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Case Report

Corrosion of Modular Dual-Mobility Acetabular Components Leading to Acetabular Bone Loss and Protrusio

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A B S T R A C T

Dual-mobility bearings are being increasingly utilized in total hip arthroplasty. Contemporary modular designs often feature inner cobalt-chromium liners that are seated in outer titanium acetabular shells. However, mating of these 2 dissimilar metals may lead to complications. We present a case report of a patient who was found to have osteolysis and acetabular protrusio due to an adverse local tissue reaction from corrosion between a cobalt-chromium liner and titanium acetabular shell that appeared to be well-seated clinically and radiographically. This case suggests that implant failure and associated adverse local tissue reactions may occur even in seemingly well-seated modular dual-mobility implants.

Introduction

The use of dual-mobility components in both primary and revision total hip arthroplasties (THAs) has grown substantially in recent years [1,2]. Designed to prevent dislocation, dual-mobility bearings have become an attractive option for patients who are at increased risk [3-10]. Earlier constructs featured monoblock cobalt-chromium acetabular components that made implant placement challenging due to their rigidity and inability to attach an insertion handle or place acetabular screws [11,12]. Contemporary modular designs feature a titanium acetabular shell, which allows for an insertion handle and acetabular screws into which a liner, typically cobalt-chromium, is inserted [4]. However, this interface may lead to unforeseen complications [13].

Micromotion at the liner-shell interface may lead to fretting and mechanically assisted crevice corrosion (MACC) due to the dissimilar metals used and ultimately cause an adverse local tissue reaction (ALTR) [11,14-17]. Corrosion has been observed in simulated models [14,18,19], retrieval studies [15,16,19-21], and case reports [11,13]. However, literature regarding ALTRs due to corrosion at the liner-shell interface remains limited to 4 patients [11,13]. Of these 4 patients, 2 possessed cobalt-chromium femoral heads, and as a result, the ALTR may have been caused by corrosion at the trunnion/cobalt-chromium head interface, cobalt-chromium liner/titanium cup interface, or both. In the 2 patients with ceramic heads, one was found to have a malseated liner, which has been shown to predispose to corrosion [14], and one was treated for a concomitant infection, which may have contributed to the inflammation, bone loss, and loosening observed.

We present a case of acetabular component protrusio from an ALTR possibly due to MACC at the liner-shell interface in a patient with a liner that appeared to be well-seated both clinically and radiographically and with no other sources of potential corrosion or inflammation.

Case history

A 69-year-old male presented 2 years following a primary THA with modular dual-mobility components and a ceramic head at an outside hospital (Trident II acetabular component with Modular Dual Mobility [MDM], Secur-Fit femoral component: Stryker [Mahwah, New Jersey], 28mm Biolox delta ceramic head: Exactech [Gainesville, Florida]). He reported only occasional muscle soreness

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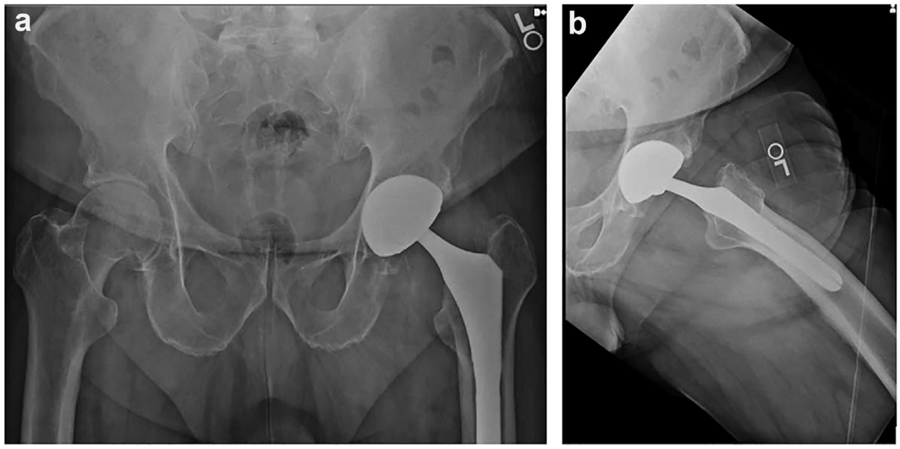

Figure 1. (a and b) Postoperative anteroposterior and cross-table lateral radiographs 1.5 years following initial arthroplasty demonstrating well-positioned components.

during the first 1.5 years following surgery, after which point he developed atraumatic hip pain. Radiographs were obtained, which demonstrated well-positioned components (Fig. 1), and he was diagnosed with a hamstring strain. Following the persistence of symptoms, a computed tomography (CT) scan was performed 3 months later, which demonstrated protrusio of the acetabular component (Fig. 2). An intra-articular hip aspiration produced brown fluid with <1 polymorphonuclear neutrophils. He was subsequently referred to our institution for further care.

Following presentation, repeat radiographs and a CT scan were obtained, which demonstrated protrusio with a displaced medial wall acetabular fracture and minimally displaced anterior and posterior wall fractures (Figs. 3 and 4). The presence of pelvic discontinuity could not be determined on a CT scan. There was no radiographic evidence of liner malseating (Fig. 3). Serum cobalt and chromium levels were elevated at 1.3 and 0.3 ng/mL, respectively. White blood cell count, erythrocyte sedimentation rate, and C-reactive protein values were all within normal limits. Given the

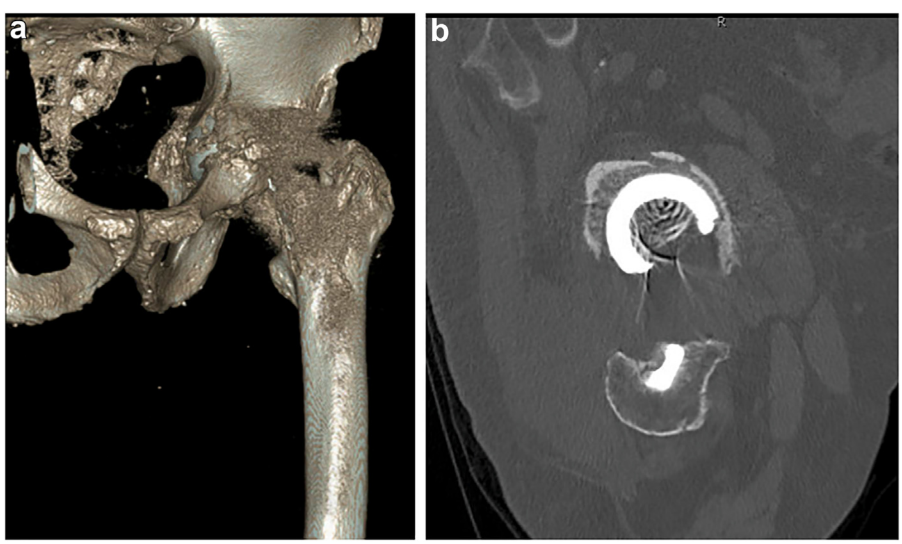

Figure 2. (a and b) Subsequent computed tomography (CT) image and three-dimensional reconstruction 2 years following initial arthroplasty demonstrating medialization of the acetabular components beyond the medial wall of the acetabulum.

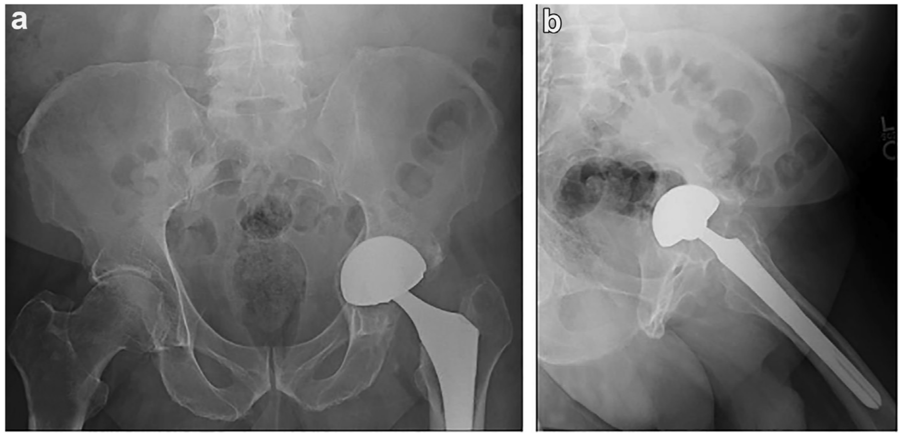

Figure 3. (a and b) Anteroposterior and cross-table lateral radiographs performed at our institution roughly 2 years and 1 month following initial arthroplasty demonstrating medialization of the acetabular component beyond the medial wall of the acetabulum without evidence of liner malseating on the lateral radiograph.

concern for ALTR and malignancy in the setting of atraumatic acetabular fractures, magnetic resonance imaging was performed, which revealed a T2 hyperintense and T1 hypointense signal along the anterior and posterior aspects of the acetabulum that decompressed into a 7.8 $\times$ 6.5 $\times$ 8.5 cm heterogeneous ALTR posteriorly along the gluteus musculature (Fig. 5).

The decision was made to proceed with revision THA. The previous posterolateral incision was utilized. Upon incising the fascia, an ALTR posterior to his femur was encountered. Multiple samples were collected. On gross inspection, the hip abductors were necrotic with degradation of >50% of the musculature (Fig. 6). The attenuated posterior capsule was incised, and cloudy synovial fluid was encountered. Intraoperative manual cell count demonstrated 180 white blood cell counts with 75% polymorphonuclear neutrophils. The synovium was debrided with multiple tissue samples collected. The hip was then dislocated. The dual-mobility femoral head was removed from the neck, and no signs of corrosion were noted at the trunnion. The acetabular component had migrated medially and superiorly. It was grossly loose and easily removed. There was evidence of prior bony ingrowth on the cup, indicating that the cup had likely been well-fixed and subsequently loosened. There was no clinical evidence of liner canting or malseating. The liner was well-fixed within the acetabular shell and could not be removed with traction or repeated impaction using a bone tamp on the liner edge. A reciprocating saw without a blade was utilized to provide consistent vibration to disengage the liner from the shell at the inner morse-taper junction. Black debris, pitting, and etching were noted on nearly 50% of the backside of the liner and the inner surface of the shell (Fig. 7).

The acetabulum was then evaluated. A small anterior superior defect was noted, and the anterior and posterior wall fractures were noted to not connect. As there was no evidence of pelvic discontinuity, the decision was made to reconstruct using allograft, augments, and a fully porous jumbo cup. Allograft chips were placed into the anterior superior defect. Two trabecular metal augments (Trabecular Metal Revision System: Zimmer-Biomet

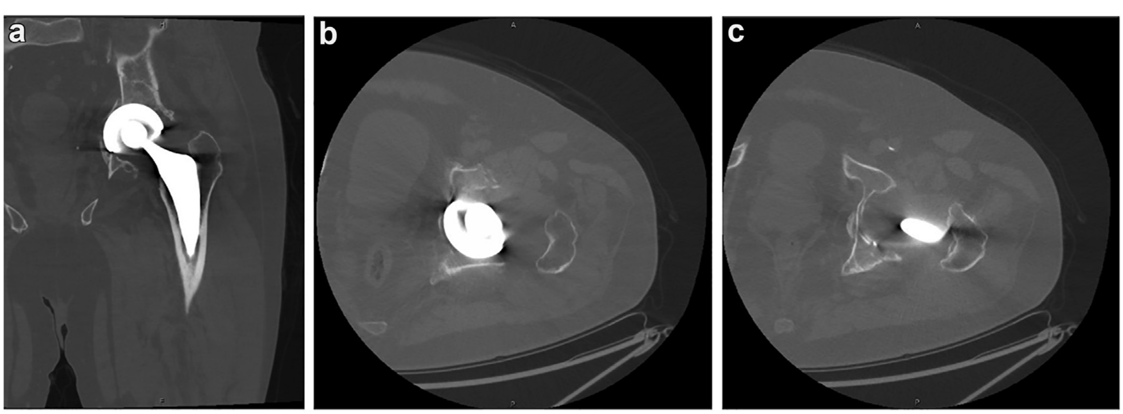

Figure 4. Computed tomography (CT) images with (a) coronal and (b and c) axial cuts demonstrating displaced medial acetabular wall fracture and minimally displaced anterior and posterior wall fractures.

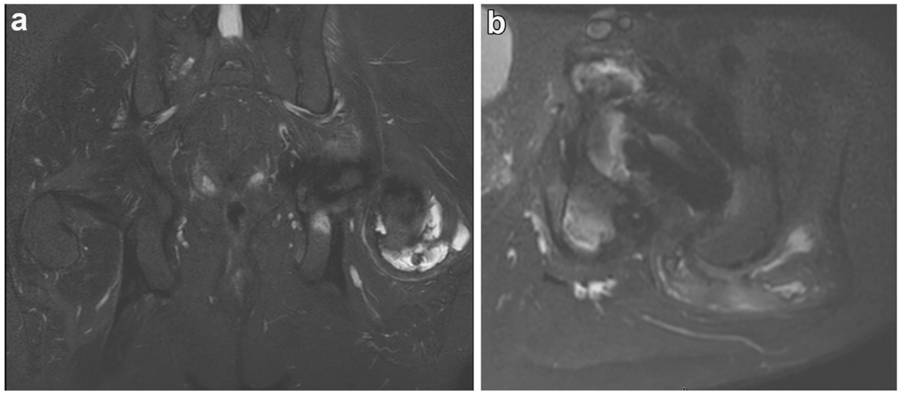

Figure 5. Magnetic resonance imaging (MRI) images with (a) coronal and (b) axial cuts demonstrating focal T2 hyperintense signal about the hip capsule that decompresses posteriorly to a 7.8 × 6.5 × 8.5 cm heterogeneous fluid collection posteriorly along the gluteus maximus musculature.

[Warsaw, Indiana]) were wedged into the medial defect. A porous multi-hole 66 mm titanium shell (G7: Zimmer-Biomet) was inserted. The augments were cemented together, and the cup was cemented to the augments, with one package of antibiotic-laden cement (Palacos R + G cement: Heraeus Medical [Yardley, Pennsylvania]). Multiple screws were placed through the cup with 2 screws placed through the cup and augments. A 40 mm, 10-degree face-changing liner (G7: Zimmer Biomet) along with a 40 mm + 7.5 mm cobalt chromium head was utilized given his deficient abductor musculature. He was unstable with a shorter head length, likely related to his abductor muscle deficiency, and as a result, the +7.5 mm size femoral head was implanted, which was only available in cobalt chromium.

No organisms grew from intraoperative cultures. On histopathological assessment, tissue from the ALTR demonstrated fibrous tissue with distinct cellular and acellular zones with loss of normal tissue arrangement. Synovial tissue demonstrated moderate loss of the synovium with an abundant amount of fibrous tissue.

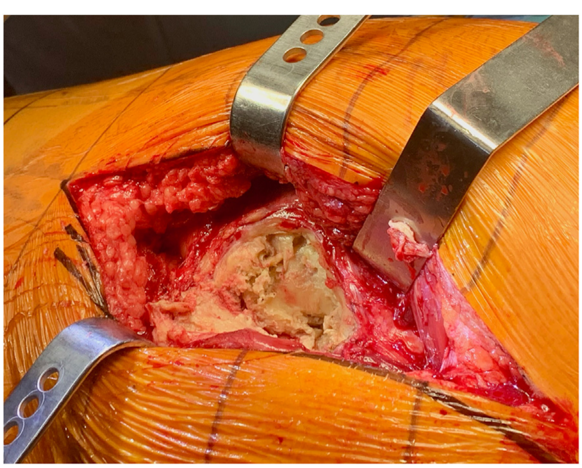

Figure 6. Intraoperative photographs demonstrating degradation of the hip abductor musculature.

Both tissues demonstrated a mixture of macrophages and lymphocytic cells without neutrophilic inflammation. At his 6-week follow-up visit, the patient denied pain, radiographs demonstrated well-aligned components, and serum cobalt and chromium levels had returned to within normal levels (cobalt: 0.8 ng/dL, chromium: 0.2 ng/dL). At his 1-year postoperative visit, the patient remained pain-free, postoperative radiographs demonstrated well-aligned components without any interval changes (Fig. 8), and serum metal ion levels had decreased further (Table 1).

Discussion

To the best of our knowledge, this is the first reported case of aseptic loosening and bone loss due to ALTR likely caused by corrosion at the liner-shell interface in a patient with well-seated modular dual-mobility components and without other potential sources of corrosion or concomitant infection.

Although modular dual-mobility bearings have been shown to be effective in reducing instability, they are not without potential complications. In addition to intraprosthetic dislocations, which are seen in both monoblock and modular designs [22], malseating of the liner and corrosion at the liner-shell interface are unique to modular designs [14]. The incidence of liner malseating ranges from 5.0%-16.4% [14,23-25]. Malseated liners have been shown in simulation models to be at a higher risk of fretting corrosion than well-seated liners [14]. Even when the liner is well-seated, fretting corrosion may occur, similar to fretting corrosion previously observed between well-fixed femoral heads on metal trunnions [17]. As 2 dissimilar metals are used, micromotion will lead to the repetitive disruption of the protective metal oxide passivation layer on the surface of the metals and subsequent release of fretting debris [17]. This debris may then cause an ALTR, an immune-mediated inflammatory response that can result in osteolysis and soft tissue destruction [26].

Our patient's case demonstrates that an ALTR due to corrosion may occur even in well-seated modular implants. Our patient had neither radiographic nor intraoperative signs of liner malseating. The liner was well-seated within the acetabular shell and could not be disengaged despite multiple efforts, ultimately requiring

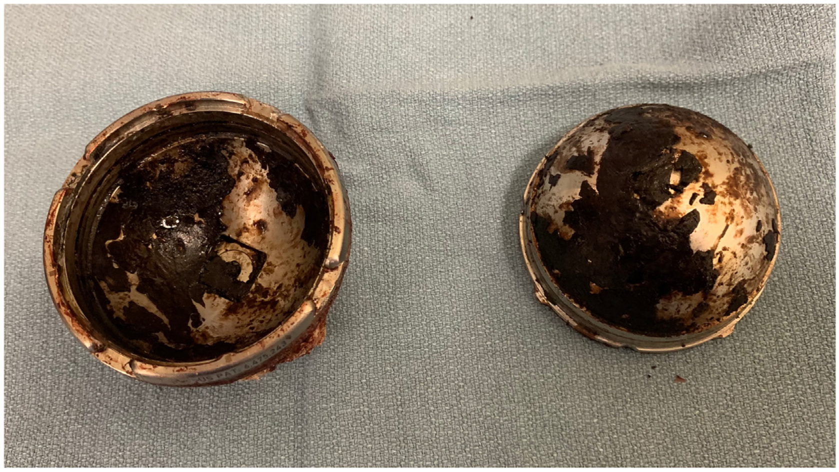

Figure 7. Intraoperative photographs demonstrating black debris, pitting, and etching of the inner surface of the titanium acetabular shell and the backside of the cobalt-chromium liner. Note the chromium-rich black surface consistent with mechanically assisted crevice corrosion (MACC).

prolonged consistent vibration from a reciprocating saw to disengage the liner from the shell in a technique similar to that described by Kaplan et al [27]. Once the liner was removed, black debris, pitting, and etching were noted on >50% of the backside of the cobalt-chromium liner and the inner surface of the titanium shell, reflecting severe corrosion per the classification system described by Goldberg et al [28]. Following revision surgery, the patient's elevated serum cobalt and chromium levels quickly returned to normal limits. However, the clinical significance of elevated levels remains unknown [29-31].

This case report is not without limitations. The dark material within the acetabular components may be from other causes, such as particles caused by abrasive wear. However, these other etiologies are less likely. The wear between the inner liner and the outer shell may have been due to abrasion rather than corrosion. However, corrosion is more likely, as corrosion has been documented in both retrieval studies and simulated in laboratory studies [11,13,15,16,20,21], whereas abrasion, to the best of our knowledge, has not been. Also, although the clinical assessment and radiographs were reassuring, it is possible that the liner may have been malseated microscopically or undetectably. The inability to easily remove the liner from the shell clinically and reassuring radiographs do not preclude malseating, especially as the patient had a liner with an elevated rim, which has been shown to be more difficult to evaluate for malseating [32].

Summary

The current case report describes the successful treatment of a patient with acetabular loosening and osteolysis secondary to an ALTR from presumed MACC between a cobalt-chromium liner and titanium acetabular shell that appeared to be well-seated both clinically and radiographically. As dual-mobility bearings, especially modular designs, become more utilized, we espouse the judicious use of this technology given the potential complications that may occur even with liners that appear to be well-seated.

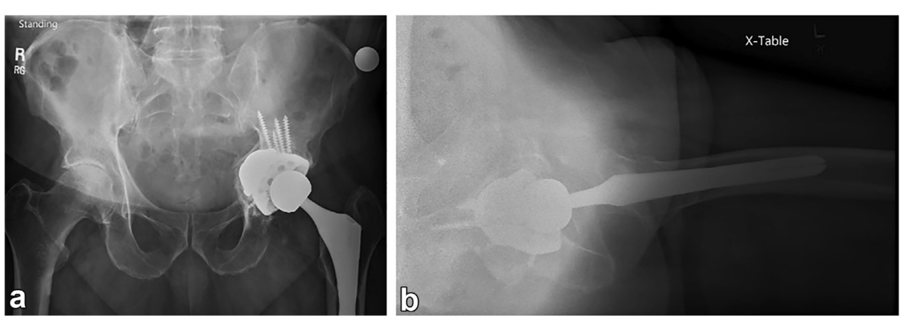

Figure 8. Anteroposterior and cross-table lateral at 1 year following revision arthroplasty.

Table 1
Preoperative and postoperative serum cobalt and chromium levels.

Timing	Serum cobalt level (ng[a]/mL[b])	Serum chromium level (ng[a]/mL[b])
1 month prior to revision THA[c]	1.3	0.3
6 weeks following revision THA	0.8	0.2
3 months following revision THA	0.6	0.2
6 months following revision THA	0.4	0.2
1 year following revision THA	0.2	0.1

[a] Nanograms (ng).
[b] Milliliters (mL).
[c] Total hip arthroplasty (THA).

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101543.

Informed patient consent

The author(s) confirm that written informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

CRediT authorship contribution statement

JaeWon Yang: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Suhas P. Dasari:** Writing – review & editing, Writing – original draft, Conceptualization. **Howard A. Chansky:** Writing – review & editing, Writing – original draft. **Nicholas M. Hernandez:** Writing – review & editing, Writing – original draft, Conceptualization.

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