5:** Standing anteroposterior radiograph of both knees at final follow-up.
**Fig 1:** Anteroposterior (A) and lateral (B) radiographs of the right knee after explantation and insertion of an articulating antibiotic cement spacer.
CASE 3

Metaphyseal Bone Deficits in Revision Total Knee Arthroplasty: Treatment With Metaphyseal Cones

Fig 2: Intraoperative photos showing femoral (A) and tibial (B) metaphyseal bone defects.
Fig 3: Intraoperative photos showing femoral (A) and tibial (B) metaphyseal titanium cones used to reconstruct the bone defects.
**Fig 4:** At 4-month follow-up, anteroposterior (A) and lateral (B) radiographs of the right knee showing condylar-constrained knee implant with stems and femoral and tibial metaphyseal cones.