Salvage of Failed Total Hip Arthroplasty With Proximal Femoral Replacement

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As a result of reading this article, physicians should be able to:

1. Identify the available types of reconstruction for failed total hip arthroplasty.
2. Summarize the preoperative workup of patients with failed total hip arthroplasty and massive proximal femoral bone loss.
3. Assess the surgical technique of proximal femoral replacement for failed total hip arthroplasty.
4. Recognize treatment complications, patient outcomes, and survival of proximal femoral megaprostheses for revision of failed total hip arthroplasty.

ABSTRACT

Despite recent advances in device manufacturing and surgical techniques, the management of proximal femoral bone loss in revision total hip arthroplasty remains challenging. Currently, failed total hip arthroplasty in elderly and less active patients, nonunion of the proximal femur with multiple failed attempts at osteosynthesis, resection arthroplasty, and massive

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Proximal femoral bone loss can be salvaged with proximal femoral replacement using a megaprosthetic. The procedure is technically demanding and requires careful preoperative planning. Instability and aseptic loosening are the major complications, especially in younger and more active patients. The new generation of modular proximal femoral replacement megaprostheses and the increased experience obtained with these surgeries have reduced complication rates and improved outcomes. [Orthopedics. 2014; 37(10):691-698.]

Revision total hip arthroplasty (THA) procedures are expected to increase by 137% until the year 2030.\(^1\) Reconstruction of major proximal femoral segmental defects is one of the most difficult challenges in these cases. Factors that may contribute to massive loss of femoral bone stock after THA include osteolysis secondary to particulate debris, stress shielding with adaptive bone remodeling, mechanical loosening, infection, periprosthetic fractures, and multiple previous failed reconstructive procedures.\(^2\)

Options for treatment of a compromised femur with bone loss include cementless fixation with a modular tapered fluted stem, impaction grafting,\(^3\) allograft prosthetic composites,\(^4\) proximal femoral replacement with a megaprosthetic,\(^5,6\) and resection arthroplasty. However, for massive proximal femoral bone loss, reconstruction options are limited to proximal femoral replacement and allograft prosthetic composites; their survival has been reported to be longer than other reconstruction options.\(^9\) Compared with allograft prosthetic composites, proximal femoral replacements are not as technically demanding and do not require biologic healing of the allograft-host interface.\(^7,10\)

**HISTORY**

Proximal femoral replacement is a limb-salvage procedure originally designed for reconstruction of bone defects after tumor surgery, when the majority of the proximal bone has been surgically resected or when the biology of the remaining bone is expected to be markedly impaired due to adjuvant chemotherapy and/or irradiation.\(^11,13\) The first report of proximal femoral replacement with a metallic implant was by Moore and Bohlman\(^11\) in 1940 in a patient with a giant cell tumor of the proximal femur. In 1949, Seddon and Scales\(^12\) reported the use of a titanium segmental implant as a salvage procedure in more than 250 patients with nonmalignant and malignant tumors, metastases, and failed THA or osteotomy. In 1981, Sim and Chao\(^13\) reported early success with segmental replacement prostheses in patients with tumors around the hip and therefore began to use a similar technique in patients with failed THA and proximal femoral bone loss. Since then, the indications have expanded and the use of proximal femoral replacement in non-neoplastic conditions has evolved (Figure 1).

**Figure 1:** A 75-year-old woman with a failed total hip arthroplasty revised twice. Anteroposterior radiograph of the left hip showing significant acetabular wear, osteolysis, and bone loss of the proximal femur (A). Intraoperative photographs before (B) and after (C) revision of the femoral prosthesis showing extensive proximal femur bone loss. Revision with a cemented proximal femoral megaprosthetic with a hydroxyapatite collar and a constrained acetabular component (D). Two years postoperatively, the patient was clinically well; lateral (E) and anteroposterior (F) radiographs of the left hip showing no evidence of loosening of the megaprosthetic reconstruction.

**PREOPERATIVE WORKUP**

Patients undergoing proximal femoral replacement are usually elderly, may have had multiple surgeries, and may have medical comorbidities that should be evaluated preoperatively to avoid any perioperative complications because of the complex reconstruction. Each patient must be evaluated to determine whether his or her hip or thigh pain is the result of the failed THA or other conditions such as lumbar...
Local markers such as synovial C-reactive protein, and leukocyte interleukin-6 (IL-6) and other cytokines, are considered the most important diagnostic tool in ruling out periprosthetic infection. Intraoperative photographs at the first stage showing significant bone loss around the femoral prosthesis (D) and removal of the femoral and acetabular prostheses and application of a vancomycin-loaded custom-made spacer (E and F). Intravenous and oral antibiotics were administered for 3 months. Intraoperative photographs at the second stage showing removal of the spacer (G) and implantation of a cemented proximal femoral megaprostheses (H). At 5-year follow-up, the patient was clinically well; anteroposterior radiograph of the left hip showing no evidence of loosening of the megaprosthetic reconstruction (I).

Preoperative examination should include gait analysis and specific tests for the hip, such as the Trendelenburg test for integrity of the abductors, the straight leg test, and the Thomas test. The range of hip motion, motor and sensory function, and vascular status of the lower limb should be documented. Limb lengths are routinely assessed by using blocks under the shorter leg. Any discrepancy between apparent and actual limb length needs to be investigated, and the patient should be informed for the possibility of remaining limb-length discrepancy postoperatively. Infection should be excluded. Laboratory evaluation should include white blood cell count, erythrocyte sedimentation rate, C-reactive protein, complete chemistries, and urinalysis. Joint aspiration is considered the most important diagnostic tool in ruling out periprosthetic infection (Figures 2-3). Local markers such as interleukin-6 (IL-6) and other cytokines, synovial C-reactive protein, and leukocyte esterase from joint aspirate have been proposed with an accuracy of more than 90% in predicting periprosthetic infection. In addition, any other sources of potential or coexisting infection must be treated preoperatively.

Anteroposterior and lateral radiographs of the entire femur are necessary to assess for any femoral deformity, determine the extent of bone resection, estimate the size of the planned megaprostheses, and evaluate bone stock for distal fixation. However, standard radiographs may underestimate the amount of bone loss, particularly if osteolysis is present. Conventional and 3-dimensional reconstruction computed tomography is helpful in establishing periprosthetic osteolysis and its severity. Magnetic resonance imaging is useful to evaluate the medullary canal and soft tissues around the hip joint. Bone scans may be used to diagnose the presence of infection and exclude any metastatic disease.

Preoperative templating is necessary to plan the megaprosthetic reconstruction. However, even with the most accurate preoperative templating, a variety of prosthetic sizes, acetabular cups and rings, and potentially constrained liners should be available in the operating room for the possibility of intraoperative modifications and adjustments of the size of the prosthesis and complex acetabular reconstructions. Instruments for removal of existing hardware should be available.

The surgical wounds around the hip should be inspected and, if possible, a previous skin incision should be used. If a new incision is planned, the possibility of skin flap necrosis should not be ignored. Because proximal femoral replacement may require extensive soft tissue dissection, it is important to be prepared for the possibility of a large volume of blood loss. The use of a cell saver should be considered in noninfected cases. The type of anesthesia is also critical; spinal anesthesia is preferred.

**Surgical Technique**

The surgical technique of proximal femoral replacement has been previously described by Sim and Chao and more recently by Parvizi et al. The patient is placed in the lateral decubitus or supine position. An anterolateral or posterolateral approach with trochanteric slide osteotomy is routinely used. Multiple previous surgeries and scar tissue may make muscle identification difficult, emphasizing the need for adequate exposure and skin incision. Careful soft tissue handling helps the tissues to heal and minimizes postoperative complications. The abductors are identified, transected through
their tendinous attachments, and retracted, exposing the joint and acetabulum. The vastus lateralis should be preserved for coverage of the prosthesis. The pseudocapsule and scar should be removed to expose the prosthesis. After a thorough capsulectomy, the hip is dislocated, and meticulous debridement is performed to remove metallic debris and hardware around the femur, if present. Deep tissue specimens for frozen section and cultures should be obtained.\textsuperscript{13,15}

The acetabulum is examined carefully. If a previous acetabular component is in place, the stability and orientation of the component should be evaluated intraoperatively. If the component is appropriately positioned and stable, it may be left in place and its liner exchanged after femoral reconstruction. If no previous component is in place and/or the fixation and orientation are not appropriate, acetabular revision should be performed. The type of acetabular liner should be determined after reconstruction of the femur because it may be necessary to use constrained liners if intraoperative instability is documented. An absolute indication for the use of a constrained liner is intraoperative instability secondary to soft tissue deficiency in patients with properly positioned components and equal or near-equal leg length.\textsuperscript{13,15}

A vertical osteotomy to split the proximal femur may be required if the femur is intact, to facilitate removal of the previous prosthesis. Soft tissue attachments are preserved. The distal osteotomy is performed distally to the bone defects; the goal is to retain the maximum possible length of the distal femur for optimal stability of the megaprosthesis.\textsuperscript{15} The femoral canal is prepared with reamers and broaches for intramedullary stem fixation. After completion of femoral canal preparation, trial components are inserted. A trial reduction assesses stability and soft tissue tension, which must be sufficient to provide joint stability and avoid dislocation. The length of the prosthesis should equal the length of the resected bone segment. Balancing tension, restoring limb length, and avoiding extensive tension on the sciatic nerve are important.

Cemented fixation of the megaprosthesis is performed.\textsuperscript{9,13,15} A polyethylene cement restrictor is placed 2 cm beyond the tip of the chosen femoral stem whenever possible. The femoral canal is washed and cleaned with pressure lavage and dried with a gauge. Cement is prepared with vacuum mixing and centrifugation; then, cement is delivered into the dried femoral canal with a cement gun in a retrograde manner. Next, the stem is introduced.

Figure 3: A 76-year-old diabetic woman with multidrug-resistant Pseudomonas aeruginosa–infected failed total hip arthroplasty. Anteroposterior radiograph of the right hip showing loosening of the prosthesis (A). A 2-stage revision surgery was performed. Removal of the infected prosthesis at the first stage (B) and application of a colistin-loaded cement spacer (C). Intravenous colistin was administered for 6 weeks. Intraoperative photographs at the second stage showing removal of the spacer (D) and implantation of a cemented proximal femoral megaprosthesis (E). At 3-year follow-up, the patient was clinically well; anteroposterior radiograph of the right hip showing no evidence of loosening of the megaprothetic reconstruction (F).
with axial pressure, avoiding varus positioning. The implant is held in place as the extra cement is removed, and the cement is allowed to polymerize. A cement-within-cement technique may be used in situations where there is an intact cement mantle. In these cases, the existing old cement is prepared with either a burr or an ultrasound tool to create a surface that will promote interdigitation of the new cement. Then, the cement mantle is cleaned and dried, and the new cement is placed in the canal in the liquid phase.\textsuperscript{19,21}

The hip is irrigated and reduced, and the posterior capsule, short rotators, and abductors are repaired using sutures passed through the holes of the prosthesis. Occasionally, the abductor mechanism is attached to the vastus lateralis, the tensor fasciae lata, or the host greater trochanter, if present. Some megaprostheses allow direct reattachment of the abductors with a plate and screws. Alternatively, soft tissue reattachment can be done by using synthetic tubes such as from polyethylene terephthalate (Trevira; Telos, Hungen-Observohofen, Germany).\textsuperscript{22}

Intravenous prophylactic antibiotics are administered until final cultures are obtained. Thromboembolic prophylaxis with low-molecular-weight heparin is administered for 5 weeks. Postoperative mobilization with a hip abduction brace is important to reduce the dislocation rate.\textsuperscript{9,13,15} Sim and Chao\textsuperscript{13} used a balanced suspension splint for 7 to 10 days postoperatively and reported a dislocation rate of 10%. Protected weight bearing is instructed for 12 weeks for adequate soft tissue healing; within this period, the patient is usually able to ambulate with the use of a walking assistance.\textsuperscript{15}

**Complications**

The 2 major complications of proximal femoral replacement for failed THA are instability and aseptic loosening; other reported complications are periprosthetic fracture, infection, and leg-length discrepancy.\textsuperscript{5,6,8,13,17}

The rate of instability ranges from 18% to 50%.\textsuperscript{5,6,8,17} The degree of instability is higher than that of a conventional revision THA surgery,\textsuperscript{23} but is comparable with that of an allograft prosthesis composite for revision of a failed THA.\textsuperscript{24} The causes of instability include age, multiple previous operations with a loose soft tissue envelope and compromised abductors, inability to achieve secure repair of the abductors and secure fixation of the prosthesis to the remaining host bone, and inappropriate soft tissue tension.\textsuperscript{3} To reduce the risk of dislocation, it is important to retain the abductor mechanism and as much of the proximal bone (although of poor quality) as possible and reattach to the megaprosthesis. Cortical struts to enhance the bone stock and provide more surface for soft tissue attachment are desirable for this purpose.\textsuperscript{25,26} In addition, limb-length equality and soft tissue tension are important.\textsuperscript{25,26}

Factors to improve outcomes are intraoperative examination of the stability of the construct, use of a large femoral head, appropriate reconstruction and reattachment of the soft tissue, optimal orientation of the femoral and acetabular implants, use of constraint acetabular liners if hip joint stability is questionable, limb-length equality, and soft tissue tension.\textsuperscript{14} According to Parvizi et al,\textsuperscript{14} the stability of the hip must be examined intraoperatively. A decision regarding the type of acetabular liner to be used should be deferred until the reconstruction of the femur is completed and an impression about the stability of the hip is obtained. Constrained acetabular liners are required in approximately half of patients with a failed THA treated with proximal femoral replacement, when the components are properly positioned and the length is equal or near-equal but instability is observed intraoperatively.\textsuperscript{14} However, with the availability of larger femoral heads in elderly patients who have a low level of activity, constrained liners may be used less frequently.\textsuperscript{20}

Postoperatively, routine use of an abduction brace is recommended.\textsuperscript{9,13,15}

The rate of aseptic loosening of the acetabular and femoral components after proximal femoral replacement for failed THA is relatively high.\textsuperscript{5,8,17} Biomechanically, the long lever arm of the femoral component with the distally fixed portion predisposes the bone-cement prosthesis to high torsional and compressive stresses, leading to early loosening.\textsuperscript{6,9,25} Malkani et al\textsuperscript{6} and Parvizi and Sim\textsuperscript{17} attributed the high rate of loosening of the acetabular component to a 32-mm femoral head and recommended the use of 28-mm instead of 32-mm femoral heads to reduce volumetric wear. Improvements in cementing techniques using pulse lavage and tapping of the canal for better cement interdigitation, as well as availability of implants with longer stems, have contributed to the reduction of the rate of loosening.\textsuperscript{9,25} In addition, the less active the patients, the lower the incidence of radiolucency and prosthesis loosening.

Failures are often multifactorial and include poor cement technique, undersized broaches, increased stem offset, decreased stem length, rough stem surface, and circular stem cross-section.\textsuperscript{27-30} Offset options are limited in megaprosthesis designs. Larger prostheses may increase the lever arm on the intramedullary fixed stem. The geometry of the stem determines much of the implant’s stability; a smooth surface minimizes abrasion of the cement mantle and allows controlled subsidence within the cement.\textsuperscript{27} Preserving good-quality cancellous bone during femoral canal preparation and centralizing the stem in the cement mantle to avoid areas of weakness or access pathways for particles to the cement-bone interface are important.\textsuperscript{30} Third-generation cement techniques using vacuum mixing and centrifugation reduce the porosity of the cement.\textsuperscript{28} However, there is no convincing evidence that third-generation techniques significantly improve the results of cemented stems.\textsuperscript{28} The cement-within-cement technique has
been advocated in situations where there is an intact cement mantle. Indications for the technique include femoral component removal to increase exposure of the acetabulum, femoral stem fracture with an intact distal cement mantle, or debonding of the femoral component from the cement mantle.\textsuperscript{19,20,31}

Dislocation is the most common complication after primary or secondary femoral megaprosthetic reconstruction, regardless of the indication.\textsuperscript{5,9,32} The rate of hip dislocation following reconstruction of proximal femoral tumors with a megaprosthesis ranges from 2% to 37.5%; bipolar systems are more stable than conventional THA.\textsuperscript{5,9,32} The main reason for dislocation is the lack of abductor force and inappropriate soft tissue reattachment.\textsuperscript{33} To limit the risk of dislocation, a retention cup and postoperative bracing to immobilize the hip in abduction are recommended.\textsuperscript{9} To avoid dislocation of an unconstrained megaprosthesis, soft tissue reconstruction is necessary by using a technique such as direct reattachment to the megaprostheses or indirect reattachment to artificial ligaments and tubes, such as the Trevira tube. The Trevira tube is fixed to the megaprostheses, and the muscles are reattached using non-absorbable sutures.\textsuperscript{22,33,34}

**Outcomes**

The literature lacks information regarding patient outcomes and survival of proximal femoral megaprostheses for revision of failed THA.\textsuperscript{6,8,13-15,35} The clinical results in virtually all related series show significant improvement from preoperative hip scores with respect to pain and function with an acceptable complication rate.\textsuperscript{6,8,13,15} Parvizi et al\textsuperscript{15} reported a similar mode of failure in patients with proximal femoral replacement for a failed THA and for tumors with no difference in outcome with respect to failure, loosening, limp, pain relief, and use of walking aids.

The preliminary report of Sim and Chao\textsuperscript{13} on 21 patients with failed THA indicated that the procedure is valuable in patients for whom resection arthroplasty is the only alternative. At 6-year follow-up, implant survival was 90%; all patients had significant pain relief, and only 1 patient had loosening of the acetabular component.\textsuperscript{13} Johnsson et al\textsuperscript{37} compared the outcome of proximal femoral replacement with that of conventional THA and reported similar passive hip motion, hip muscle strength, walking ability, and activities of daily living. However, limp and positive Trendelenburg sign were more common after proximal femoral replacement. Complications included dislocation in 2 of 9 patients and femoral condyle fracture and stem breakage in 1 patient each.\textsuperscript{9} Malkani et al\textsuperscript{6} reported more than 10-year results of 49 patients (50 hips) with a mean age of 60.6 years who underwent proximal femoral replacement for failed THA. Mean postoperative Harris Hip Score improved significantly at 1 year and remained better, although not significantly so at last follow-up. Pain relief was achieved in 88% of patients at 1 year and 73% of the patients at last follow-up. There was significant improvement in gait and ambulation. However, the rate of failure was higher compared with conventional THA, with an overall megaprostheses survival of 64% at 12 years. The most common complications were loosening of the acetabular (37%) and femoral prostheses (30%) and dislocation (22%). Loosening was the main reason for revision surgery.\textsuperscript{6}

Haventjes et al\textsuperscript{6} studied 19 patients with a mean age of 78 years who underwent proximal femoral replacement for failed THA (aseptic loosening and severe proximal femoral bone loss) for a mean of 5 years. All patients had hip pain relief, but all needed a crutch or other walking aid for ambulation. According to the Merle d’Aubigné hip score, no patient had excellent results, 1 had very good results, 8 had good results, 5 had fair results, and 2 had poor results. Four patients experienced an intraoperative fracture, 7 experienced a dislocation, 2 had a deep infection, and 3 had progressive loosening of the screws fixing the greater trochanter to the femoral component.\textsuperscript{6} Klein et al\textsuperscript{25} reported the short-term results of 21 patients with a mean age of 78.3 years with Vancouver type B3 fractures (periprosthetic fracture with severe proximal bone deficiency and a loose femoral prosthesis) treated with proximal femoral replacement. At a mean of 3.2 years, all patients except 1 were able to walk independently with minimal or no pain. Complications included a non-progressive and asymptomatic radiolucent line at the bone-cement interface of the femoral prosthesis in 4 patients, persistent wound drainage in 2 patients, dislocation in 3 patients, fracture distal to the stem in 1 patient, and acetabular failure in 1 patient.\textsuperscript{35} Shih et al\textsuperscript{36} evaluated the clinical outcome of 12 patients with a mean age of 59 years. At a mean of 5.7 years, 8 patients experienced a satisfactory result, 1 a fair result, and 3 a poor result; mean Harris Hip Score improved significantly at last follow-up. Complications included dislocation in 5 patients, deep infection in 4, heterotopic ossification in 1, more than 3-cm limb-length inequality (shortening) in 2, displacement of the greater trochanter in 3, and aseptic loosening in 1. The high early dislocation rate improved significantly with routine use of an abduction brace.\textsuperscript{36}

Parvizi et al\textsuperscript{4} studied 48 patients with a mean age of 73.8 years who underwent proximal femoral replacement with or without bone grafting for a periprosthetic fracture, failed infected THA, nonunion of an intertrochanteric fracture, and radiation-induced osteonecrosis with a subtrochanteric fracture. At a mean of 36.5 months, no significant improvement of function (Harris Hip Score) was observed. Survival of the megaprostheses was 87% at 1 year and 73% at 5 years; 10 patients required a reoperation because of at least 1 complication.\textsuperscript{34} Hrdes et al\textsuperscript{37} reported the complications and function of 28 patients with an average age of 72 years treated with a proximal femoral replace-
ment for a failed THA secondary to large bone defects, infection, periprosthetic fracture, or aseptic loosening. At a mean of 43 months, 8 patients underwent 1 or more revision surgeries because of dislocation, aseptic loosening, and infection. Pain relief was significant in all patients; however, walking aids were necessary for the majority of them.37 Sewell et al38 studied 15 patients with a mean age of 67 years who underwent proximal femoral replacement for a failed THA (infection, aseptic loosening, periprosthetic fracture, and painful resection arthroplasty). Mean Harris Hip Score and Toronto Extremity Salvage Scores improved significantly at last follow-up. Five-year survival of the megaprostheses was 87%; failures included 2 dislocations and 2 infections.38 Al-Taki et al59 evaluated the quality of life (Western Ontario and McMaster University Arthritis Index score, Oxford Score, and Short Form 12 score) of 63 patients who underwent proximal femoral replacement for severe bone loss after failed THA. At a mean of 3.2 years, pain relief and function were similar to patients who had revision using a conventional hip revision system. Although quality of life improved, improvement was not as remarkable with patients with conventional hip revision, probably because the patients with proximal femoral replacement had undergone a larger number of previous operations.39

**Conclusion**

Proximal femoral replacement is a valuable option for patients, especially elderly patients with large femoral bone defects. However, careful preoperative planning is necessary, and surgical expertise is important for optimal patient outcomes.

**References**


