ABSTRACT

Background: In revision total hip arthroplasty (THA), modular femoral components aid the surgeon in reconstructing joints compromised by loss of bone and soft-tissue integrity, providing customization to address bony deficits, deformity, limb length, and offset challenges. The purpose of this study was to review the survival and outcomes at minimum five-year follow up of patients who underwent revision THA at our center with a single modular femoral revision hip system offering a wide range of proximal...
body and distal stem geometries and sizing options.

Materials and Methods: A query of our private practice arthroplasty registry revealed 66 consented patients (69 hips) who underwent revision THA using a modular femoral stem between December 2009 and July 2013 with minimum five-year follow up. There were 35 men (53%) and 31 women (47%). Mean age was 65.2 years (range, 36–87). Etiology for index revision was 32 aseptic loosening, 20 infection, nine periprosthetic fracture, three nonunion of internal fixation, three instability, one stem breakage, and one metal complication.

Results: Mean follow up was 6.3 years (range, 5–9). Harris Hip Scores improved from a mean of 45.4 preoperatively to 72.0 at most recent evaluations. There have been four re-revisions of the femoral stem: one infection, two periprosthetic femoral fracture, and one (proximal segment only) for instability. Radiographic assessment revealed satisfactory position, fixation, and alignment in all hips. Radiographic subsidence of 6–10mm occurred in four (none revised), and none had subsidence > 10mm. There were no modular junction failures. Kaplan-Meier survival to endpoint of femoral revision was 93.3% (95% CI ±3.3%) at 8.7 years.

Conclusions: The minimum five-year results of this modular THA revision system are promising, with low rates of aseptic failure, minimal subsidence, and no modular junction failures. While there may be roles for the use of non-modular revision stems, the mid-term clinical results in this cohort of patients was found to be acceptable.

INTRODUCTION

In revision hip arthroplasty, the primary goals are to provide a stable construct and to relieve pain. Oftentimes, in the revision setting, there is proximal bone loss from stress shielding, osteolysis, or possibly from iatrogenic damage during implant removal. When the proximal bone is too deficient to support a stem that relies on proximal fit and fill, diaphyseal engaging stems are the best available options. These include monoblock extensively-porous-coated stems, monoblock fluted-tapered stems, and finally modular-fluted-tapered stems.

Expanded cortices, varus remodeling, leg-length discrepancy, and instability are other common challenges surgeons may face with femoral revision. With monoblock fully-coated stems, attaining hip stability and implant fixation can be extremely difficult in these situations. Modularity allows hip surgeons to address complex scenarios in the revision setting. Specifically, femoral reconstruction in the setting of bone deficiency often requires customization of version as well as proximal to distal sizing. The authors currently utilize a modular fluted tapered stem for the majority of femoral revisions because of the ease of implantation and versatility of the modular design.

We previously reported on the early results of this modular tapered femoral stem, and now we review the mid-term clinical results. This stem design has undergone a proprietary process of roller-hardening of the taper junction, which provides up to three times more strength in cantilever beam testing. This process helps prevent modular junction failure, which has been reported in the literature with several modular stem designs. We review the indications, surgical technique, mid-term clinical and radiographic results, and survival of a consecutive series of patients undergoing revision THA performed using a single modular femoral revision system that offers three proximal body types, five distal stem geometries, and a wide range of offset and sizing options.

MATERIALS AND METHODS

A query of our private practice’s arthroplasty registry revealed 66 patients (69 hips) who signed an IRB-approved general research consent allowing retrospective review, and they underwent THA performed with a modular, titanium alloy femoral revision system using tapered stems (Fig. 1; Arcos® Modular Revision Hip System; Zimmer Biomet Inc., Warsaw, Indiana) between December 2009 and July 2013. There were 35 men (53%) and 31 women (47%). Mean patient age at surgery was 65.2 years (range, 36–87) and body mass index (BMI) was 30.9 kg/m² (range, 19–49). Procedures performed were conversion in five (7.2%), revision in 45 (65.2%), and two-staged exchange for infection in 19 (27.5%). The underlying diagnoses for conversion cases were Crowe III developmental dysplasia previously treated with multiple surgeries including osteotomies of the pelvis and femur in one, failed open reduction and internal fixation (ORIF) of fracture secondary to non-union in two, and failed hemiarthroplasty due to femoral loosening in two. For the revision procedures, underlying diagnoses were aseptic loosening in 30, periprosthetic femoral fracture in nine, instability with insufficient femoral offset in three, and one each component breakage, septic arthritis, and adverse reaction to metal debris (ARMID) from taper corrosion.
Participants in the present study underwent a detailed history and physical examination, and good-quality radiographs were obtained. A laboratory profile, including complete blood count, erythrocyte sedimentation rate, and C-reactive protein, was performed on all patients to screen for periprosthetic joint infection, and if elevated, an aspiration was performed. Radiographs were scrutinized to determine the extent of osteolysis, cortical perforations, proximal deformity, cement mantles, and the need for a femoral osteotomy. Templating was performed to determine the approximate stem length and diameter as well as proximal body size and offset.

When choosing a surgical approach for revising femoral components, a number of factors must be taken into account. Surgeon preference and experience, type of stem being revised, bone quality, and whether concomitant acetabular revision is required are all critical. The authors’ preferred approach for revision hip surgery is a direct lateral approach with minimal dissection of the anterior third of the gluteus medius and minimus. A proximal femur osteotomy is sometimes performed depending on the fixation of the proximal femur osteotomy fragment. The vastus lateralis and the anterior third of the abductors are elevated from the anterolateral femur as one continuous sleeve of tissue. Anterior-based osteotomies are preferred by the authors if a proximal femur osteotomy is required. Two major advantages of the anterior-based osteotomy are excellent access to the existing stem as well as allowing the canal to be prepared with a straight tapered reamer, while minimizing the risk of anterior cortical perforation.

Once the previous stem and any remaining cement have been removed from the femoral canal, the femur is prepared using sequential straight tapered reamers. A hand-reaming technique is preferred because of the tactile feedback provided. Removing too little bone may lead to implant subsidence, while removing too much bone may weaken the cortex. The surgeon must be careful to ensure the reamers are going straight down the canal and not perforating the cortex. Fluoroscopy can be used to assist if there is any question about perforation. The implant system has markings on the instrumentation to measure depth from the tip of the greater trochanter. After the appropriate depth and adequate reaming is achieved, a trial or final tapered stem is inserted into the diaphysis. If an osteotomy was performed, a prophylactic cable is placed distal to the osteotomy to resist hoop stresses. If this prophylactic cable is not placed, these aforementioned hoop stresses could lead to fracture distal to the osteotomy site during stem insertion. Longer stems have a bow to accommodate the anterior bow of the femur. The implant is driven down until it ceases to advance any further distally, and then the proximal femur is prepared with specific reamers to accept the largest possible diameter proximal body. Proximal bodies and heads are trialed until the appropriate length, offset, and anteverision are determined. After selecting and securing the appropriate proximal body, the femoral osteotomy fragment can now be secured with cables.

The main risk for intraoperative complication with implantation of this type of stem is femoral perforation during reaming and seating of the component. As mentioned previously, reaming under fluoroscopy and using anterior-based proximal femur osteotomies decreases the risk of this complication. Postoperative complications specific to this type of stem design include subsidence and component breakage at the modular junction. Tactile feedback from hand reaming, and examining the amount of bone removed allows the surgeon to remove an appropriate amount of bone to decrease subsidence risk. Modular junction fracture has decreased over the years because of manufacturer modifications, including utilization of the propriety roller hardening process. There is still an increased risk in femurs with complete loss of proximal bone that leaves the modular junction unsupported. These cases are probably better suited for proximal femur replacements.

Postoperatively, patients were typically placed on toe-touch weight-bearing restrictions for six weeks and then

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**Figure 1.** The modular, tapered titanium-alloy femoral revision hip system used in the current study (Arcos®, Zimmer Biomet Inc.). The three proximal and five distal stem geometry options provide surgeons with a wide range of different proximal/distal combinations and multiple auxiliary options to address femoral defects. (Photo reproduced courtesy of Joint Implant Surgeons, Inc.)
gradually progressed according to the level of healing and complexity of the revision. Patients were evaluated at six weeks, one year, and annually thereafter with clinical assessment including the Harris Hip Score (HHS). Radiographs obtained at each visit included standing anteroposterior (AP) pelvis, lateral, and an additional AP view of the affected hip. The femoral component was assessed using the zones of Gruen, noting the presence of bone deficits, osteolysis, radiolucency, hypertrophy of the femoral shaft, heterotopic ossification according to the Brooker classification, stem subsidence or migration, healing of the greater trochanter, healing of any fracture site, and presence of radiolucencies about any ORIF device used.

RESULTS

The surgical approach was direct lateral in all cases, with femoral osteotomy required in 17 hips (25%). Of those, two were a simple episiotomy and 15 were the anterior extended trochanteric osteotomy. Type of proximal femoral component bodies used were cone in 62 (90%), broached in one (1%), and calcar in six (9%). Proximal component diameters used were 18.5mm (A) in 28 (41%), 20.5mm (B) in 14 (20%),

Figure 2. A 64-year-old male patient with a BMI of 40.9 kg/m2 and a history of diabetes mellitus presented 18 years after primary left cementless total hip arthroplasty with a well-functioning modular stem and complaint of moderate pain and fullness in the proximal thigh beneath the previous incision. He also had a persistent high fever. Laboratory profile confirmed diagnosis of infection. a) Preoperative radiograph reveals a cementless S-ROM femoral component (DePuy Synthes, Warsaw, Indiana) with mild osteolysis in Gruen zones 1, 2, 6, and 7. b) The patient was treated with a two-staged exchange for infection. Radiograph revealed placement of a molded spacer of antibiotic-laden cement after complete debridement of the joint via an extensile direct lateral approach with anterior trochanteric osteotomy. c) After an interval of six weeks, with intravenous antibiotics administered in consultation with an infectious disease specialist, the patient underwent reimplantation with an Arcos® modular revision femoral component with calcar high offset proximal body mated with a straight tapered splined distal stem, ultraporous acetabular component with multiple screw fixation and highly crosslinked polyethylene liner, and a 40mm cobalt chromium head. Polymer cables and a claw were utilized to close the osteotomy. d) At five years postoperative, the patient is doing well with no pain and has a Harris Hip Score of 90.5. Radiograph reveals healing of the previous osteotomy and development of Brooker III heterotopic ossification which has had no clinical significance.
abductor tendon repair in two patients due to persistent weakness and pain, one incision and debridement with revision of the head and liner due to a non-healing wound, a partial two-staged exchange of the acetabular component only for infection, and open reduction and internal fixation of a periprosthetic femoral fracture in one patient at an outside hospital. Kaplan-Meier survival to endpoint of femoral revision was 93.3% (95% CI 2.3-33.3%) at 8.7 years.

Postoperative radiographs were available for review for all 69 THA in 66 patients. Analysis of the femoral components revealed satisfactory fixation and alignment in 64 hips. Bone was maintained and healing of osteotomies and fracture sites was evident in these hips. Four hips had radiographic changes including bone deficit, osteolysis, radiolucency in one or more zones, and one hip had Brooker III heterotopic ossification. Four stems showed evidence of subsidence between 6 and 10mm, but subsequently stabilized, obviating the need for further revision. No stems subsided beyond 10mm.

Our minimum five-year results with the Arcos® modular tapered stem are promising. Mid-term results of other modular tapered stem designs used in revision hip arthroplasty have been reported and demonstrate excellent survivorship beyond five years.7,11-17 Multiple reports have demonstrated success of modular tapered stems in patients with extensive femoral bone loss. Mid-term survival rates were well over 90%, maintenance of bone stock was achieved, and there were low rates of subsidence.5,18-19 Implant stability, bony ingrowth, restoration of leg length, and appropriate offset across all Paprosky classifications has also been demonstrated.20 In addition to being a good option for bone loss, these stems are also ideal in reconstruction after periprosthetic femoral fracture. With a variety of stem lengths available, high rates of fracture union, bone preservation, and implant osseointegration have been shown in these studies.21-23 Better outcome scores and less intraoperative fractures have also been found with modular tapered stems compared to fully-porous-coated cobalt-chromium stems.24,25

Some studies argue that modularity is not always necessary, mainly because monoblock stems tend to be less expensive, yet have similar outcomes.24,27 Modular junction failure is also a concern with these types of implants.1-4 With manufacturing improvements and better patient selection, the risk of stem fracture at the modular junction is much lower than in the past. In our cohort of patients, there were no modular junction failures at an average of 6.3 years’ follow up. One study comparing modular and monoblock stems showed a higher rate of re-revision in the monoblock group as well as a Kaplan-Meier estimated survival of only 72.9% at four-year follow up.28

There are clear advantages of modularity in femoral stems. Modularity allows the surgeon to make more precise intraoperative adjustments in anteversion and sizing, which may lower the risk of instability and promote osseointegration. Monoblock fully-porous-coated designs are unable to have this type of versatility in complex scenarios and are more prone to failure.26 The tapered geometry of the modular stem allows it to be used in the most severe cases of femoral bone loss which would be more difficult with a fully-porous-coated stem. As was the case when we reported on the early results of the Arcos® stem,2 HHS in this series are also relatively low, but significantly improved compared to the preoperative levels, and showed improvement with longer follow up. In our earlier review, we observed a mean HHS of 66.0 at 1.5 years’ follow up, compared with a mean HHS of 72.0 in the current study at a mean follow up of 6.3 years. This suggests that patients continue to improve beyond the initial 18 months postoperative. Our excellent radiographic results and mid-term survival of this modular tapered stem support that it is a more than acceptable option for tackling the daunting task of revision hip arthroplasty (Fig. 3a–d).

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### DISCUSSION

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Mid-Term Results of Modular Tapered Femoral Stems in Revision Total Hip Arthroplasty

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roles for the use of non-modular revision stems, the mid-term clinical results in this cohort of patients was found to be acceptable.

AUTHORS' DISCLOSURES

Research funding in direct support of this study was received from Zimmer Biomet, Inc. Dr. Lombardi and Dr. Berend are consultants to, and receive royalties from Zimmer Biomet Inc., receive royalties from Innomed, Inc., and have minority investment interests in SPR Therapeutics, Joint Development Corporation, Elute Inc., and ValMed.

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