Fracture of a Dual-Modular Femoral Component at the Stem–Sleeve Junction in a Metal-on-Metal Total Hip Arthroplasty

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Abstract

Innovations in the design of dual-modular femoral components have afforded surgeons several intraoperative advantages during both primary and revision total hip arthroplasty (THA). Although use of these implants has become more popular, the long-term outcomes and potential complications of introducing a second modular junction are still to be determined. In addition, concerns about corrosion potentiation at modular junctions in metal-on-metal (MOM) THA have arisen in recent studies.

In this article, we present a unique case of fracture at the modular junction of the stem and modular sleeve of a dual-modular femoral component implanted with a MOM articulation. The proposed mechanisms of failure, including crevice and fretting corrosion as well as the potential effect of metal debris generated by MOM articulations, are reviewed. This case report is the first to describe component fracture at the stem–sleeve junction of this modern-generation dual-modular femoral component.

Surgeons who encounter a painful dual-modular femoral stem must entertain this mode of failure and consider junctional failure as a potential diagnosis for such a patient, particularly in the setting of a MOM articulation.

Use of modular components during total hip arthroplasty (THA) has continued to increase in popularity over the past decade.[1-5] Advances in dual-modular femoral components offer surgeons several advantages over single neck–head taper or monoblock designs, including the ability to independently adjust femoral anteversion, limb length, and offset. The flexibility afforded by these implants theoretically allows the surgeon to optimize the head–neck ratio in an effort to maximize stability and minimize implant wear. In addition, uncoupling the neck and stem body allows for optimal fixation of the femoral stem without the limitations of a non-modular femoral neck/proximal segment.

Despite these advantages, long-term outcomes of implanting dual-modular femoral implants have been inconsistently reported, and use of some implant designs for primary THA remains controversial. There have been conflicting reports regarding incidence of corrosion[6-11] and metal ion release caused by presence of multiple modular interfaces (head–neck, neck–stem, stem–sleeve). Further, significant complications associated with increased modularity have been reported,[6,9,12-14] including fretting, crevice and galvanic corrosion, component loosening, and implant fracture.

Several authors have recently documented fracture of the femoral component as a potentially serious but underreported mode of failure of dual-modular femoral components.[15-23] In this article, we present a case of fracture at the modular stem–sleeve junction associated with the Emperion dual-modular femoral component (Smith & Nephew, Memphis, Tennessee),[24] in a metal-on-metal (MOM) THA. The patient provided written informed consent for print and electronic publication of this case report.

Case Report

At an outside institution, an active 51-year-old woman (5 ft 8 in, 145 lb; body mass index, 21.6) underwent right THA for treatment of degenerative joint disease secondary to developmental dysplasia of the hip. Review of the operative report revealed use of a standard posterior approach with no reported intraoperative complications. The prosthetic components used (all Smith & Nephew) included an Emperion titanium press-fit dual-modular femoral stem with a modular, porous-coated hydroxyapatite metaphyseal sleeve; a Birmingham Hip Resurfacing monoblock cobalt-chromium acetabular dysplasia component secured with 2 periacetabular screws; and a modular cobalt-chrome femoral head. The initial postoperative course was uncomplicated, and the patient reported significant resolution of preoperative symptoms and resumed a majority of her preoperative activities.

The patient remained asymptomatic for 5 years, but then experienced acute onset of right groin pain while attempting

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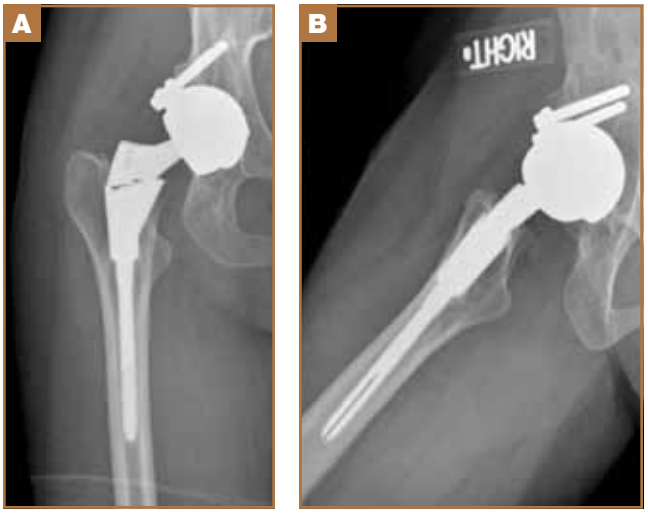

Figure 1. Preoperative anteroposterior (A) and lateral (B) hip radiographs show fracture of femoral component proximal to stem–sleeve modular interface in dual-modular femoral component (Emperion; Smith & Nephew, Memphis, Tennessee).

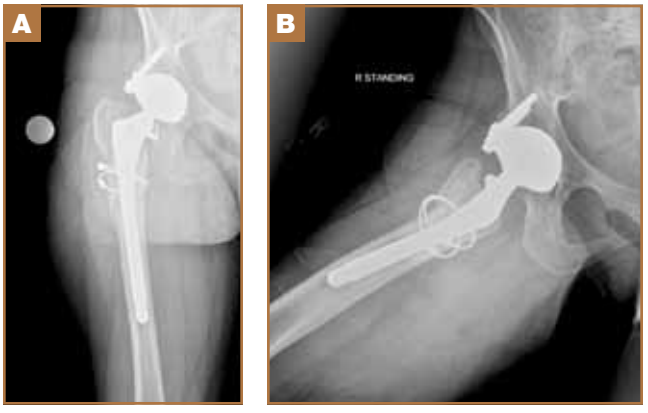

Figure 2. Anteroposterior (A) and lateral (B) hip radiographs about 4 months after surgery show components in appropriate position without evidence of loosening or fracture.

to rise from a seated position, with progressive inability to bear weight on the affected extremity. She went to a local community emergency department, where physical examination revealed a well-healed incision with no signs of erythema or infection. A leg-length discrepancy of 0.5 cm was noted. Radiographs showed a fracture of the femoral component proximal to the junction of the modular sleeve and prosthetic stem (**Figure 1**). Laboratory markers, including erythrocyte sedimentation rate and C-reactive protein level, were within normal limits.

The patient was transferred to our institution for operative treatment by Dr. Levine. The prior incision was used for a standard posterior approach to the hip. An adverse local tissue reaction consistent with metal debris was appreciated in the deep capsular tissues surrounding the proximal part of the implant where a fracture of the stem, proximal to the modular metaphyseal sleeve, was noted with corrosive material at the margins of the fracture site. The modular head and residual prosthetic neck were easily removed from the acetabular component, but the remaining stem and modular metaphyseal sleeve were fully ingrown and well fixed to the proximal femur. A short trochanteric osteotomy was performed, and the bond between the modular sleeve and metaphyseal bone was disrupted. Intraoperative frozen section and cell counts were inconsistent with infection. The stem was removed and revised to a size 12 standard-offset beaded full-coat femoral component (Versys; Zimmer, Warsaw, Indiana), which was impacted into place with a 0.5-mm press-fit. The acetabular component was well fixed, and, given the history of compromised bone stock secondary to acetabular dysplasia, the monoblock cup was retained. A dual-mobility articulation was implanted using a 28-mm, +3.5-mm ceramic head with a 42-mm outer polyethylene articulating surface (Biomet, Warsaw, Indiana). A Dall-Miles cable (Stryker, Kalamazoo, Michigan) was used to secure the osteotomy. There were no intraoperative or postoperative complications.

At most recent follow-up, 6 months after surgery, the patient had no complaints of hip or groin pain. She ambulated with a mild Trendelenburg gait but had returned to activities of daily living. Most recent radiographs showed healing of the trochanteric osteotomy with no evidence of component loosening or subsidence (**Figure 2**).

Discussion

Although reports of complications of implanting dual-modular metaphyseal femoral components in the setting of MOM-THA are limited, our patient's case demonstrates fracture of a contemporary implant at the stem–sleeve modular junction in a MOM-THA. Corrosive material was identified near the margins of the fracture edges within the implant, and an adverse local tissue reaction was found in the capsular tissues at time of revision, suggesting that micromotion at the modular junctions along with particulate debris from the MOM articulation may have subsequently contributed to a fatigue fracture in this patient.

Innovations in the design of modular femoral components in THA over the past several decades have led to the development of interfaces between the head and neck, neck and stem, and stem and metaphyseal sleeve, permitting tremendous intraoperative flexibility in the ultimate customization of the femoral component at the surgeon's discretion.[1-5] For these reasons, it is thought that modular implants may more effectively address cases involving altered proximal femoral anatomy, particularly in patients with developmental hip dysplasia or other congenital deformities.[14,25]

Despite the theoretical advantages afforded by modular implants, these devices are not without their limitations. Increasing modularity leads to more junctions where particulate debris may be generated and corrosion may occur. Several retrieval studies[6,8,14,26-28] have demonstrated that all modular junctions are subject to mechanically assisted crevice corrosion. Crevice and/or fretting corrosion remains the most commonly reported mechanism of failure associated with

modular THA implants,[29-32] particularly at the head–neck junction of devices featuring a titanium alloy stem coupled with a cobalt–chromium–molybdenum femoral head.[6,7,13,14,16,22,33-40] This mechanism has also been identified in modular-neck devices.[23,27,41]

Kop and Swarts[27] retrieved 16 double-tapered cone hip prostheses (DTC Margron; Portland Orthopaedics, Matraville, Australia), found 6 components with significant fretting and crevice corrosion of the neck–stem taper with a mean implantation time of 39 months, and noted an increased amount of fretting and corrosion in components with longer implantation time. In a separate retrieval analysis, Kop and colleagues[14] described the potential effects of micromotion at the neck–stem junctional interface, noting increased fretting and crevice corrosion at the neck–stem junction as compared with the head–neck junction, which subsequently led to increased local and systemic metal debris and soluble metal ions in patients with dual-modular femoral stem implants.

Although corrosion certainly may be implicated as a primary mechanism leading to component fracture in dual-modular femoral components, other implant-specific characteristics may also play a synergistic role in the multifactorial mode of failure. MOM articulations are intended to produce less wear debris than metal-on-polyethylene designs, but concerns about increased metal ion production and possible local effects[42] and/or systemic effects[43-48] remain. Several authors have postulated that wear debris generated by MOM articulations may migrate to bone–implant surfaces and facilitate osteolysis; this would increase micromotion within the THA construct and predispose to implant failure.[11,37,49,50] These effects may be particularly exacerbated when jumbo femoral heads are used. Garbuz and colleagues[41] recently described substantially higher serum ion levels in patients who underwent large-head MOM-THA when compared with MOM resurfacing arthroplasty.[6,47,50]

Failures of the dual-modular femoral stems at the modular interface have been described in several recent case reports,[15-23] with the most common mechanisms for failure including taper fretting, fatigue fracture, and local corrosion. Stem fretting has been noted at the metaphyseal neck–stem modular interface in the S-ROM femoral component (Joint Medical Products, Stamford, Connecticut).[12,51,52] Fracture at the modular stem–sleeve junction in the S-ROM design was also reported by Patel and colleagues,[18] who implicated several factors in the failure of these devices, including increased torsional demands at the stem–sleeve junction, micromotion associated with the additional junction leading to fretting and corrosion, and the theoretical risk for osteolysis. Biomechanical evaluation of the S-ROM has also recognized that slippage may occur between modular components at physiologic loads if the modular junction experiences blood or tissue contamination at time of implantation, which theoretically could increase wear debris during cyclical fatigue loading.[53]

We are unaware of any outcome studies of the clinical performance of the Emperion dual-modular femoral component or of any case reports regarding failures of this component.[24] We believe this is the first report to describe component fracture at the stem–sleeve junction of this modern-generation dual-modular femoral component. We propose that several of the risk factors for implant failure and fatigue fracture previously identified in outcome studies investigating the S-ROM component likely apply to our patient's case. The effect of fretting and crevice corrosion at modular interfaces likely generated particulate metal debris, which predisposed the implant to fatigue fracture. Moreover, the presence of a jumbo-femoral-head MOM articulation may have exacerbated this situation with the production of increased metal debris, which could have facilitated corrosion development and subsequent fatigue fracture.

Conclusion

Although the case reported here represents a rare complication with a multifactorial mode of failure, we believe it illustrates how the effects of fretting, corrosion, and metal debris may synergistically contribute to a local environment conducive to junctional fatigue failure in dual-modular femoral stems. These effects may be particularly emphasized when jumbo-femoral-head MOM articulations are used with these implants. Accordingly, the potential for corrosion and metal debris with modular interfaces, especially when larger femoral heads are used in MOM-THA, warrants further clinical and laboratory investigation.

We believe that surgeons who encounter a painful dual-modular femoral stem must entertain this mode of failure and consider junctional failure as a potential diagnosis for such a patient, particularly in the setting of a MOM articulation. Further clinical outcome data are needed to determine the ultimate clinical performance and surgical indications of all modern-generation dual-modular femoral implants in both primary and revision hip arthroplasty.

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