



Case Report

Bilateral Mechanically-Assisted Crevice Corrosion Resulting in Femoral Stem-Head Dissociation in Metal-on-Polyethylene Total Hip Arthroplasty

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ABSTRACT

There are emerging reports of complications related to corrosion in modular femoral components. We report a unique case describing an 83-year-old man with bilateral mechanically-assisted crevice corrosion in hip replacements performed 10 years previously, by the same surgeon using the same size 3 Accolade TMZF stem and same 44-mm CoCr LFIT V40 head (Stryker Orthopedics, Mahwah NJ). Our patient presented with complete femoral stem-head complex dissociation of his right hip and elevated serum cobalt and chromium levels. He subsequently underwent right hip revision arthroplasty while his contralateral hip is monitored closely as an outpatient. This case helps to define the poorly understood mechanisms and component design factors implicated in this emerging issue. We also hope to provoke discussions about guidelines for monitoring and revising failing metal-on-polyethylene arthroplasty systems.

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Introduction

The introduction of modular femoral components established a new era of total hip arthroplasty (THA). Modularity refers to extra locked interfaces between the femoral head, neck, and stem which enables the use of various component combinations. This most commonly occurs at a Morse taper between the femoral neck and head which joins the 2 rotating components of the THA construct [1]. This design allows for intraoperative adjustment of leg length, restoration of horizontal femoral offset, differing head sizes, and improved exposure during revision surgeries. On the other hand, increasing modularity increases the risk of mechanical failure normally seen as wear, fretting damage, loosening, or fracture [2,3].

Mechanically assisted crevice corrosion (MACC) or trunnionosis is an uncommon but significant consequence of modular implants which has become increasingly reported since 2010 and now accounts for 1.7%–3.3% of all indications for revision hip arthroplasty

[4,5]. MACC occurs at the interface between the femoral neck and head and can result in metal ion release from corrosion, complete implant dissociation, and various forms of adverse local tissue reactions (ALTRs) [6–8]. MACC was previously thought to only occur in metal-on-metal (MoM) implants, but it is now recognized in metal-on-polyethylene (MoP) arthroplasty, albeit less prevalent. Metallosis in MoP arthroplasty is thought to be a direct consequence of head-neck junction tribocorrosion alone [4,9,10].

A number of specific femoral component designs have been implicated in the literature for higher rates of femoral head-stem dissociation and gross trunnion failure (GTF) [11,12]. In 2012, the FDA recalled 2 of Stryker's modular femoral stems made of a proprietary material "TMZF"—Rejuvenate and the ABG II (Stryker Orthopedics, Mahwah, NJ). Postmarket analysis of both these stems showed increased rates of fretting and corrosion resulting in ALTR and early mechanical failure. The Accolade TMZF stem (Stryker Orthopedics, Mahwah, NJ) is also under investigation for early failure and need for revision. The Accolade II has been redesigned with a predominantly titanium (Ti-6Al-4V) composition to address this. In 2016, there was a subsequent recall of Stryker's LFIT v40 cobalt chrome head in the United States for "defective design/taper lock failure" but only in certain sizes [13].

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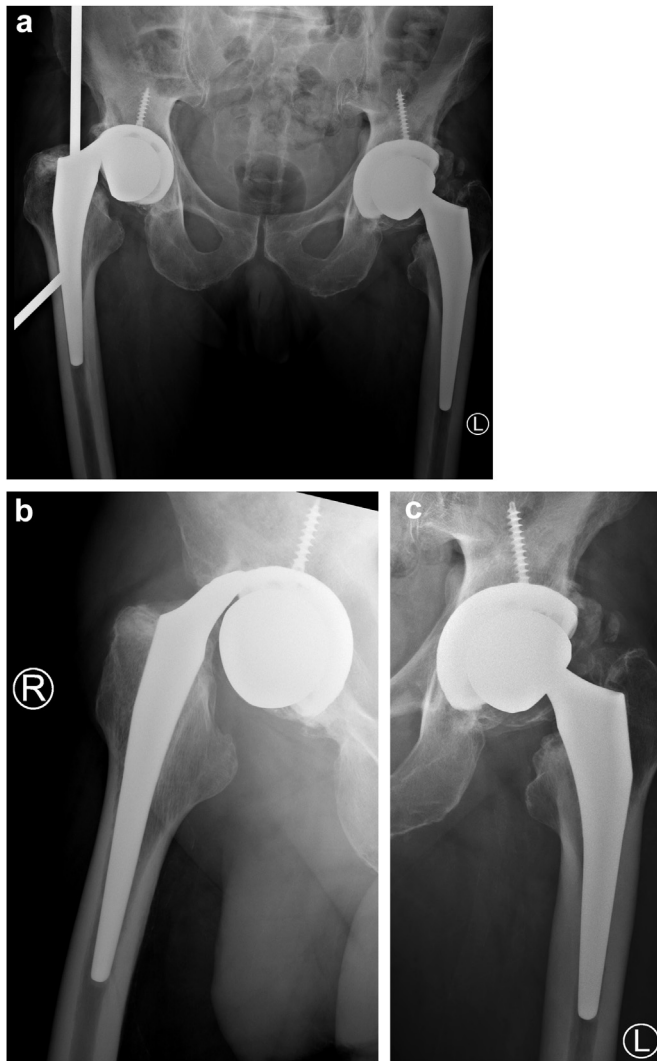


Figure 1. (a, b) Antero-posterior XR performed on presentation showed complete head-neck taper dissociation with malalignment and shortening. No obvious signs of peri-prosthetic osteolysis, suggestive of infection or component loosening. Advanced imaging was unnecessary because of the obvious need for revision. (c) The contralateral left THA showed peripheralization of the femoral stem in relation to the femoral head. This may demonstrate asymmetrical trunnion wear and impending dissociation.

The developing literature on this topic is helping us define the typical presentation, component design factors, and biomechanical causes for this issue; however, there remains a relative paucity of data on this topic [14]. We report on a unique case demonstrating MACC in bilateral hip replacements using the Accolade-Trident system, performed within 3 months of each other, by the same surgeon using the same femoral stem and head size. Our patient gave written informed consent for the publication of this report and associated imaging.

Case report

This case describes an 83-year-old Caucasian man who presented to the emergency department with pain, decreased range of motion, and inability to bear weight on his right hip that occurred after crossing his legs. His initial radiographs demonstrated complete dissociation of the right modular femoral component suggesting GTF. Peripheralisation of his contralateral, left femoral stem with an increased axial tilt in relation to the femoral head was also

noted. (Fig. 1a-c) This was however asymptomatic. Our patient had a BMI of 22.4, was 175 cm in height, and his past medical history included hypertension, triple coronary bypass grafting, and a mitral valve repair for which he took warfarin. He was 9 years and 9 months after his index right total hip and exactly 10 years after his left hip replacement, both of which were for severe osteoarthritis.

Our patient had the uncemented Accolade-Trident system inserted bilaterally via the postero-lateral approach. The right hip was replaced in April 2010 using an Accolade TMZF #3 femoral stem with a lateralized offset (127° neck-shaft angle). A 44/0 cobalt-chrome LFIT v40 femoral head was selected for stability. The acetabulum was replaced with a 58-mm acetabular cup with a 44-mm, press-fit, X3 polyethylene liner inserted. Offset and leg length were increased to compensate for preoperative discrepancy on patient request.

The left hip was replaced 3 months previously, in January 2010 using a postero-lateral approach to implant an Accolade TMZF #3 stem, with a 127° neck-shaft angle and +5 44/0 cobalt-chrome head. This was paired with a trident acetabular shell; size 64-mm with a size 44-mm X3 polyethylene liner. A single 40-mm screw was placed in the superior acetabulum. Both replacements had uncomplicated postoperative courses until his presentation with gross trunnion failure 9 years and 9 month later.

Our patient's laboratory investigations included hemoglobin of 11.6 g/dL (normal, 13.5-17.5 g/dL), white blood cell count of $7.8 \times 10^3/\mu\text{L}$ (normal, $3.48\text{-}9.42 \times 10^3/\mu\text{L}$) with 21% lymphocytes and 70% neutrophils, platelets $147 \times 10^9/\text{L}$ (normal, $150\text{-}400 \times 10^9/\text{L}$), and C-reactive protein of 69 mg/L (which decreased to C-reactive protein 15 after 11 hours; normal, <10 mg/L). Our patient's metal ion levels perioperatively, at 3 months and at 6 months were serum cobalt (Co) 274 nmol/L (normal, <10 nmol/L), Co 91 nmol/L and Co 45 nmol/L, and serum chromium (Cr) level of 94 nmol/L (normal, <15 nmol/L), Cr 65 nmol/L and Cr 66 nmol/L, respectively.

Intraoperative findings during the right hip revision surgery showed darkened synovial fluid and necrotic-looking, fibrous tissue suggesting metallosis of the intracapsular space, and femoral medullary canal. There was no obvious pseudotumour or heterotopic ossification along the greater trochanter, and the abductors were fully intact. The posteromedial calcar was preserved. The femoral stem was removed without the need for an extended trochanteric osteotomy and exhibited severe trunnion corrosion without signs of fatigue or fracture. There was also significant medial wear of the femoral neck. The Co-Cr head was intact with minor abrasions at the taper junction but no loss of material internally or externally (Fig. 2a-d).

An Exeter number 1 stem with 44 offset, length 150 mm, was cemented in situ. A Stryker V40 stainless steel femoral head, size 32/0, was impacted to the stem. The trident acetabular cup was deemed stable after explantation of the polyethylene insert, which was exchanged. Intraoperative tissue and synovial fluid specimens both returned sterile (Fig. 3). At 6-month follow-up, our patient had returned to his baseline, unaided level of mobility. He was satisfied with the outcomes of the right hip revision surgery but has declined surgery for the contralateral side. His Oxford Hip Score was 37/48.

Discussion

The increasing number of reports indicating implant failure secondary to MACC suggests this is an emerging problem that is not limited to metal-on-metal implants. This unique case raises a number of questions about the poorly defined etiology of MACC. In 2 total hip replacements performed on the same patient, at roughly the same time, by the same surgeon using the same implant



Figure 2. (a) The recovered accolade TMZF explant showed severe corrosion of the modular junction and corrosion of the medial portion of the femoral neck. (b) There was no increased wear visible inside or outside the size 44/0 cobalt-chrome head. (c, d) Rotational views of the recovered explant demonstrate the extent of corrosion present without fracturing of the stem.

system, both experienced mechanically-assisted crevice corrosion, but one was significantly more damaged than the other.

A combination of patient and implant factors is implicated in mechanically-assisted crevice corrosion. In a case series of 5 patients with trunnionosis of the accolade TMZF stem, Matsen-Ko et al. postulate that a BMI $>30\text{kg/m}^2$, male sex, and increased cobalt-chromium head size $>36\text{ mm}$ may increase the risk of corrosion. They also suggest an association between extended femoral neck and high offset and fretting [15]. Dyrkacs et al. and Elkins et al. have demonstrated that as head size increases in THA, torque increases which results in increased contact stress and wear of the trunnion [16,17]. Elkins et al. also found diminishing benefit in stability when the head size was $>40\text{ mm}$ [16,17]. Both implants in our case had a lateralized offset which medialises the trunnion, and both hips had size 44/0 CoCr heads inserted. The leg lengths were adjusted within 0.5 cm of each other with a +5-mm head on the left.

The intimacy of the morse taper relationship with the femoral head is essential to reduce oscillatory micromotion between the 2 modular components. A certain degree of separation will always exist because of the variable rigidity and surface materials used in 2 different components [18]. The importance of this factor in implant failure should be seen as an indication for developing a more accurate

method of assessing the cold-weld of the head to the stem at final hardware insertion apart from the intraoperative shuck test [19]. Both our patient's hips were operated on by the same surgeon within 3 months of each other using the same combination of implants, which will control for some of the confounding variables in this regard.

The Accolade TMZF tapered wedge stem (Stryker Orthopedics, Mahwah, NJ) is made of a proprietary β -titanium alloy (titanium–molybdenum–zirconium–iron). It was designed to simulate the feel of natural bone and improve functionality compared with other noncemented, tapered stems. It has a reduced modulus of elasticity to improve stress shielding and a trapezoidal neck that should also allow for improved range of motion and may reduce the occurrence of instability. However, the typical pairing of the Accolade TMZF with a CoCr head has been problematic. Concerns have been raised about GTR and ALTR from tribocorrosion at the femoral stem-head junction. It is suggested that disruption of the protective oxidative layer on the titanium stem because of metal mismatch may accelerate corrosion [20]. A number of articles have now advocated against the use of mixed alloy head-stem couples although a clinical evidence base has not yet supported this [21,22]. One study showed increased serum Co and Cr levels when the Accolade-Trident system was used in conjunction with a size 36-

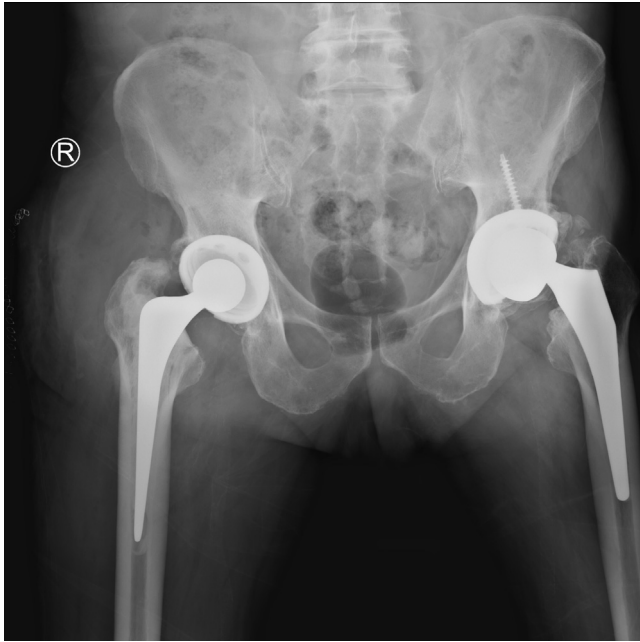


Figure 3. Post operative XR showed successful single-stage revision with a cemented exeter stem. The femoral stem of the contralateral left hip remains off-centre in relation to the femoral head.

mm LFIT V40 CoCr head compared with a 28-mm head. They subsequently showed that there was no difference in metal ion levels between 36-mm and 28-mm head sizes used with the Exeter orthonix prosthesis [23,24].

The LFIT Anatomic CoCr V40 femoral head had a limited, voluntary recall by the FDA in August 2016 for taper lock failure. The femoral heads recalled included those manufactured between 2002 and 2011 with diameter and offsets of 36 + 5, 40 + 4, 54 40 + 8, 40 + 12, 44 + 4, 44 + 8, and 44 + 12 (head diameter, neck offset). LFIT CoCr V40 femoral heads in other sizes and outside this 9-year period are still available [11]. Our case demonstrates the unrecalled 44/0 head failing twice.

A report of 30 implants with either GTF or mechanically-assisted crevice corrosion suggests that unexplained painful THA in which infection, aseptic loosening, and iliopsoas tendonitis have been ruled out should warrant a workup for mechanically-assisted crevice corrosion. The authors do however acknowledge that trunnionosis is usually asymptomatic unless found incidentally or GTF occurs [25]. Others suggest that impending GTF can be diagnosed by close examination of radiographs, which will exhibit an asymmetrical alignment between the modular femoral components and an oblique femoral head in relation to the neck taper. Diagnosis of significant MACC has also been based on the aspiration of black synovial fluid from the suspected hip joint [11,26].

Metal artifact reduction sequence resonance imaging (MARS-MRI) is widely considered as the gold standard for diagnosis. Multiacquisition with variable resonance image combination and slice-encoding metal artifact correction are 2 modern techniques of MARS that have further increased diagnostic confidence in delineating ALTR, pseudotumours, and abductor/soft-tissue involvement [27]. The sensitivity and specificity of MARS compared with ultrasound is 100% and 92%, respectively [28].

Cobalt and chromium serum levels have also been shown as early indicators for early MACC, the ratio of such being slightly higher in MoP implants than in MoM implants (1:5 to 1:10) [25] Cooper et al. [4] describe 10 cases of MoP MACC and found all 10 had elevated serum cobalt levels, whereas only 7 had elevated

chromium. They also found the cobalt levels were significantly higher than the reference range [4]. Of note, the metal ion levels in our case are relatively low for a case of bilateral mechanically-assisted crevice corrosion which suggests they may not be the most specific method of diagnosing GTF, although this also explains why no pseudotumour was present [29].

Summary

MACC and ALTR in MoP hip replacements represent 2 potential emerging problems. Having a case where the same patient underwent almost identical surgeries bilaterally controls for a number of variables implicated in mechanically-assisted crevice corrosion. We propose the reason for gross trunnion failure in this case is related to the femoral head size, offset, and implant system selected. There may also be biological or immunological predispositions to trunnionosis. The reason the right hip experienced more MACC remains unclear but may be related to the increased neck length and reduced acetabular diameter on that side. There are currently no guidelines for when to surgically intervene in trunnion corrosion, and there are only guidelines for how to monitor patients with MoM implants [30]. Otherwise, it is suggested that patients with tolerable symptoms or normal MARS MRI are followed up with bi-annual cobalt chromium serum levels and annual clinical examination for instability or pain [12].

This case report should provoke discussions about guidelines for monitoring metal-on-polyethylene implants. There should also be further research into metal-on-polyethylene mechanically-assisted crevice corrosion especially with the accolade-trident system, which is commonly implicated in tribocorrosion.

Conflict of interest

The authors declare there are no conflicts of interest.

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