Total hip arthroplasty (THA) is one of the most successful surgical procedures, offering substantial improvement in a patient's quality of life as well as function [1]. Implant modularity of the THA femoral component became widespread in the late 1980s with modular heads and sleeves, and more recently options for modularity of the neck to the stem body were introduced [2,3]. Benefits of modularity include reduced implant inventory, the capability of retaining the stem and performing a head exchange, and significant intraoperative flexibility to optimize stability, leg length, offset, and neck anteversion [2-4]. However, as of late, there have been concerns over fretting and crevice corrosion at the taper junction [5-7]. Fretting occurs when there is micromotion at the taper junction that causes injury to the passivation layer and metal grains nearest to the implant surface. Microscopic cracks create an aqueous microenvironment that disrupts the passivation layer, outlining the principles of crevice corrosion.

Corrosion at both the head-neck and neck-stem interfaces of modular femoral components have been identified as potential sources of adverse local tissue reactions along with elevated metal ion levels and clinical symptoms [2,3]. Adverse local tissue reactions (ALTRs) can occur secondary to corrosion at the modular femoral head-neck junction regardless of the bearing, and their presentation is comparable to the ALTRs seen in patients with large-diameter metal-on-metal (MoM) bearings. In addition to corrosion, modular femoral components are associated with numerous disadvantages. Fracture of the component at the stem-neck adapter interface has been reported with risk factors including male gender, weight >100 kg, and retroverted titanium necks [8,9]. Sporer et al [10] reported on neck disassociation, but this appears to be a rare occurrence.

Traditionally, the findings of corrosion at the femoral head-neck junction have been made during revision cases with very few cases of catastrophic failure [11,12]. We present 3 cases of patients who underwent revision THA at our institution and had corrosion at
the modular femoral stem-neck adapter junction. The purpose of the present report is to describe tips and tricks in the operative treatment of patients with failed modular neck stems.

Case Example 1

A 56-year-old male patient presented to our facility 2.5 years after undergoing a primary, cementless left metal-on-polyethylene (MoP) THA elsewhere. Implants included a recalled modular neck femoral component. The patient required an iliotibial band tenotomy and gluteus medius repair secondary to chronic trochanteric bursitis 18 months after his primary THA. Patient presented to our center with complaints of significant pain located about the groin that occurred with sitting and ambulating long distances. Conservative treatment in the form of strengthening exercises failed to improve his condition. Patient walked with a limp, but did not require any support for ambulation. Exam revealed his hip flexion was 90° with very limited abduction, adduction, internal rotation, and external rotation. Radiographs demonstrated THA components in satisfactory position and alignment with no significant osteolysis (Fig. 1). Laboratory values were within normal limits, with white blood cell count (WBC) 7.5 x 10^3/μL (normal 4.0-10.5), erythrocyte sedimentation rate (ESR) 1 mm/h (normal 0-20), and C-reactive protein (CRP) 2.0 mg/L (normal 0-9.9). Aspiration revealed serosanguineous fluid with WBC of 2300/mm³ and 48% of polymorphonuclear cells with all cultures being negative. Metal ion levels were obtained from the serum and revealed chromium (Cr) 2.2 μg/L (reference interval 0.1-2.1), and cobalt (Co) 3.6 μg/L (reference interval 0.0-0.9). Metal artifact reduction sequence magnetic resonance imaging demonstrated periarticular fluid distending the left iliopsoas tendon sheath with a loculated fluid collection abutting the posterior cortex of the greater trochanter representing a possible seroma. Using the risk stratification algorithm developed by Kwon et al [13], the patient's risk was high, and revision surgery was recommended. On revision surgery, there was significant corrosion observed at the tapered junction of the modular femoral neck and stem (Fig. 2). Revision surgery included revision of the liner, head, and femoral stem using a highly cross-linked polyethylene liner, 36-mm Biolox delta ceramic head (CeramTec GmbH, Plochingen, Germany) with a 3 mm titanium option taper adapter, and a cementless modular, tapered revision stem augmented with cerclage cables. Take home points from this case include the following:

- ALTRs can arise secondary to corrosion at the modular junctions regardless of the bearing surface [3,14].
- When evaluating metal ion levels in the face of corrosion of modular junctions, cobalt ion levels tend to be higher than chromium [3,14,15].
- Metal ion levels may be elevated with in the presence of bearing combinations other than MoM [15,16].

Case Example 2

A 49-year-old male presented 4 years after undergoing left primary, cementless THA performed elsewhere with a 58-mm MoP
(10° hooded liner) cup, 36-mm standard ceramic head, and a recalled modular neck stem. He reported multiple dislocations over time with complaints of intermittent groin pain, and that serum metal ion testing for cobalt only ordered by his primary care physician revealed highly elevated levels. The patient had exhausted multiple modalities of conservative treatment. His hip flexion was 90° and abduction, adduction, internal, and external rotation each measured 15°. Radiographic imaging demonstrated satisfactory component position. Laboratory profile was obtained, WBC $7.3 \times 10^9/\mu$L (normal 4.0-10.5), ESR 30 mm/h (normal 0-20), and CRP 6.5 mg/L (normal 0-9.9). A metal artifact reduction sequence magnetic resonance imaging was obtained that revealed a 9-cm peritrochanteric aseptic lymphocyte-dominated vasculitis-associated lesion (Fig. 3). Risk level was assessed as high, and revision was recommended secondary to a massive pseudotumor damaging the soft tissues. At the time of revision surgery, significant corrosion was found at the taper with substantial necrosis of the abductors secondary to the pseudotumor. Intraoperative cultures were negative. Extraction of the stem was performed using a posterior approach extended trochanteric osteotomy (ETO). Revision of the liner, head, and stem was completed using a cementless modular, tapered revision stem, a highly cross-linked polyethylene liner, and a 40-mm Biolox delta ceramic head with a −3 mm titanium option taper adapter. Serum metal ion testing for cobalt only obtained by the primary care physician at 2 months postoperative to revision revealed cobalt level declining to 1.6 μg/L (reference interval 0.1-0.4). Take home points from this case include the following:

- Corrosion at modular head-neck and stem-neck junctions may lead to ALTRs [3,14].
- Elevated serum ion levels can be present with non-MoM articulations [15].
- Metal ion levels do not always correlate with the extent of ALTRs [17].

**Case Example 3**

A 36-year-old male patient presented 3 years after undergoing right primary, cementless MoP THA performed elsewhere for avascular necrosis using a 54-mm cup, 36-mm head, and a modular neck stem. The patient subsequently had an iliopsoas injection as well as an iliopsoas tendon release. He had ongoing complaints of right groin pain and a sensation of instability since his initial surgery. The patient had exhausted multiple modalities of conservative treatment. His limb lengths were equal with range of motion measuring: flexion 90°, abduction 45°, internal rotation 20°, external rotation 70°, and adduction 20°. Radiographs revealed components in satisfactory position, but there were significant radiolucencies about the cup noted in zone II and zone III. Laboratory profile was completed and was within normal limits, with WBC $6.5 \times 10^9/\mu$L (normal 4.0-10.5), ESR 6 mm/h (normal 0-20), and CRP <2 mg/L (normal 0.0-9.9). Serum metal ion levels revealed chromium 0.3 μg/L (reference interval 0.1-2.1) and cobalt <1.0 μg/L (reference interval 0.0-0.9). Right hip computed tomography scan demonstrated atrophy of iliopsoas with no periarticular pseudotumors or masses. Revision surgery was recommended secondary to aseptic loosening of the acetabular component. Intraoperative cultures were negative. Findings at the time of revision surgery included significant corrosion at the modular neck-stem junction, no fluid collections or masses, and the stem was found to be well fixed. An anterior Wagner-type ETO was performed that allowed for stem removal. Both the cup and stem were revised (Fig. 4). Implants included a 60-mm porous cup with adjunct screw fixation, a highly cross-linked polyethylene liner, a modular revision stem (50-mm cone body proximal, 13 mm × 150 mm straight tapered splined distal stem) with cerclage cables, and a 36-mm Biolox delta head with −6 mm titanium option taper adapter. Demineralized bone matrix was used to enhance bone healing. Take home points from this case include the following:

- Despite the fact that the femoral component may be well fixed, be prepared to revise a modular femoral component in the face of corrosion at the modular stem-neck junction.
- THA revision surgery often necessitates considerations concerning stability including larger femoral head sizes, dual mobility articulations, and even possible constrained implants [18].

**Stem Revision Techniques**

The difficulty of extracting a well-fixed femoral prosthesis lies in the preservation of bone stock. Several methods of femoral implant extraction can be used depending on multiple factors: implant type, implant shape, and the stability of the bone-prosthesis interface. Axial distraction methods include the use of flexible and rigid osteotomes. An adjunct technique for removal of a well-fixed stem uses Steinman pins to disrupt the interface using a rotation mechanism rather than an axial force [19].

When axial distraction methods prove unsuccessful, an ETO may be performed through either a posterior or lateral approach. Indications for ETO in the revision setting have been well documented in the literature [20]. An ETO has its risks including bone loss, nonunion, subsidence, fracture, nonunion, delayed union, hardware complications, and the possibility for repeat surgery [21]. When dealing with removal of a shorter proximally coated femoral component, an anterior Wagner-style osteotomy may facilitate stem removal and avoid the possible risk of trochanteric nonunion.

**Stability Options**

Multiple options exist to enhance stability in revision of modular THA including large-diameter femoral heads, dual
mobility articulations, tripolar articulations, and constrained liners. The appeal for larger head use is built on the direct relationship between increasing head size and hip stability [22-24]. Data from our institution revealed a dislocation incidence of 0.05% with the use of larger diameter heads over an 8-year period [24]. The dual mobility articulation has recently gained attention as an alternative option in the prevention and treatment of instability in revision THA as it offers increased stability without compromising outcomes and implant longevity. It was developed by Gilles Bousquet and André Rambert in 1974 with the goal of attaining the best possible range of motion in a stable situation while also reducing wear. The literature has demonstrated survivorship of dual mobility articulations, tripolar articulations, and constrained liners. In 1994, Grigoris et al [31] first reported on a small subset of patients undergoing revision surgery for recurrent dislocations. They found no repeat episodes of instability with the use of a tripolar articulation. Levine et al [16] evaluated a cohort of 31 patients revised with a tripolar articular construct. They established that a tripolar articulation was effective in eradicating instability in 93% of complex revision cases.

Kung et al [32] found the use of a large-diameter head does not reduce the rate of dislocation if the abductor mechanism is absent. Constrained liners are indicated if there is abductor dysfunction. Indications for the use of constrained liners today include recurrent instability after THA, intraoperative multidirectional instability, neuromuscular diseases impairing hip dynamics, neurologic diseases that impair the patient's ability to restrict activities, proximal muscle weakness, abductor dysfunction, and multiple revisions [33,34]. The potential risks associated with the use of constrained acetabular components include component dissociation, decreased hip range of motion, and increased interfacial stresses subsequently resulting in acetabular loosening [33,35].

Conclusions

In patients who present with unexplained pain or late instability after THA using modular femoral stems, consider corrosion as a source of failure. Corrosion-related failure of modular femoral component in THA is now becoming more commonplace. When revision surgery is indicated for failed modular neck stems, we recommend a thoughtful approach with contemporary extraction techniques and options to enhance stability.

References