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Case report

Adverse Local Tissue Reaction due to Acetabular Corrosion in Modular Dual-Mobility Constructs

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ABSTRACT

Dual-mobility (DM) bearings in total hip arthroplasty (THA) have been reported to reduce dislocation rates, especially in high-risk patients, and are being rapidly adopted in primary and revision THAs. However, this technology introduces additional interfaces that have the potential to result in unforeseen complications. We present a series of 3 patients with mechanically assisted crevice corrosion at the acetabular component–metal dual-mobility liner interface. Consequently, we urge judicious use and close clinical observation of this new, effective technology in THA.

Introduction

The use of dual-mobility (DM) constructs in total hip arthroplasty (THA) has expanded recently because of the potential ability of DM bearings to decrease dislocation rates, particularly in patients with high risk of instability [1-3]. This is achieved predominantly through a larger effective head size that results in greater impingement-free range of motion and a greater jump distance. DM is frequently used in the revision setting because of a higher risk of dislocation and has demonstrated favorable results compared with 36-mm traditional heads [4]. In addition, extensive interest in the hip-spine relationship has prompted consideration of DM as a viable option to minimize the risk of dislocation in that challenging clinical setting [5,6].

Despite the proven benefits of DM, the potential downsides cannot be overlooked. These include intraprosthetic dislocation (IPD), a known complication that occurs with some frequency, and mechanically assisted crevice corrosion (MACC) from the articulation of the cobalt-chromium liner on the titanium acetabular component which can potentially result in adverse local tissue reaction (ALTR) if a cobalt alloy component is used. This potential exists for the modular version of DM bearings, in which the cobalt-chromium liner is separate from the titanium acetabular shell and is seated into the socket with a Morse taper connection. Although IPD is relatively rare, it is well described in the literature [7,8]. Alternatively, MACC from a DM construct resulting in clinical ALTR is considered by many to be a theoretical concern only [5,9]. In one study, metal-ion levels were observed to remain within normal limits after implantation of DM components with ceramic heads [10]. Other studies have observed elevated metal-ion levels in DM constructs with ceramic and metal heads [11,12]. There is only one report currently in the literature of ALTR after DM constructs, and the ALTR occurred in patients with cobalt-chromium heads, which could serve as another possible source of corrosion [11]. We present a series of 3 patients with MACC after placing DM constructs, 2 of which were with ceramic femoral heads.

Case histories

Case 1

The first case involves a 71-year-old female who underwent index right THA in 1990 that was subsequently revised in 2015 for aseptic femoral loosening and polyethylene wear to a tapered modular stem and a DM head and liner construct with a ceramic femoral head. She presented 3.5 years postoperatively with

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Figure 1. Anteroposterior (AP) radiograph of case 1 at presentation with dual mobility right THA without radiographic evidence of failure.

increasing groin and thigh pain without any radiographic evidence of implant failure (Fig. 1). Infection workup was negative, but her cobalt (2.5 ppb) and chromium (1.2 ppb) levels were both elevated. Metal artifact reduction sequence magnetic resonance imaging (MARS-MRI) demonstrated blooming metallic artifact in the right gluteus medius muscle consistent with ALTR. She did have a cobalt-chromium head in her left THA, but she was asymptomatic and MARS-MRI demonstrated normal findings on the left side. A diagnostic right hip injection provided 100% pain relief. She underwent revision THA with removal of the DM construct and exchange to a 40-mm ceramic head on sequentially annealed highly cross-linked polyethylene. At the time of surgery, the synovial fluid was brownish gray consistent with ALTR. The abductor musculature appeared relatively normal on gross inspection. The DM cobalt chrome liner was found to be canted eccentrically on close inspection and demonstrated corrosion at the liner shell interface (Fig. 2). Intraoperative cultures were negative for infection. The acetabular and femoral components were well fixed and in an appropriate position. The femoral stem trunnion was pristine without evidence of corrosion. At the latest follow-up 4 months postoperatively, she was progressing well with no assist device and complete resolution of her hip pain. She was subsequently seen by our spine partner at 10 months postoperatively with no hip complaints.

Case 2

The second case was a 56-year-old female who underwent index right primary THA in 2014 with a DM bearing couple including a skirted cobalt-chromium head (Fig. 3). She had an acute onset of groin pain just over 4 years postoperatively and was admitted with bacteremia secondary to methicillin-resistant *Staphylococcus aureus*. In addition, metal-ion levels were obtained and showed elevation of cobalt (1.3 ppb) with normal chromium (0.6 ppb). She underwent explant with placement of an antibiotic cement spacer. Manual intraoperative cell count revealed 217,000 white blood cells (WBCs) with 98% polymorphonuclear leukocytes poly (PMNs). Implants were well fixed, the trunnion had Goldberg grade 4 trunnionosis on the head and neck [13], and the cobalt-chromium DM liner was canted with visible corrosion at the liner-shell interface (Fig. 4). The abductor musculature appeared normal on visual inspection. Intraoperative cultures grew methicillin-resistant *Staphylococcus aureus*. She subsequently underwent a resection and two-stage reimplantation, and at the latest follow-up 1 year after reimplantation, she was off antibiotics and progressing well without hip pain.

Case 3

The third case involves a 43-year-old male who underwent index right THA in 2014 with a DM construct with a ceramic femoral head. He presented to our practice 4 years postoperatively with 7 days of acute right groin pain and was found to have an acetabular component, which was loose and had migrated with substantial acetabular bone loss (Fig. 5). Infection workup was negative; therefore, plans were made for revision THA. Intraoperatively, milky synovial fluid was encountered, and intraoperative cell count demonstrated 2075 WBCs with 88% PMNs, which prompted explant and placement of an antibiotic cement spacer. Again, the abductor musculature appeared normal. The trunnion was pristine, but there was substantial corrosion at the Morse taper junction of the DM liner-shell interface consistent with MACC, after disengaging the cobalt alloy liner (Fig. 6). Metal-ion levels were drawn, and the cobalt was elevated (1.7 ppb), while the chromium was normal (0.3 ppb). Intraoperative cultures were negative. He underwent reimplantation 6 weeks later with a 40-mm ceramic head on a polyethylene liner. He initially did well but developed drainage 1 month postoperatively requiring two-stage revision. Cultures at

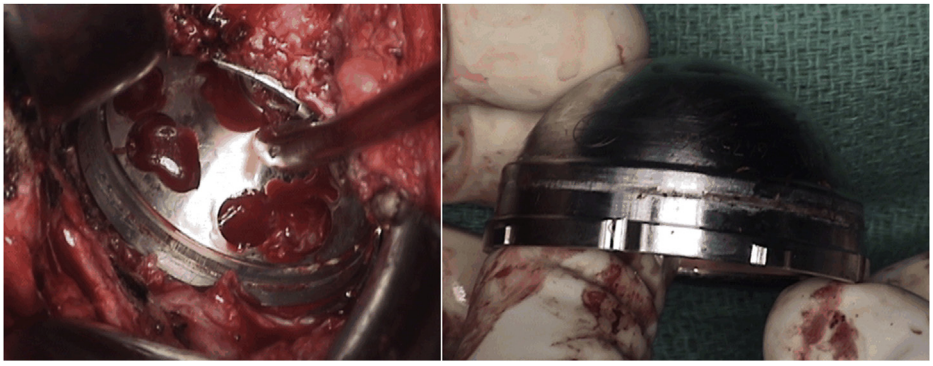

Figure 2. Intraoperative photographs of case 1 at time of revision demonstrating corrosion at the liner-shell interface.

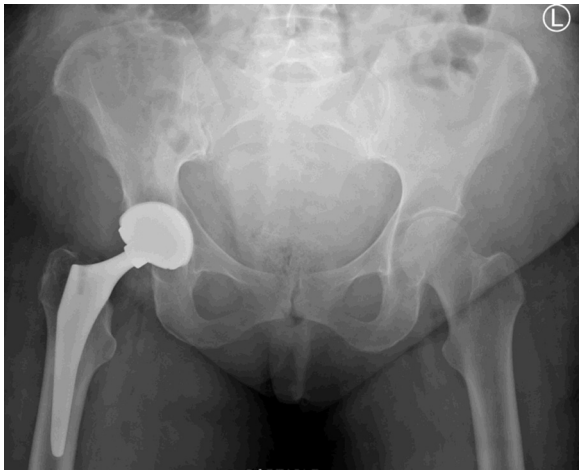

Figure 3. Anteroposterior (AP) radiograph of case 2 at presentation with dual mobility right THA without radiographic evidence of failure.

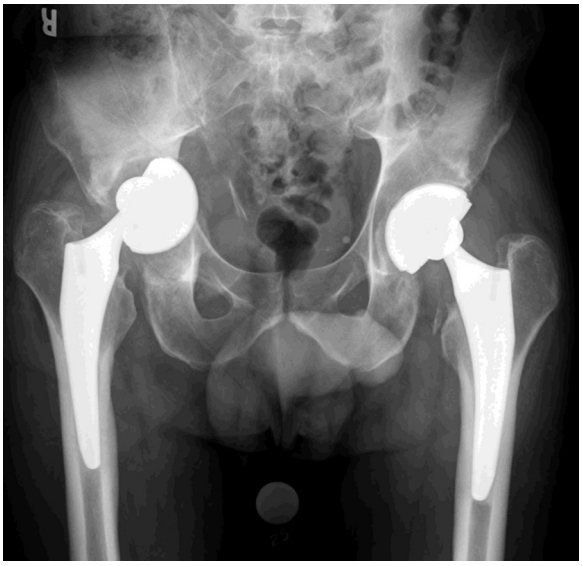

Figure 5. Anteroposterior (AP) radiograph of case 3 at presentation with dual mobility right THA demonstrating acetabular loosening with migration and bone loss.

the time of the first stage grew methicillin-sensitive *Staphylococcus aureus*. This required multiple repeat debridements for persistent infection, and he was successfully reimplanted 4 months after explant. At the last follow-up 5 months later, he was doing well off antibiotics without evidence of recurrent infection. He was scheduled to return at 1 year postoperatively but was unable because of the coronavirus pandemic.

Discussion

The use of DM constructs in THA has been growing because of the ability to decrease dislocation rates in high-risk situations [1-6]. However, there is concern that the introduction of additional mechanical interfaces may result in unintended consequences. To this point, the concern for MACC from the articulation of a cobalt-chromium liner on the titanium acetabular component has yet to be reported. Nam et al reported 4 cases of cobalt elevation out of 26 patients receiving DM inserts [12]. However, none of these 4 patients had any negative clinical consequences at the time of the publication; only one had a cobalt level > 1 ppb, and that patient had a cobalt-chromium head. Alternatively, 2 of our 3 patients had ceramic heads and all had cobalt levels > 1 ppb. In addition, Matsen Ko et al reported 21 patients with elevated cobalt levels out of 100 patients receiving DM components [11]. Of these, they highlight 9 patients with cobalt levels >1.6 ppb, only one of whom had a ceramic head. Four of the nine obtained a MARS-MRI because of pain, and 2 of these found evidence of ALTR. They were unable to confirm the source of ALTR as the liner-cup interface rather than the trunnion/cobalt-chromium head interface because no patients were revised. It is vital to discern the source of metal-ion production and ALTR in attempts to identify the true problem. There has been intense focus on MACC from the femoral neck taper-head interface recently but only one single report of MACC or ALTR at the metal liner–acetabular shell junction in DM constructs. Agne et al do report identifiable wear at this junction in the metal-on-metal setting but did not identify resultant ALTR [14]. Current reports in the literature have alternative sources of metal debris, namely the trunnion-head junction [11,12]. Of our 3 cases, 2 had another potential source of metal debris, but only case 2 showed evidence of damage at the alternate junction. More importantly, they all showed evidence of corrosion and/or fretting at the shell-liner junction. ALTR was clearly present in case 1 based on MRI findings. Although the abductor musculature appeared intact intraoperatively in these cases, the gray/milky appearance of the synovial fluid supports potential development of ALTR, but it cannot be definitively concluded.

It is critical to emphasize the potential deleterious effect of canting or malseating of the cobalt-chrome liner in the titanium acetabular component. Malseating of the liner theoretically increases the likelihood of MACC at this interface because canting of the liner minimizes the metal contact surface area and

Figure 4. Intraoperative photographs of case 2 at time of explant demonstrating corrosion at the liner-shell interface.

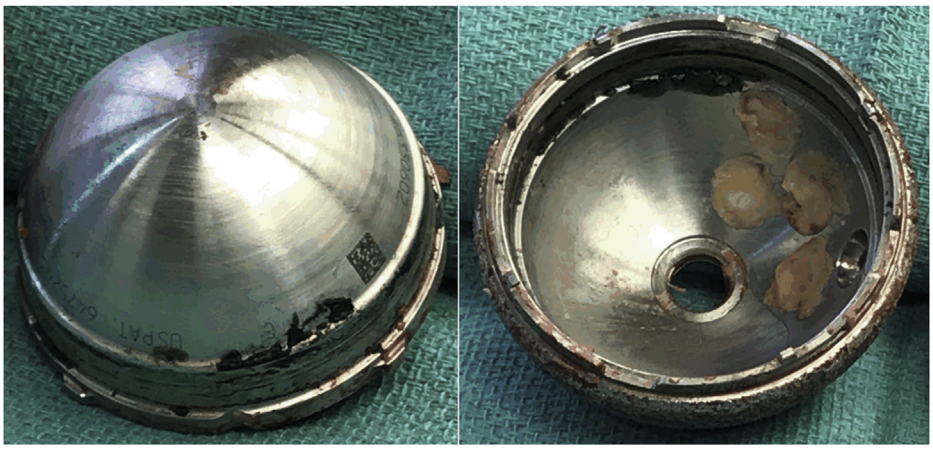

Figure 6. Intraoperative photographs of case 3 at time of explant demonstrating corrosion at the liner-shell interface.

subsequently increases the mechanical stress that can initiate MACC and possibly lead to ALTR. This potentially adverse condition of a cobalt-chrome liner malseating or canting in the titanium shell has been shown to occur with some frequency, as Romero et al presented a 5.4% incidence of liner malseating in a consecutive series of DM hips [15]. Furthermore, the series by Romero et al was based purely on radiographic evidence of malseating, which underrepresents the true clinical occurrence. In our series, 2 of 3 liners were canted on detailed inspection at the time of revision. This may support the clinical consequence of malseating of the DM liner in terms of an increasing risk of MACC and possibly resultant ALTR and emphasizes the importance of surgical technique and critical assessment of proper liner implantation in modular DM bearings.

Although DM bearings impart additional stability, given the potential for MACC from the cobalt-chrome-titanium metal liner interface, surgeons should weigh the relative risks and potential benefit of using a larger diameter ceramic head and highly cross-linked polyethylene in light of recent excellent wear data for this bearing couple [16,17]. Many studies have demonstrated the stability benefit of using larger diameter femoral heads [18-20]. Stability may be further improved with 40-mm and 44-mm heads if allowable within the cup diameter for the given implant system, but this remains to be borne out in the literature. Although not conclusively proven in the peer-reviewed literature, using a large diameter ceramic femoral head greater than 36 mm may be a viable option for improving stability without introducing the additional interfaces that come with DM. Although we have highlighted a specific potential clinical issue, additional problems exist when introducing additional interfaces with DM. In a systematic review, De Martino et al found 19 cases of IPD [8]. Fifteen of those occurred when attempting closed reduction of a dislocated DM construct. Polyethylene wear and poor compression of the head into the liner are other reported reasons for IPD [8]. Addona et al report a 4.5% rate of dislocation with DM and a 71% rate of IPD after attempting closed reduction [7]. In addition, DM constructs have demonstrated 2× early penetration and wear rates compared with highly cross-linked polyethylene in a traditional THA bearing [21]. These reported clinical issues, in addition to the problem we report, highlight the need to reserve DM constructs for scenarios in which the risk of dislocation is higher than average or adequate stability cannot be achieved intraoperatively despite the use of a larger diameter head.

Our case series does have limitations for specific interpretations and conclusions. There are certainly confounding factors in our cases, one being the presence of concomitant infection in 2 of the cases. Case 2 was revised specifically for infection with liner malseating and MACC noted at the time of revision. While case 3 developed an infection after reimplantation, retrospective review of the initial revision supports contribution of MACC and ALTR to the substantial bone loss and aseptic loosening rather than infection as a primary etiology of failure. This is presumed because of normal inflammatory markers, less than 3000 WBCs, and negative cultures. In addition, revision THA for MACC has demonstrated a high rate of early complication including infection and dislocation [22].

Another important detail to note was liner malseating in 2 of the cases. We are unable to conclude the contribution of malseating to the development of MACC, as we also observed tribocorrosion in the case where the liner was properly seated (case 3). However, we do think it is important to acknowledge that MACC can occur at this junction in cases of appropriate liner seating and malseating. This highlights 2 important points. First, surgeons should take great care to ensure appropriate seating of DM liners in attempts to minimize problems with this junction. This involves meticulous inspection of the junction to confirm that the face of the liner and the face of the cup are coplanar. While some studies have demonstrated elevated metal-ion levels in the setting of DM [11,12], Chalmers et al [10] report low ions in 24 patients with DM components with ceramic heads. This speaks of the ability to use this articulation safely when necessary. Second, MACC can still occur with a well-seated liner, thus supporting judicious use of DM constructs.

There are modular type DM implants that do not use cobalt-chromium liners (eg, Oxinium; Smith & Nephew Corporation, Memphis, TN). Although this avoids the problems associated with a cobalt-chromium liner in a titanium acetabular shell, the clinical implications of their use are unknown.

Summary

The ability of DM constructs to lower dislocation rates has prompted widespread adoption by surgeons. The use is not limited to high-risk scenarios such as revision surgery and history of lumbar spine fusion, but has conspicuously spread to the primary uncomplicated THA as well. Aggressive adoption of new technology could portend future unforeseen problems, as we have seen with other potentially innovative technology such as dual-modular necks and large-diameter metal-metal bearings. We report 3 cases of MACC at the acetabular shell–metal liner interface in modular DM constructs, one leading to definite ALTR and another presumed ALTR based on synovial fluid appearance. Although the

benefits of DM constructs are undeniable from a stability standpoint, we urge surgeons to exercise judicious use of this technology as our series illustrates a serious, albeit rare, but potentially avoidable complication. When DM is used, it is vital to ensure proper liner seating to minimize this risk.

Conflict of interests

R.M. Meneghini receives royalties from DJO and Osteoremedies, is a paid consultant for DJO, Osteoremedies, Kinamed, SCA, and KCI, holds stock ownership in Emovi, is a member of the editorial board of the *Journal of Arthroplasty* and *Orthopedics Today*, and is a board member of the Knee Society and ICJR. K.A. Sonn declares no potential conflicts of interest.

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