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Modular Femoral Tapered Revision Stems in Total Hip Arthroplasty

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Abstract

Background: Modular component options can assist the surgeon in addressing complex femoral reconstructions in total hip arthroplasty by allowing for customization of version control and proximal to distal sizing. We review the early clinical results of a single modular femoral revision system that offers 3 proximal body types, 5 distal stem geometries, and a wide range of offset, sizing and auxiliary options.

Methods: A query of our practice's arthroplasty registry revealed 60 patients (61 hips) who signed an IRB-approved general research consent allowing retrospective review, and underwent total hip arthroplasty performed with the modular femoral revision system between December 2009 and April 2012. There were 35 men (58%) and 25 women (42%). Mean age was 65.1 years (range, 35-94) and BMI was 31.3 kg.m2 (range, 14-53). Procedures were complex primary in 1 hip, conversion in 6 (10%), revision in 32 (53%), and two-staged exchange for infection in 22 (33%). Two-thirds of procedures included complete acetabular revision (n=40), while 31% (19) involved liner change only and 2 were isolated femoral revisions.

Results: At an average follow-up of 1.5 years (maximum: 3.7 years) there have been no revisions or failures of the femoral component. Average Harris hip scores (0 to 100 possible) improved from 44.2 preoperatively to 66.0 at most recent evaluation, while the pain component (0 to 44 possible) improved from 15.8 to 31.2. Complications requiring surgical intervention included intraoperative periprosthetic femur fracture in one patient returned to the operating suite same day for open reduction internal fixation, which further required incision and debridement for superficial infection at 1 year postoperative; and two patients with dislocation and fracture of the greater trochanter treated with open reduction, revision of the head and liner, and application of cerclage cables, one of which required removal of a migrated claw 10 months later followed 2 weeks subsequently with incision and debridement for a non-healing wound. Postoperative radiographs were available for review for 59 THA in 58 patients. Analysis of the femoral component revealed satisfactory findings in 50 hips (85%) while 9 had radiographic changes that included bone deficit, osteolysis, or radiolucency in one or more zones.

Conclusions: The early results of this modular femoral revision system are promising for the treatment of the deficient femur in complex primary and revision total hip arthroplasty. Patients with radiographic changes are advised to return for regular clinical and radiographic follow-up. Survival of the modular femoral component in this series was 100% at mean follow-up of 1.5 years and up to 3.7 years. While HHS clinical and pain scores were somewhat low at most recent evaluation, they were significantly improved over preoperative levels.

Introduction

The primary goals of revision hip surgery are pain

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relief and long term stable implant fixation. Femoral bone stock in revision arthroplasty is commonly compromised by osteolysis, stress shielding, and iatrogenic damage from implant removal and sometimes multiple revision surgeries. The proximal bone is typically deficient and cannot support stems that rely on proximal fit and fill. This had led to the development of diaphyseal engaging stems that load the diaphysis and bypass the deficient proximal femur. These include monoblock extensively porous coated stems, monoblock fluted tapered stems, and more recently modular fluted tapered stems.

Other common challenges in femoral revision include expansion of cortices, varus remodeling, leg length discrepancy and instability. These challenging situations can make the attainment of stable implant fixation while maintaining hip stability difficult with monoblock stems. Modular stems allow surgeons to establish stable diaphyseal fixation while attaining appropriate leg length and hip stability independently. The authors currently utilize a modular fluted tapered stem for the majority of femoral revisions.

The indications for a modular tapered stem depend on the amount of bone loss and surgeon philosophy. Some surgeons including the authors use this style of implant for the majority of femoral revisions due to the ease of implantation and versatility of the modular design. Some surgeons prefer proximal loading stems for Paprosky Type 1 [1] (Table 1) and Mallory Type 1 [2] (Table 2) femurs with an intact proximal metaphysis. Others may choose extensively porous coated stems for Paprosky Type 2 and 3A and Mallory Type 2 femurs that have intact diaphyseal bone or an isthmus of at least 4 cm for a good scratch fit. Modular tapered stems are recommended by the authors and others for severe diaphyseal bone loss including Paprosky Type 3A femurs with a diameter greater than 19 mm or Paprosky Type 3B femurs with an isthmus less than 4 cm. These situations have shown unsatisfactory failure rates with extensively porous coated stems [1]. Some surgeons have had success with modular tapered stems in Paprosky Type 4 femurs with extensive loss of diaphyseal bone however this stem is contraindicated when stable fixation of the implant is unachievable. Megaprostheses and impaction grafting with cemented stems are other options in this situation. Periprosthetic fractures requiring femoral component revision are effectively treated with modular tapered stems. After exposure and implant removal, the diaphyseal femur can be prepared with tapered reamers and a stable stem can be implanted. The appropriate proximal body is then selected to restore leg length and stability. The fracture fragments can then be reduced around the stem and secured with cables.

Table 1. Paprosky classification of femoral defects [1]

Type	Description
1	Minimal defects, similar to primary total hip arthroplasty
2	Metaphyseal damage, minimal diaphyseal damage
3A	Metadiaphyseal bone loss, 4 cm scratch-fit can be obtained at isthmus
3B	Metadiaphyseal bone loss, 4 cm scratch-fit cannot be obtained
4	Extensive metadiaphyseal damage, thin cortices, widened canals

Table 2. Mallory classification of femoral defects [2]

Type	Description
1	Cortical tube intact, cancellous bone is present
2	Cortical tube intact, cancellous bone is present
3A	Cortical tube intact, cancellous bone is present
3B	Cortical deficiency extending to between lesser trochanter and isthmus
3C	Cortical deficiency extending to between lesser trochanter and isthmus

Heinz Wagner developed a monoblock titanium grit blasted fluted tapered stem. The diaphysis is prepared with tapered reamers until a secure fit is obtained. Engaging the tapered stem into the prepared diaphysis provides axial stability for the implant. Rotational stability is provided by sharp flutes. The grit blasted surface allows for biological fixation and the titanium substrate provides a modulus of elasticity closer to that of bone than cobalt-chromium alloys. This concept may have the advantage of less stress-shielding than fully porous coated cobalt-chromium stems. Modern stem designs are based on this philosophy and have added modular proximal bodies to make the stem more versatile in challenging revision cases. After the tapered stem is secured in the diaphysis the remaining proximal femur is prepared to accept the appropriate sized proximal body. The proximal body that appropriately restores leg length, anteversion, offset and hip stability is attached to the upper portion of the stem. Multiple proximal body geometries are offered by different vendors. A cone proximal body is versatile in allowing customization of version during surgery. A tapered body can allow loading of the proximal femur within the metaphysis. A calcar body also allows loading of the proximal femur via platform loading of the remaining medial supportive bone. The major concern for this type of design is an unsupported taper junction that can be weakened by repetitive stresses. Fractures at the modular junction are reported in the literature on multiple stem designs [3-7]. Manufacturers have developed methods for strengthening the taper junction. The authors currently use a stem design that has undergone a proprietary process of roller-hardening of the taper junction (Biomet, Inc., Warsaw, IN), which according to the manufacturer provides up to three times more strength in cantilever beam testing. We review the indications, surgical techniques utilized, early clinical results and survival of a consecutive series of patients undergoing revision THA performed using single modular femoral revision system that offers 3 proximal body types, 5 distal stem geometries, and a wide range of offset, sizing and auxiliary options.

Methods

A query of our practice's arthroplasty registry revealed 60 patients (61 hips) who signed an IRB-approved general research consent allowing retrospective review, and underwent total hip arthroplasty performed with a modular femoral revision system (Figure 1; Arcos Modular Revision Hip System; Biomet, Inc., Warsaw, Indiana, USA) between December 2009 and April 2012. There were 35 men (58%) and 25 women (42%). Mean age was 65.1 years (range, 35-94) and BMI was 31.3 kg.m2 (range, 14-53). Procedures were conversion in 7 (11%), revision in 32 (53%), and two-staged exchange for infection in 22 (33%). 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 hemiarthroplasty due to femoral loosening in two and periprosthetic femoral fracture in one, and failed open reduction internal fixation of fracture secondary to non-union in three. For revision cases, underlying diagnoses were aseptic loosening in 27, periprosthetic femoral fracture in two, and one each component breakage, failed open reduction internal fixation (ORIF) of fracture secondary to non-union, and instability with insufficient femoral offset. Preoperative femoral deformities according to the Mallory classification were Type 2 in 7 hips (11.5%), Type 3A in 10 (16.4%), and 22 each (36.1%) of 3B and 3C. The planning process begins with a detail history and physical exam as well as appropriate radiographs. All revision cases must have an evaluation to rule out periprosthetic joint infection. Radiographs are examined to determine the extent of femoral osteolysis, cortical perforations, proximal deformity, cement mantles, and the need for a femoral osteotomy. Templating can be performed to determine the planned stem length and diameter as well as proximal body size and offset.

Figure 1. The modular, tapered titanium revision hip system used in the current study (Arcos, Biomet) features three proximal body types and five distal stem geometries with a wide range of sizes, offsets, and auxiliary options. (Photo reproduced courtesy of Biomet).

The surgical approach for femoral revision depends on multiple factors including surgeon preference and experience, type of stem being revised, associated bone loss, and whether acetabular revision is required. A proximal femoral osteotomy may be required depending on fixation of the existing stem and associated proximal femoral deformity. The authors preferred exposure is via an anterolateral abductor splitting approach. The vastus lateralis along with the anterior third of the gluteus medius and minimus are elevated as a continuous soft tissue sleeve from the anterior femur. If a proximal femoral osteotomy is required, the authors prefer either a Wagner transfemoral osteotomy or an anterior extended trochanteric osteotomy (ETO). These anterior based osteotomies provide excellent access to the existing stem as well as remaining cement mantles after cemented stem removal. Another advantage of an anterior based osteotomy is that it allows the surgeon to prepare the canal with straight tapered reamers while avoiding perforation of the anteriorly bowed femur.

Once the previous stem and any remaining cement mantle are removed the surgeon begins preparing the femur with straight tapered reamers. Reaming proceeds until good engagement of the reamer is obtained. The authors prefer to use a hand reaming technique as to gain the appropriate tactile feel of the reaming. Insufficient reaming may lead to subsidence of the implant and over-reaming will remove excess bone leading to weakening of the diaphysis and possible fracture or perforation. Inspection of the reamers provides feedback to how much bone is being removed. Care is taken to make sure the reamers are advancing straight down the shaft of the femur. Fluoroscopy may be used with long reamers to monitor for perforation or to verify the surgeon has bypassed any cortical defects. Most implant systems have markings on the reamers to judge depth based on the tip of the greater trochanter. Once adequate depth and size of reaming is achieved either a trial or final tapered stem is implanted into the diaphysis. If a femoral osteotomy was performed a prophylactic cable is placed distal to the osteotomy before stem insertion. This will help resist the high hoop stresses in this area which can fracture the femur. Longer stems will usually have a bow just proximal to the flutes and tapered region to accommodate for the anterior bow of the femur. The implant is driven into the femur with moderate taps of the mallet until it ceases to advance. The proximal femur is then prepared with implant specific reamers to accept the largest possible diameter proximal body. Trial proximal bodies are placed on the distal stem until the appropriate length, offset and anteversion are determined. The actual selected proximal body is then placed on the distal stem in the desired position determined by trialing and secured according to the vendor's specifications. The hip is then reduced with the appropriate size femoral head. If an extended trochanteric osteotomy was performed the fragment can now be reduced and secured to the femur with cables. A burr is used to shape the undersurface of the fragment if it does not fit ideally against the femur with the prosthesis in place.

The main intraoperative complications specific to modular tapered stems are femoral perforation and fracture during reaming and implantation. As described above, an anteriorly based proximal femoral osteotomy and reaming under fluoroscopy can decrease the risk of perforating the anterior cortex due to the femoral bow. A prophylactic cable distal to the femoral osteotomy will help resist high hoop stresses in this area which could result in fracture.

Postoperative complications specific to this type of stem are implant subsidence and fracture at the modular junction. As described above, hand reaming the canal allows the surgeon to have tactile feel of the reamer engaging the diaphysis. This technique aids in achieving an adequate ream to prevent subsidence while not removing excessive bone. Fluoroscopy can also be used to evaluate the size of the last reamer in relation to the size and shape of the canal. Manufacturers have made modifications to the modular junction to prevent the risk of fracture. Despite these modifications, femurs with complete loss of proximal bone will leave the modular junction unsupported and at risk for fracture. These cases may be better treated with a proximal femoral replacement.

Postoperatively, patients were typically placed on weight bearing restrictions for 6 weeks and then progressed according to the level of healing and complexity of revision. Patients were evaluated at 6 weeks, 1 year, and annually thereafter with clinical assessment including the Harris hip score (HHS) [8]. Radiographs obtained at each visit included standing anteroposterior (AP) pelvis, lateral and additional AP view of the affected hip. The femoral component was assessed using the zones of Gruen [9], noting presence of bone deficits, osteolysis, radiolucency, hypertrophy of the femoral shaft, heterotopic ossification according to the Brooker classification [10], stem subsidence or migration, healing of the greater trochanter, healing of fracture site, radiolucencies about and fixation of ORIF device.

Results

The surgical approach was the anterolateral abductor splitting in all cases, with femoral osteotomy required in 25 (41%). Of those two were a simple episiotomy, 3 were Wagner transfemoral, and 20 were the anterior extended trochanteric. Proximal type femoral component bodies used were cone in 54 (89%), broached in 6 (10%), and calcar in one. Proximal component diameters used were 18.5mm (A) in 20 (33%), 20.5mm in 13 (21%), 22.5mm (C) in 10 (16%), 24.5mm (D) in 14 (23%), and 26.5mm (E) in 4 (7%). A 28.5mm diameter (F) is also available. Standard offset proximal bodies were used in 25 hips (41%), while high offset bodies with an added 6mm horizontally were used in 34 (56%). Distal femoral stems were straight tapered splined (STS) in 55 (90%), bowed STS in 5 (8%), and bowed interlocking distal porous coated in one. Distal diameters utilized ranged from 12- to 25mm, with 15mm being used most frequently (12; 20%). Distal stem lengths utilized were 150mm in 28 hips (45%), 190mm in 27 (44%), 250mm in 5, and 300mm in one. Femoral fixation was augmented by use of cables in 34 hips (56%), a trochanteric grip or plate in 9 (15%), strut allografts in 4 (7%), and crushed cancellous or bone graft substitute in 11 (18%).

Two-thirds of procedures included complete acetabular revision (n=40), while 31% (19) involved liner change only and 2 were isolated femoral revisions. Acetabular components utilized were one custom triflange based on preoperative imaging, one cemented all-polyethylene constrained, 5 standard porous hemispheric, and 33 ultraporous metal. Constrained liners were used in a total of 11 hips including the aforementioned all-polyethylene, and dual mobility devices were used in three. Porous metal augments were used in 2 cases including one posterior column buttress and one further reinforced with impaction grafting. Impacted crushed cancellous allograft was used in 6 additional acetabular reconstructions, bone graft substitute was used to fill cavitary defects in one, and femoral head autograft fixed with 2 cortical screws was used to fill a superior defect in the case of severe dysplasia.

At an average follow-up of 1.5 years (maximum: 3.7 years) there have been no revisions or failures of the femoral component. Five patients died during the study period, with 2 deaths occurring within 90 days of the index procedure. One was an 88-year-old female with BMI of 14.3 kg/m2 who fell and sustained a Vancouver B3 periprosthetic fracture. The other was a 67-year-old male patient undergoing treatment for liver cancer who was revised for gross loosening with impending fracture of a cemented stem. Both patients had returned for their 6-week follow-up visit.

Average Harris hip scores (0 to 100 possible) improved from 44.2 preoperatively to 66.0 at most recent evaluation, while the pain component (0 to 44 possible) improved from 15.8 to 31.2. Complications requiring surgical intervention included intraoperative periprosthetic femur fracture in one patient returned to the operating suite same day for ORIF, which further required incision and debridement for superficial infection at 1 year postoperative; and two patients with dislocation and fracture of the greater trochanter treated with open reduction, revision of the head and liner, and application of cerclage cables, one of which required removal of a migrated claw 10 months later followed 2 weeks subsequently with incision and debridement for a non-healing wound.

Postoperative radiographs were available for review for 59 THA in 58 patients. Analysis of the femoral component revealed satisfactory fixation and alignment in 57 hips (97%) with evidence of bone maintenance and healing of osteotomies and fracture sites. Brooker III heterotopic ossification was evident in one hip. Two hips showed evidence of proximal bone loss or radiolucency in one or more zones, but had healing of osteotomy sites. None showed evidence of loosening or subsidence.

Discussion

Early to midterm results of modular tapered stems used for femoral revision are now being published [5,6,11-18]. One study documented success in achieving implant stability and osteointegration, as well as restoring leg length and offset across all Paprosky classifications [15]. Multiple reports from one institution have demonstrated the success of modular tapered stems for cases of proximal femoral bone loss. The authors demonstrated high mid-term survival rates of 90-94%, maintenance or improvement of bone stock and low subsidence rates [4,13]. Higher outcome scores, better bone restoration and less intraoperative fractures were also found with modular tapered stems compared with fully porous coated cobalt-chromium stems [11,12]. In addition the modular tapered stems were typically used for cases of worse femoral bone loss. Two other papers document high midterm success with these stems in Mallory Type IIIC and Paprosky Type III and IV femurs [16,17].

Encouraging early results in treatment of periprosthetic femur fractures with modular tapered stems are also being reported. These stems were used in Vancouver B2 and B3 femur fractures. High rates of fracture union, maintenance of bone stock and implant osteointegration have been shown in these studies [19,20].

Modular tapered stems are valuable tools in femoral revision cases. The versatility of the design allows for independent attainment of implant fixation and hip stability, which can be challenging with mono-

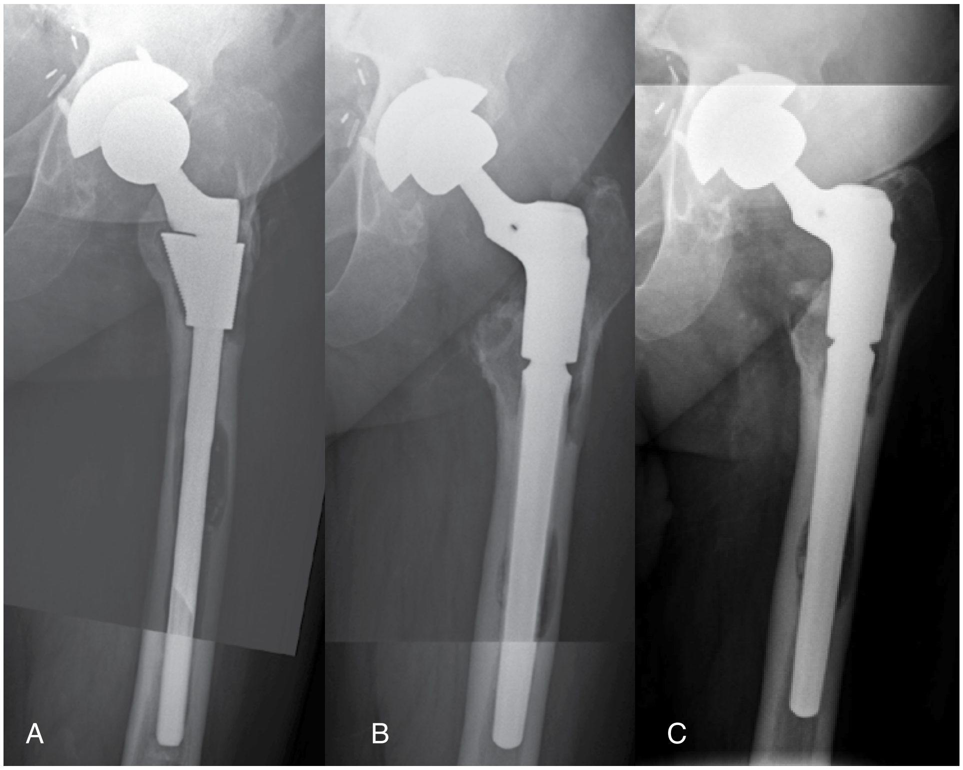

Figure 2. A 65-year-old male patient with BMI of 38.4 kg/m2 presented to our practice 3 years after undergoing left revision cementless THA. He complains of pain and difficult ambulation. He describes the pain as moderate, in the buttock, and occurring intermittently. A) Preoperative radiograph reveals a cementless S-ROM revision femoral component with osteolysis and radiolucencies in all zones. B) Immediate postoperative radiographs reveal treatment with revision of the femoral component and exchange of the polyethylene liner. A cone standard offset body with 22.5mm diameter and 60mm length was used proximally, and mated with a 17x150mm splined tapered straight distal stem. A bone substitute putty was used to fill cavitary defects in the femoral canal. C) At 2 years postoperative the patient is doing well with no pain and Harris hip score of 89. Radiograph reveals satisfactory component fixation and position, with progressive healing of osteolytic defects.

block stems (Figure 2). The tapered geometry of the stem allows for its use even in severe cases of femoral bone loss which preclude the use of fully porous coated stems. Recent advances in design of the modular taper have lead to a decrease in cases of stem fracture. While postoperative Harris hip scores are relatively low in the current series, they were significantly improved over postoperative levels, and likely have not reached maximum benefit given the early follow-up. Excellent radiographic results and early survival are encouraging for the use of this modular hip system in a variety of complex reconstruction scenarios.

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