Operative Techniques in
Orthopaedics

Femoral Revision

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With the expanding demand for total hip arthroplasty comes a concomitant rise in the need for revision surgery. Surgeons who focus on total joint arthroplasty and perform revision surgery are likely to face a significantly increasing demand over the next decades. Total hip revision surgery is most commonly performed for infection, aseptic loosening and instability and presents unique challenges for the surgeon regarding prior implant removal, preservation of bone stock, and adequate reconstruction. This article details a stepwise approach for the preoperative planning and surgical techniques required to address revision of the femoral component.
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Introduction

Demand for total hip arthroplasty (THA) is estimated to increase by 174% by the year 2030, with concordant increases in the number of revision procedures performed.[1] Despite the success of THA complications with the femoral component remain a challenge due to difficulties with loss of bone stock, removal of components or cement, and fracture. The focus of this article is on the diagnosis, preoperative planning, and operative techniques for femoral revision.

Indications

The most common indications for revision THA include instability, aseptic loosening, infection, and periprosthetic fracture. Gross instability and periprosthetic fracture do not present as many specific diagnostic challenges, however aseptic loosening and infection can be difficult to differentiate. Up to 11% of patients presenting with periprosthetic fractures have also been found to have infections, so the treating surgeon needs to maintain a high index of suspicion for infection.[2] While this discussion will be focused on the femoral component, the treating surgeon needs to rule out any complications with the acetabular component and be prepared to address the acetabulum intraoperatively.

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Preoperative Planning

History and Physical

A detailed history is critical in determining the cause of a painful THA. Timing, location, and quality of the pain can provide clues as to what specific component is causing a patient's pain. For example, "start up" pain is often a sign of loose components. Patients presenting with acute pain should raise suspicion of fracture or dislocation, while those who never achieved a pain-free interval should be worked up for causes of pain outside the hip (ie, back pain). Details of the prior surgical interventions on the affected hip are critical, including the index procedure and any subsequent revisions. Obtaining operative reports of these procedures, noting approach and implants used, can be critical for preoperative planning.

Similarly, a thorough physical exam is critical and provides valuable information to be used in the preoperative planning such as limb length discrepancies, prior incisions, limp and specific muscle weakness, and neurologic status. Leg length differences are important to note preoperatively as there may be a requirement to lengthen the affected side at the time of revision. Prior incisions may dictate which surgical approach should be used.

Standard laboratory values such as the C-reactive protein and erythrocyte sedimentation rate as well as image guided hip aspiration are useful to rule out infection prior to undertaking revision.

Standard orthogonal anterior/posterior and lateral radiographs of the affected joint are critical in determining the cause of pain and in preoperative planning and should be the first study obtained. Frog-leg lateral radiographs show the femoral component well, however acetabular

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version is better assessed on a cross-table lateral. Full-length standing films can be particularly useful in a true assessment of leg length as well as to elucidate femoral deformity. Additionally, prior radiographs can be helpful in determining the stability of the implants and to gauge the rate of liner wear, bone resorption, or remodeling. Any heterotopic ossification should also be noted as this may increase the difficulty of the surgical exposure and subsequent implant removal.

Other imaging studies, such as bone scans and tagged white blood cell scans, can be useful when evaluating for loosening or infection, but are less helpful in terms of surgical planning. Cross-sectional imaging is usually not required, but could be used at the discretion of the treating surgeon. In cases with extensive heterotopic ossification or malalignment/malrotation of components CT scans may be particularly useful for surgical planning.

Classification of Bone Stock

The amount of bone loss in the proximal femur will dictate what reconstruction options are required. The most common classifications of femoral bone loss are the American Academy of Orthopedic Surgeons and the Paprosky classification (Table 1).[3] A simplified decision tree for dealing with bone loss is presented in Figure 1.

The amount and location of any bone loss is critical for preoperative planning as the surgeon should plan for addressing such bone loss with the subsequent implant and this will dictate the surgical plan.

Surgical Approach

While revisions may be performed through any surgical approach many surgeons prefer to utilize a posterior or anterolateral approach given their extensile nature and relative ease of femoral exposure. Direct anterior approaches are converted to an extensile anterolateral approach when addressing the femur. One may also elect to utilize a posterior based approach even if the original procedure was performed through an anterior-based approach. A detailed review of each surgical approach is not the focus of this review however it is critical that the surgeon choose an approach that allows access to the entire femur if necessary.

Implant Removal

Femoral implant removal poses a significant challenge for the treating surgeon, with the goal to retain as much native bone stock as possible. Both cemented and uncemented implants pose unique problems in this regard. Well-fixed, uncemented implants can result in significant bone loss on removal. Cement removal is often challenging as removing cement from the distal canal is difficult and often necessary, especially in the setting of infection. The surgeon should be prepared for an osteotomy in all cases if necessary. Table 2 lists the common instruments which should be available when planning a femoral revision.

The principles of implant removal are to disrupt the bone-implant interface such that the implant may be removed with limited disruption of the surrounding bone stock. Implant

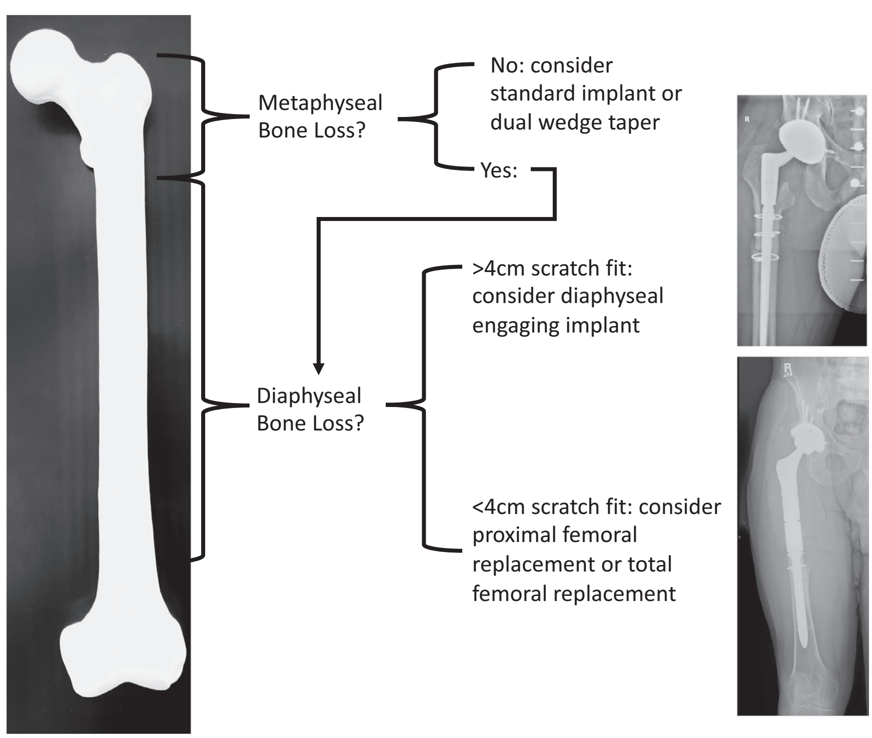

Figure 1 A simplified decision tree for femoral reconstruction.

Table 1 Proximal Femoral Bone Loss Classifications.

Classification			Description
Paprosky		I	Metaphyseal bone loss: *minimal* Diaphyseal Support: *Intact*
		II	Metaphyseal bone loss: *extensive* Diaphyseal Support: *Intact*
		IIIA	Metaphyseal bone loss: *extensive* Diaphyseal Support: > *4cm*
		IIIB	Metaphyseal bone loss: *extensive* Diaphyseal Support: < *4cm*
		IV	Metaphyseal bone loss: *extensive* Diaphysis: *unsupportive*
AAOS	Defect Classification	I	Segmental defects from cortical bone
		II	Cavitary loss of cancellous bone (cortex intact)
		III	Combined cortical and cancellous bone loss
		IV	Malalignment
		V	Femoral stenosis
		VI	Discontinuity
	Defect Stability	I	Complete bone-implant contact without the need for grafting
		II	Incomplete bone-implant contact with need for grafting, but not for stability
		III	Incomplete bone-implant contact with need for grafting for implant stability
	Level of Defect	I	Proximal to lesser trochanter
		II	Lesser trochanter to 10 cm distal
		III	10 cm distal to the knee joint

removal often is the most challenging portion of a femoral revision procedure, but care and patience may prevent an iatrogenic complication such as a periprosthetic fracture or cortical perforation.

Surgical Technique

Implant Removal

Extended Trochanteric Osteotomy

The extended trochanteric osteotomy (ETO) is useful in the setting of a well fixed stem, removal of a distal cement plug, proximal femoral remodeling, and improved surgical exposure. An appropriately performed osteotomy minimizes bone loss and allows for controlled removal while decreasing the risk of fracture.

Planning the Osteotomy

The length of the osteotomy will be determined by the indication for revision, however it is important not to make the osteotomy too short distal to the lesser trochanter such that adequate fixation can be achieved. This is the case in the setting of performing the ETO for improved surgical exposure. In the setting of removal of a distal cement plug, the osteotomy needs to be within a few centimeters of the plug such that adequate access can be achieved while still retaining a much diaphysis as possible. For proximal remodeling, the distal extent of the osteotomy should fall at apex of the deformity. One should also consider what implant will be used for the reconstruction such that adequate bone stock is retained to ensure a stable implant.

Using a posterior approach, the proximal femur is exposed by releasing the posterior aspect of the vastus lateralis and the gluteus maximus from the gluteal sling as needed depending on the length. The length of the osteotomy may now be marked on the femur, either measuring from the tip of the greater trochanter, using the removed femoral stem to be revised, or with the aid of intraoperative fluoroscopy. The proximal portion of the osteotomy should remove the greater trochanter in its entirety and the distal aspect should have the corners rounded to prevent stress concentrations which may lead to iatrogenic propagation of a fracture. This can be done with a small burr tip.

A sagittal saw is then used directing the blade from posterolateral to anterolateral with the goal being to remove the lateral 1/3 of the femur. If the femoral stem has been removed then the sagittal saw can be directed to the anterolateral cortex and the intramedullary cortex scored as to create a stress riser and/orgreenstick fracture when the osteotomy is later levered open

Table 2 Instruments for Femoral Revision.

Implant removal
Manufacturer specific tools
High speed burr with multiple tips
Flexible osteotomes
Cement extraction tools
Ultrasonic devices (if removing cement)
Curettes
Long pituitary rongeurs
Trephines
K-wires
Acetabular removal instruments
Osteotomy instruments
High dpeed burr
Oscillating saw
Multiple wide osteotomes
Cerclage cables or wires
Reconstruction instruments
Revision implants
Allograft struts
Claw plates
Periprosthetic fracture plates

with wide osteotomes. If the femoral stem remains then a series of burr holes are created along the proposed line of the anterior portion of the osteotomy. Osteotomes are used to further create this anterior portion. The goal is to keep the periosteum of the anterior portion of the osteotomy intact. If the femoral component has not been removed, then the saw must be directed around the lateral stem to create as large a piece of bone as possible. The distal extent of the osteotomy is completed with a high-speed burr. If desired, a prophylactic cerclage wire can be passed just distal to the osteotomy to reduce the risk of iatrogenic fracture propagation when booking open the osteotomy as is also useful for preventing fracture during reconstruction.

Next the osteotomy is booked open using wide osteotomes to distribute the force evenly across the length of the bone from posterior to anterior. It is important to avoid dissection on the anterior limb of the osteotomy as this is where the neurovascular supply of the vastus originates. It is also possible to perform an ETO from an anterolateral approach with the posterior portion structures of the osteotomy retained however the vastus lateralis must be split the length of the osteotomy in order to achieve this.

In the setting of a well fixed noncemented implant with a fully porous coated distal or fluted stem engaging the diaphysis, an ETO can be performed and the metaphyseal and cylindrical diaphyseal portions of the implant may be divided with a metal cutting burr. The proximal metaphyseal portion may be removed with the microsagittal saw and flexible osteotomes.

A trephine is often used to remove the straight portion of the distal stem, limiting the length of the ETO needed for implant removal. It is important that the stem portion of the implant being removed be straight such that the trephine can pass over it. A trephine approximately 1 mm larger in diameter than the stem diameter is selected to help prevent binding of the trephine on the implant.

Surgical Techniques: Reconstruction

Reconstruction techniques rely on obtaining secure, stable fixation of the femoral stem in the appropriate rotation. Achieving fixation depends on the amount of bone loss that has resulted from the pathologic process or during removal of prior hardware(Figs. 2-6). A stepwise approach can be used to help determine the best reconstruction technique (Fig. 1).

Minimal Proximal Bone Loss

In the setting of minimal proximal bone loss (Paprosky Type I), if standard components of a larger size are not satisfactory, one may select a proximal fit and fill style stem which distributes the stress over a larger surface area of the proximal metaphysis with a dual wedge taper design. If there is any doubt as to the integrity of the proximal bone stock or obtaining appropriate metaphyseal press-fit fixation then cemented implants or press-fit diaphyseal fixation should be considered. If a cemented implant has been removed with the cement mantle intact a cement-in-cement technique can be utilized.

Metaphyseal and/or Calcar Bone Loss

When there is significant loss of the metaphyseal bone (Paprosky Type II and IIIA), the femoral stem must then rely on a diaphyseal cortical fit. This can be achieved using monoblock or modular cylindrical or tapered stem design, provided there is at least 3-4 cm of intact circumferential cortical bone for fixation. These are of various surface designs ranging from fully porous coated to tapered and fluted with an ongrowth surface. The stems are placed much in the same way as primary implants, with reaming distally and broaching or reaming proximally. In the setting of a previously

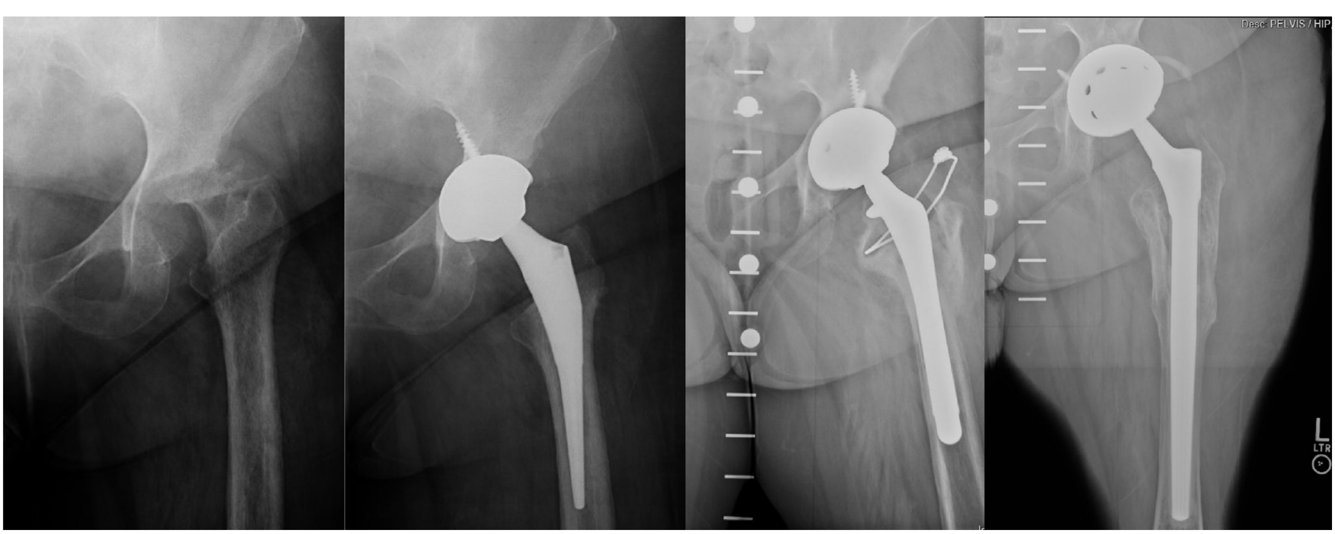

Figure 2 A 58-year-old woman with left hip postinfectious arthritis who underwent multiple revisions for recurrent prosthetic joint injections. At each revision the patient was treated with 2 stage antibiotic spacer placement and underwent aspiration prior to reimplantation of the revision hardware. She had extensive proximal femoral bone loss and therefore a monoblock tapered stem was selected for reconstruction.

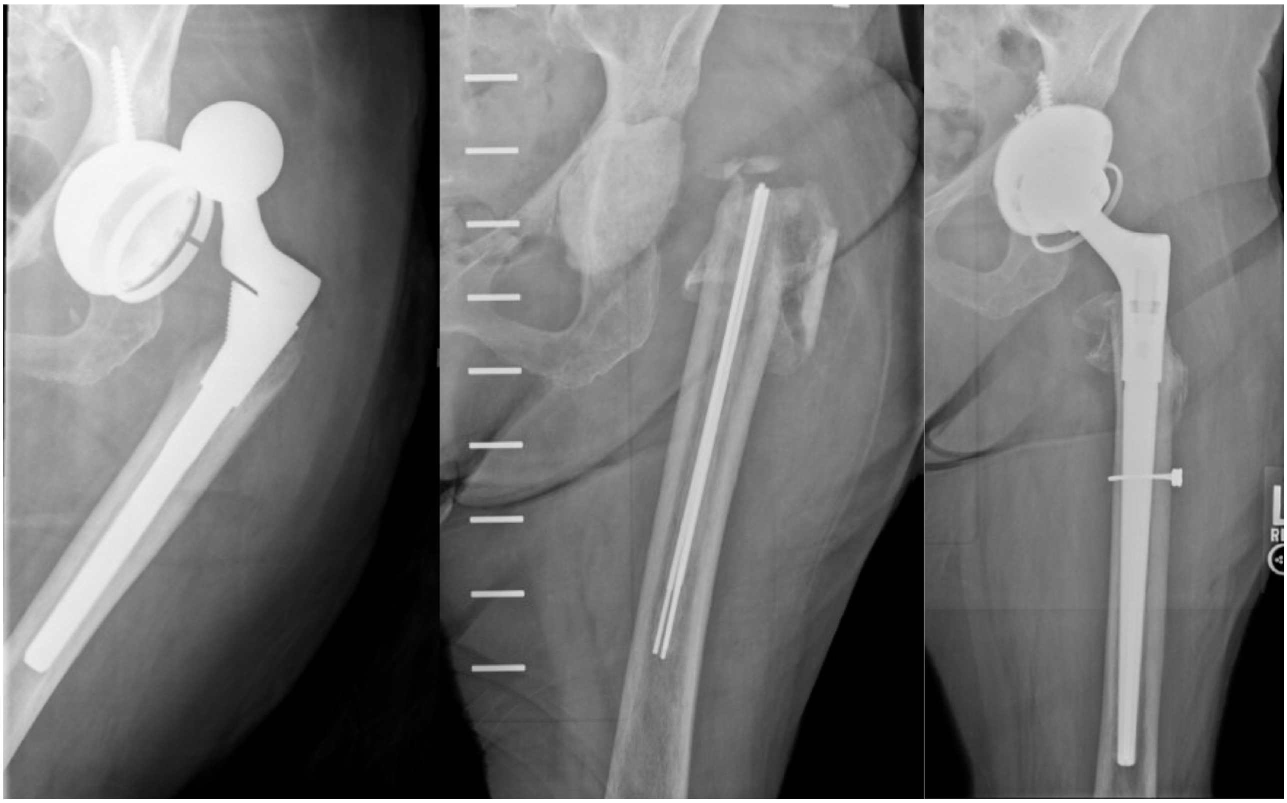

Figure 3 A 76-year-old woman who was transferred for management of a chronically dislocated constrained revision total hip arthroplasty which was infected and had a draining sinus. She underwent implant removal, placement of an antibiotic spacer, and ultimately reconstruction with a tapered modular diaphyseal engaging stem with a constrained acetabular component. The cerclage wire was placed prophylactically to reduce the risk of intraoperative fracture when implanting the press-fit stem.

performed ETO, the osteotomy should be planned to end at least 1-2 cm proximal to the zone of fixation. The surgeon also needs to consider the size of the femoral canal and the length of the planned stem as smaller diameter stems which are bridging a longer distance from the unsupported metaphysis may be at risk of fatigue failure.

Modular Stems

Modular stems, which consist of distal femoral shaft and proximal femoral body segments as independent components, offer some advantages over monoblock stems. The design of these implants allows for distal fixation in the diaphysis of the femur. These designs rely on approximately 3-4 cm of quality diaphyseal bone for adequate fixation, a design feature which must be considered when planning other steps of the procedure, such as an ETO.

The diaphyseal portion of the implant has multiple design options depending on the implant, which can include a conical and/or tapered design or cylindrical design. The cylindrical design can utilize either a smooth design or an ingrowth surface. The tapered design relies upon hoop stresses proximally and requires adequate cortical bone to support such forces.

After removal of the prior femoral component and any cement, the femoral shaft is reamed with the appropriate reamer. The stem is then impacted into place and its stability checked in all directions. Once adequate fixation, the proximal portion is then trialed with the appropriate body and/or head and neck components to restore leg length and soft tissue tension for stability. This usually gives the option to adjust version as well. Once adequate stability is achieved, the trial components are then removed and the proximal body is then attached to the well-fixed stem. Attaining good proximal body fill may require contouring of the proximal segment, with the goal of achieving good bone and/or implant apposition to allow for bony ingrowth. This can be achieved with implant specific instruments, the high-speed burr, or rongeurs and/or curettes. The ETO, if performed, is then repaired with cerclage cables. It is important to note that there is some debate about the actual amount of good diaphyseal bone necessary to support a tapered, fluted design with some surgeons advocating for as little as 2-3 cm necessary.

Significant Metaphyseal and Diaphyseal Bone Loss

Proximal Femoral Replacement

Proximal femoral replacement is typically reserved as a salvage procedure for patients who have extensive bone loss proximally (Paprosky IIIB). As with the above procedures, the preoperative planning is critical and this includes

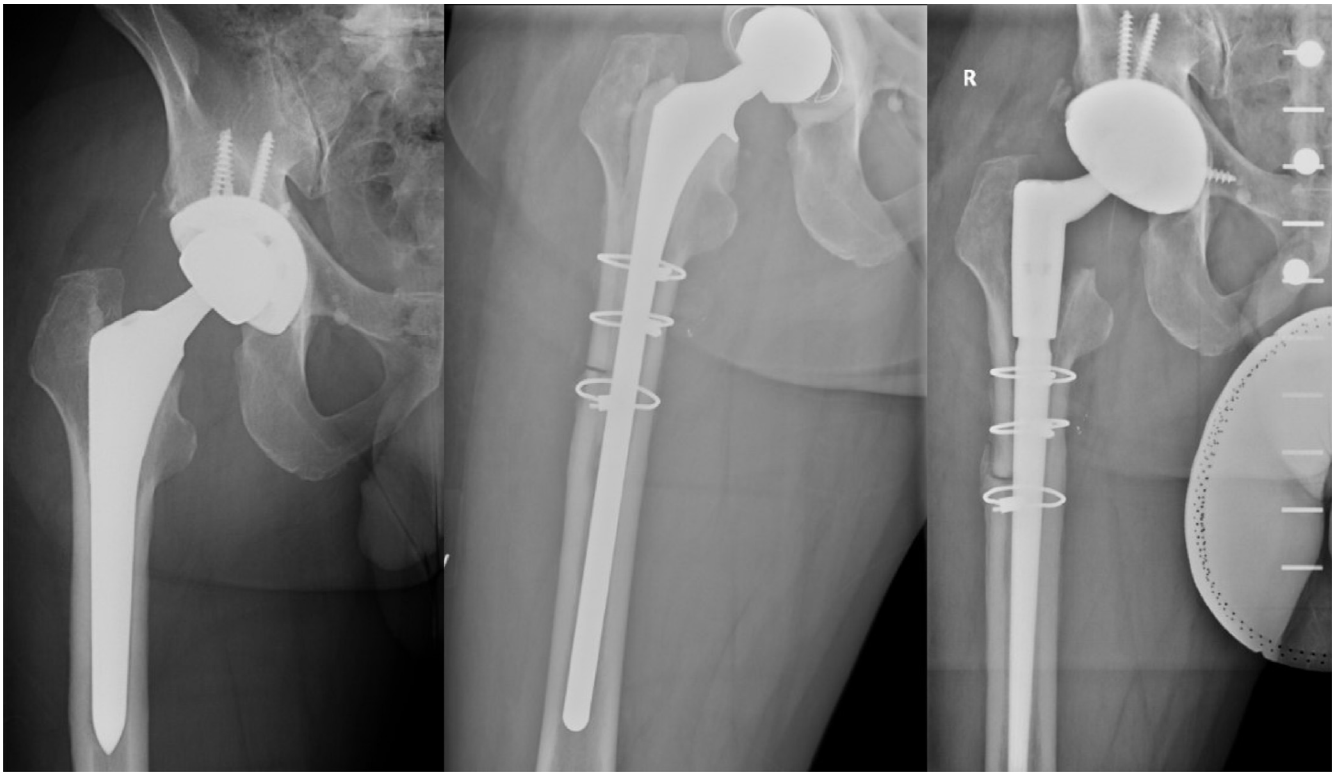

Figure 4 A 66-year-old man revised for infection requiring extended trochanteric osteotomy for implant removal. He underwent antibiotic spacer placement and ultimately was reconstructed with tapered modular diaphyseal engaging stem.

obtaining a thorough history and physical noting any prior procedures, prior scars, any leg length discrepancy, and the function of the abductors. Leg length differences are of particular importance as the operative leg may need to be lengthened substantially to attain stability with the concomitant risk to neurologic function.

Preoperative radiographs should be carefully reviewed to note the area of quality bone stock to which the megaprosthesis will be attached. For a proximal femur replacement, approximately 10 cm of quality distal diaphyseal bone should be present. If less bone than this is available, then one may consider a total femur replacement, which will not be discussed in this review. Other options to reconstruct Paprosky IIIB defects which we will not discuss in detail include impaction bone grafting and allograft-prosthetic composites, however these techniques have largely fallen out of favor with modern implant availability and relatively poor longer term outcomes by comparison.

The femur is exposed through either a direct lateral or posterolateral approach with the use of a trochanteric osteotomy to improve exposure as needed. If any retained components need to be removed, the osteotomy is performed as far proximal as possible as to retain as much quality femoral bone as possible while making spacer for the intended implant. The proximal femur component is removed and care is taken such that the soft tissue attachments are preserved to any remaining bone to facilitate repairing these to the final prosthesis. The distal canal is then reamed to the appropriate size and the hip stability is the assessed using trial components. Any adjustments are made and then the distal stem is press-fit or cemented into place, using a cement restrictor if possible. As the cemented restrictor in this case is in metadiaphyseal bone it can often be pushed distally by the cement. Stacking multiple cement restrictors or mixing a separate small batch of cement that is allowed to harden first distally can avoid this. Care is taken to ensure the proper anteversion and the final components are assembled and implanted. The adductor complex is then secured to the proximal component using heavy nonabsorbable suture or implant-specific fixation.

Postoperative Care

The goal with each procedure is to allow early weight bearing and mobilization. However, each case should be assessed on a case-by-case basis. Adductor precautions are frequently prescribed to protect the repair of the ETO or soft tissue attachments and weight bearing is often limited initially.

Outcomes

Extended Trochanteric Osteotomy

Outcomes of the extended trochanteric osteotomy have been excellent with several authors reporting over 98% union rates.[4-7] Other complications of the technique include proximal migration of the fragment and bursitis around the trochanter.

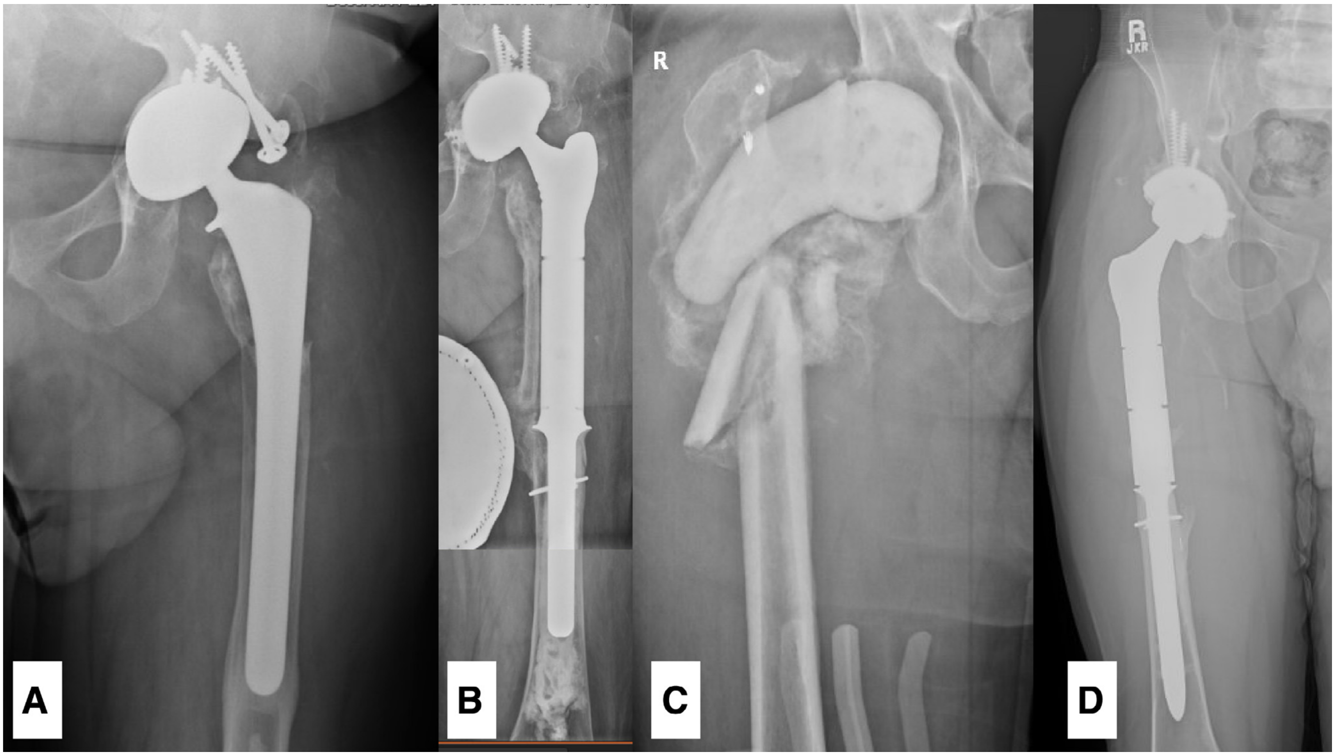

Figure 5 (A) and (B) Pre- and postoperative radiographs of a 65-year-old man who was transferred with severe bacteremia and left hip prosthetic joint infection which had previously undergone multiple revisions. He underwent implant removal and antibiotic spacer placement and ultimately reconstruction with a cemented proximal femoral replacement. (C) and (D) Pre- and postoperative radiographs of a 52-year-old man who had undergone a Birmingham hip resurfacing which was complicated by infection. The infected components were removed and an antibiotic spacer placed at an outside facility. He unfortunately fractured around the cement spacer and presented over a year later. The fractures bone was fully healed in the malunited position around the spacer and he was ultimately reconstructed with a press-fit proximal femoral replacement.

Nonmodular Stems

Extensively coated femoral components have been shown to have excellent results when used in revision hip arthroplasty, with re-revision rates as low as 2%, however this was dependent on the amount of proximal bone loss.[8] When using a nonmodular, tapered fluted design, there was no difference in reoperation when compared to a modular design in a recent retrospective review at a mean of 5-year follow-up, although they did have slightly higher subsidence.[9] Several authors have reported long term survival (>8-year follow-up) between 92% and98.5%.[10,11]

Modular Stems

Modular stems have also been shown to have excellent results and are gaining popularity because of their versatility. These systems have been shown to have excellent survivorship of up to 98% at 5 years, even in the setting of severe femoral bone loss.[12] Another recent review of over 500 revision performed for aseptic loosening showed an overall survival at 10 years of 96%, with the most common reason for re-revision being aseptic loosening.[13] Stem fracture at the modular junction is a rare, but unique complication of these systems.[14]

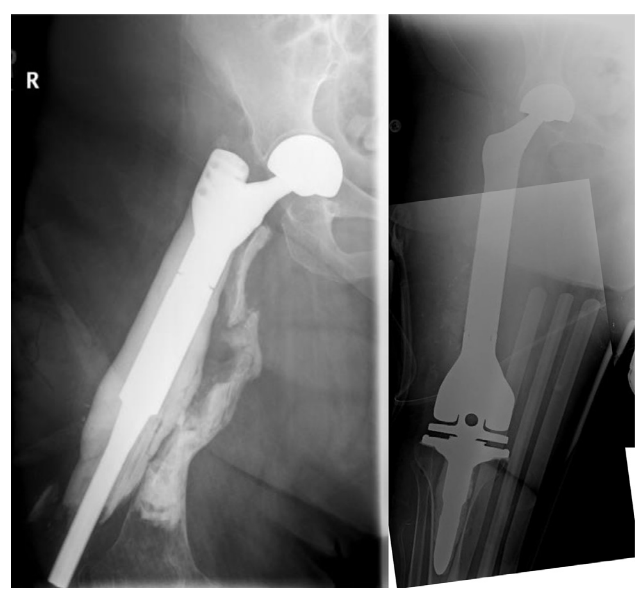

Figure 6 Pre- and postoperative radiographs of a 49-year-old woman who underwent wide resection for Ewing's sarcoma and underwent a proximal femoral replacement which was complicated by infection and treated with 2 stage exchange. She unfortunately fell and presented 3 days later to an outside hospital prior to being transferred to our center for surgical management of her periprosthetic fracture. She was reconstructed with a total femur replacement.

Proximal Femur Replacement

While proximal femur replacements were originally intended for oncology patients, their use has become more wide spread for nononcologic patients given their acceptable outcomes. A recent review by Kormin et al evaluated 14 studies including 356 proximal femoral replacements with an average of 3.8-year follow-up.[15] Nearly 25% of patients required a subsequent reoperation. Dislocation and infection were the 2 most common complications, affecting 15.7% and 7.6%, respectively. More long-term data are needed to better evaluate the outcomes and complications.

Conclusions

Revision THA can represent a significant challenge in the setting of severe bone loss. Determining the cause of the failure, detailing a thoughtful peroperative plan, and using meticulous surgical technique and patience can help to ease some of the frustrations when caring for these complex patients. Overall femoral revision results are favorable however greater bone loss increases the challenge and subsequent complications.

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