Corrosion at the Head-Neck Taper as a Cause for Adverse Local Tissue Reactions After Total Hip Arthroplasty

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Background: Corrosion at the modular head-neck junction of the femoral component in total hip arthroplasty has been identified as a potential concern, although symptomatic adverse local tissue reactions secondary to corrosion have rarely been described.

Methods: We retrospectively reviewed the records of ten patients with a metal-on-polyethylene total hip prosthesis, from three different manufacturers, who underwent revision surgery for corrosion at the modular head-neck junction.

Results: All patients presented with pain or swelling around the hip, and two patients presented with recurrent instability. Serum cobalt levels were elevated prior to the revision arthroplasty and were typically more elevated than were serum chromium levels. Surgical findings included large soft-tissue masses and surrounding tissue damage with visible corrosion at the femoral head-neck junction; the two patients who presented with instability had severe damage to the hip abductor musculature. Pathology specimens consistently demonstrated areas of tissue necrosis. The patients were treated with debridement and a femoral head and liner exchange, with use of a ceramic femoral head with a titanium sleeve in eight cases. The mean Harris hip score improved from 58.1 points preoperatively to 89.7 points at a mean of 13.0 months after the revision surgery ($p = 0.01$). Repeat serum cobalt levels, measured in six patients at a mean of 8.0 months following revision, decreased to a mean of 1.61 ng/mL, and chromium levels were similar to prerevision levels. One patient with moderate hip abductor muscle necrosis developed recurrent instability after revision and required a second revision arthroplasty.

Conclusions: Adverse local tissue reactions can occur in patients with a metal-on-polyethylene bearing secondary to corrosion at the modular femoral head-neck taper, and their presentation is similar to the adverse local tissue reactions seen in patients with a metal-on-metal bearing. Elevated serum metal levels, particularly a differential elevation of serum cobalt levels with respect to chromium levels, can be helpful in establishing this diagnosis.

Level of Evidence: Diagnostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Modularity at the head-neck junction of the femoral component in total hip arthroplasty has several benefits, including intraoperative flexibility, the ability to change the femoral head later if necessary, and decreased implant inventory[1-3]. This design feature initially became popular in the late 1980s and early 1990s[4,5], but soon thereafter concerns

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TABLE I Demographic and Initial Surgical Data

Case	Age (yr)	Sex	Body Mass Index (kg/m^2)	Femoral Component	Taper	Head Size, Neck Length (mm)	Interface	Time to Revision (After Index Op.) (yr)
1	66.5	F	31.9	Zimmer VerSys Beaded FullCoat	12/14	32, +3.5	Co alloy/Co alloy	3.4
2	65.0	F	24.3	Zimmer VerSys Beaded FullCoat	12/14	28, +10.5	Co alloy/Co alloy	6.5
3	69.9	F	25.2	Zimmer VerSys Beaded FullCoat	12/14	36, +7	Co alloy/Co alloy	4.3
4	58.1	F	27.2	Zimmer VerSys Beaded FullCoat	12/14	28, +10.5	Co alloy/Co alloy	5.1
5	41.1	F	28.0	Zimmer VerSys Beaded FullCoat LHC	12/14	32, +5	Co alloy/Co alloy	2.1
6*	61.5	M	27.3	Zimmer VerSys Beaded FullCoat Revision	12/14	32, +10.5	Co alloy/Co alloy	0.8
7	46.5	M	36.0	Zimmer VerSys Fiber Metal Taper	12/14	32, −3.5	Ti alloy/Co alloy	5.1
8	62.6	F	36.0	Zimmer M/L Taper, Kinectiv Modular Neck	12/14	32, +0	Ti alloy/Co alloy	0.7
9	55.5	F	32.1	DePuy Bantam Full Porocoat	10/12	28, +5	Co alloy/Co alloy	8.9
10*	70.4	F	25.2	Stryker Accolade	V40	36, +0	Ti alloy/Co alloy	2.2

*The patient was referred from another facility.

about fretting and crevice corrosion at the modular taper junction, particularly with mixed-metal junctions, were reported[4,6-10]. Subsequent design and manufacturing improvements minimized these concerns, allowing a nearly universal adoption of modular femoral head-neck tapers in modern total hip arthroplasty. As a result of these design improvements, corrosion at this modular taper interface has received relatively little attention over the last decade[5,11,12].

Historically, a diagnosis of corrosion at this femoral head-neck interface has been made only on the basis of retrieval analysis[2-5,8,13-18] or, rarely, in cases of catastrophic failure[2,7]. Although there have been sporadic reports of elevated serum metal levels[1] and particle deposition within local tissues[19] and isolated case reports of soft-tissue reactions[20-22] associated with corrosion of modular implants, symptomatic adverse tissue reactions have not been described in a cohort of patients, to our knowledge. We identified ten patients with adverse local tissue reactions following total hip arthroplasty with a metal-on-polyethylene bearing secondary to corrosion at the modular head-neck taper junction. These adverse tissue reactions are similar to the deleterious local tissue reactions reported in some patients with metal-on-metal bearing surfaces[23-26]. The purpose of the present report is to describe the clinical presentation, diagnosis, and early results of operative treatment of patients with corrosion at the modular head-neck junction of a metal-on-polyethylene total hip prosthesis.

Materials and Methods

Study Population

Ten patients underwent revision of a total hip arthroplasty at our institution for a primary or secondary diagnosis of complications arising from corrosion at the modular femoral head-neck taper junction between January 1, 2009, and August 31, 2011. These procedures represent 1.8% of the 569 revision hip arthroplasties performed at our institution over the same period. The study group consisted of eight women and two men with an average age of 59.7 years (Table I). Approval was obtained from our institutional review board prior to initiation of this study.

Patients initially presented with symptoms at a mean of 3.2 years (range, 0.7 to 8.7 years) after their index procedure. The presenting symptoms varied quite a bit among the patients but included groin and anterior thigh pain (two patients), buttock pain (two patients), lateral hip pain (one patient), generalized pain and weakness (one patient), a palpable fluid collection (one patient), and marked lower-extremity swelling (one patient). The remaining two patients presented with recurrent instability with vague hip pain; one of them reported progressive weakness and limping over the preceding year whereas the second presented with recurrent hematomas and marked weakness. Harris hip scores[27] averaged 54.5 points (range, 22 to 79 points) prior to the revision surgery.

Eight of the primary procedures were done at our institution. Five hip prostheses were implanted via a posterior approach; two, via an anterolateral approach; two, via an abductor-sparing mini-Watson-Jones anterior approach; and one, through a two-incision approach. The implanted acetabular components included nine Trilogy shells (Zimmer, Warsaw, Indiana) and one Trident PSL shell (Stryker, Mahwah, New Jersey). The bearing surface was highly cross-linked polyethylene in all ten patients, with nine having a Longevity (Zimmer) insert and one having an X3 (Stryker) insert. The implanted femoral components, femoral head sizes, and neck lengths are listed in Table I.

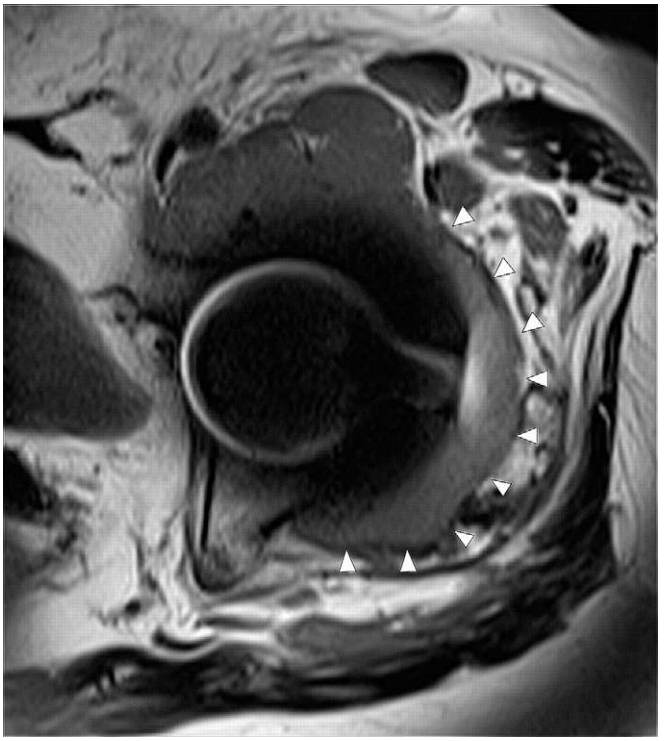

Fig. 1

Axial T1-weighted fat-suppressed MRI demonstrating a large fluid collection within the hip joint (arrowheads).

Preoperative Workup

All patients had radiographs at the time of their initial symptoms. In each case, the findings were interpreted as normal, demonstrating well-fixed components with no evidence of loosening, wear, or osteolysis. Laboratory test results included an elevated erythrocyte sedimentation rate (mean, 47.3 mm/hr; range, 4 to 108 mm/hr; normal, <27 mm/hr) in four of seven patients in whom this test was performed, and an elevated C-reactive protein level (mean, 2.6 mg/dL; range, <0.5 to 5.7 mg/dL; normal, <0.8 mg/dL) in three of six patients in whom this test was performed.

Nine of the ten patients had preoperative hip aspiration under fluoroscopy, with a mean synovial fluid white blood cell (WBC) count of 4009 WBC/μL (range, 0 to 27,500 WBC/μL) and a mean WBC differential of 62% neutrophils (range, 12% to 99%), 28% lymphocytes (range, 0% to 57%), and 10% monocytes (range, 0% to 35%). The synovial fluid WBC count was suggestive of infection in one case (27,500 WBC/μL with a differential demonstrating 99% neutrophils), but cultures did not demonstrate bacterial or fungal growth in any patient. Three patients had magnetic resonance imaging (MRI) studies and two had computed tomography scans, each of which demonstrated a large fluid collection around the hip joint (Fig. 1). Serum metal levels obtained with a previously described analytical methodology[28] demonstrated elevated cobalt levels in all ten cases and elevated chromium levels in seven of the ten cases (Table II). Notably, cobalt levels were elevated above their reference range to a significantly greater degree than chromium levels (Wilcoxon signed-rank test, $p = 0.014$). On average, it took 8.0 months (range, zero to thirty-six months) to establish a diagnosis and perform revision surgery after the patient's initial presentation of symptoms.

Revision Surgery

A posterior surgical approach was utilized in seven cases and an abductor-sparing mini-Watson-Jones anterior approach, in three. A large amount of abnormal fluid, ranging from milky white to brownish in color, was encountered on entry into the hip joint. Frozen section analysis and intraoperative cultures were performed in all cases. Hypertrophy of the synovial tissue and pseudocapsule was typical (Fig. 2), resulting in large masses in several patients.

TABLE II Preoperative Metal Ion Levels, Demonstrating Differential Elevation in Serum Cobalt Over Chromium*

	Mean ± Std. Dev.	Range	Reference Range†
Titanium	2.12 ± 0.67	1.31-3.30	2.20 ± 0.52
Cobalt	9.55 ± 12.73	1.60-42.45	0.16 ± 0.10
Chromium	1.39 ± 1.23	0.18-3.28	0.24 ± 0.35

*All values are given in ng/mL. †Reference data are from patients at our institution with a well-functioning metal-on-polyethylene total hip prosthesis at eighty-four months postoperatively[31].

Permanent histological analysis of capsular tissue was performed in eight cases. There were varying degrees of hip abductor muscle necrosis, with the two patients who had presented with recurrent instability having gross hip abductor muscle deficiency. No impingement between the prosthetic femoral neck and acetabular cup was noted at the revision surgery.

A complete synovectomy was performed, with removal of all abnormal hypertrophic tissue. In all patients, the femoral head-neck junction demonstrated obvious corrosion, seen as black, flaky material at the base of the taper (Fig. 2). The modular head remained engaged on the taper in all cases without signs of loosening. Each was disengaged from the taper, and the taper was cleaned with a dry lap pad to remove the corrosion product. Visual inspection by the surgeon revealed that the structural integrity of the trunnion was maintained in all ten implants. The femoral component was well-fixed in all cases. The acetabular component was well-fixed in nine of ten cases. It was concomitantly revised in one case because of loosening and in a second case because of component malposition; the modular liner was exchanged in the remaining eight cases.

A constrained liner was utilized in three patients: in the two with recurrent instability and in a third with moderate abductor muscle necrosis. In eight of the ten patients, a titanium-alloy adapter sleeve (CeramTec, Plochingen, Germany) was inserted over the existing taper and a BIOLOX *delta* ceramic femoral head

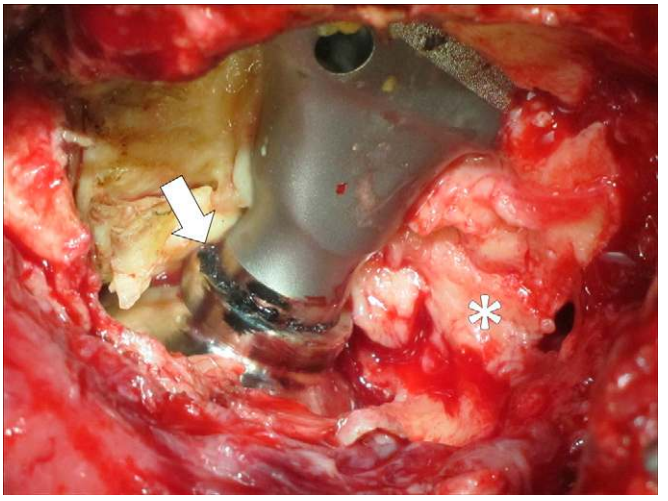

Fig. 2

Intraoperative photograph demonstrating corrosion (arrow) at the modular head-neck taper between the femoral component and a collared (+10.5-mm) head. The pseudocapsule is markedly hypertrophic and avascular (asterisk), which is typical of this adverse local tissue reaction.

TABLE III Revision Surgery and Postoperative Data

Case	Revision Procedure	Head Size *(mm)*	Head Type	Liner	Preop. Cr Level *(ng/mL)*	Preop. Co Level *(ng/mL)*	Postop. Co Level *(ng/mL)*	Complications
1	Head + liner exchange	32	Ceramic	Elevated rim	3.28	8.89	0.54 at 6.1 mo	Recurrent instability
2	Head + liner exchange	28	Ceramic	Constrained	3.16	1.67	0.36 at 22.0 mo	—
3	Head + liner exchange, acetabular revision	36	Ceramic	Neutral	1.94	10.80	—	—
4	Head + liner exchange	36	Ceramic	Neutral	0.60	6.30	—	—
5	Head + liner exchange	32	Ceramic	Elevated rim	1.23	7.21	0.20 at 14.0 mo	—
6	Head + liner exchange, irrigation and debridement	32	Ceramic	Constrained	1.69	42.45	8.93 at 2.2 mo	—
7	Head + liner exchange, acetabular revision	40	Metal	Neutral	0.18	2.72	0.18 at 12.0 mo	—
8	Head + liner exchange	32	Ceramic	Elevated rim	0.21	3.17	—	—
9	Head + liner exchange	28	Metal	Constrained	3.18	1.60	—	—
10	Head + liner exchange	36	Ceramic	Elevated rim	0.18	2.79	1.18 at 3.6 mo	—

(CeramTec) was impacted onto the adapter sleeve; the sleeve was used because of theoretical concerns about ceramic fracture with insertion onto a potentially damaged taper and to avoid the use of an additional modular junction containing cobalt alloy[29]. In the remaining two patients, a metal femoral head was used. Two 28-mm, four 32-mm, three 36-mm, and one 40-mm head sizes were utilized (Table III).

Statistical Analysis

The mean serum levels of titanium, cobalt, and chromium prior to revision surgery were calculated. Nonparametric tests were used on the basis of the results of a Shapiro-Wilk test. A Wilcoxon signed-rank test was used to compare the degree of elevation between preoperative cobalt and chromium levels. This test was also applied to longitudinal comparison of Harris hip scores and metal levels, assuming a two-tailed p value of 0.05.

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Results

Frozen sections were negative for acute inflammation in nine cases, but one patient demonstrated acute inflammation consistent with infection. *Peptostreptococcus anaerobius* grew on culture of two of two samples from that patient, whereas cultures of specimens from the remaining nine patients demonstrated no growth. Notably, the patient with the positive WBC count on preoperative hip aspiration had a frozen-section examination that was negative for infection and cultures demonstrated no growth. Histological analysis of the eight tissue specimens revealed tissue necrosis in each. Remaining viable capsular tissue demonstrated areas of dense perivascular infiltration of lymphocytes (Fig. 3).

The mean Harris hip score improved from 58.1 points (range, 32 to 79 points) prior to the revision surgery to 89.7 points (range, 76 to 99 points) at a mean of 13.0 months (range, 1.5 to 30.9 months) after it ($p = 0.01$). The post-revision hip score was classified as excellent (>90 points) in six patients, as good (80 to 89 points) in two, and as fair (70 to 79 points) in two[27]. Eight of the ten patients demonstrated an improvement of >20 points in the Harris hip score.

Postoperative metal levels were measured in six patients at nine different time points, at a mean of 8.0 months (range, 1.8 to 22.0 months) after the revision surgery. In each case, there was a decrease in the serum cobalt level with time (Fig. 4); the mean cobalt level in these six patients was 10.96 ng/mL (range, 1.60 to 42.45 ng/mL) prior to the revision surgery and decreased to a mean of 1.61 ng/mL (range, 0.18 to 8.93 ng/mL) after the revision surgery ($p < 0.05$). Neither the titanium levels (mean, 2.02 ng/mL

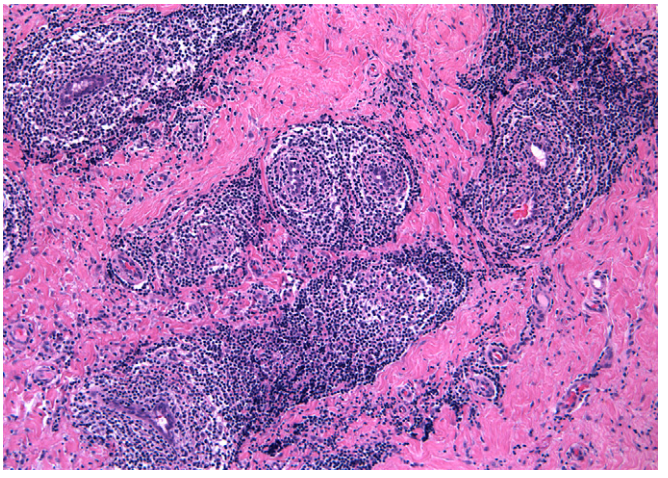

Fig. 3

Case 8. Photomicrograph of the pathology specimen (hematoxylin and eosin, ×125). Viable areas of the joint pseudocapsule demonstrated a dense perivascular infiltration of lymphocytes. Large areas of the specimen were necrotic (not visualized on this image).

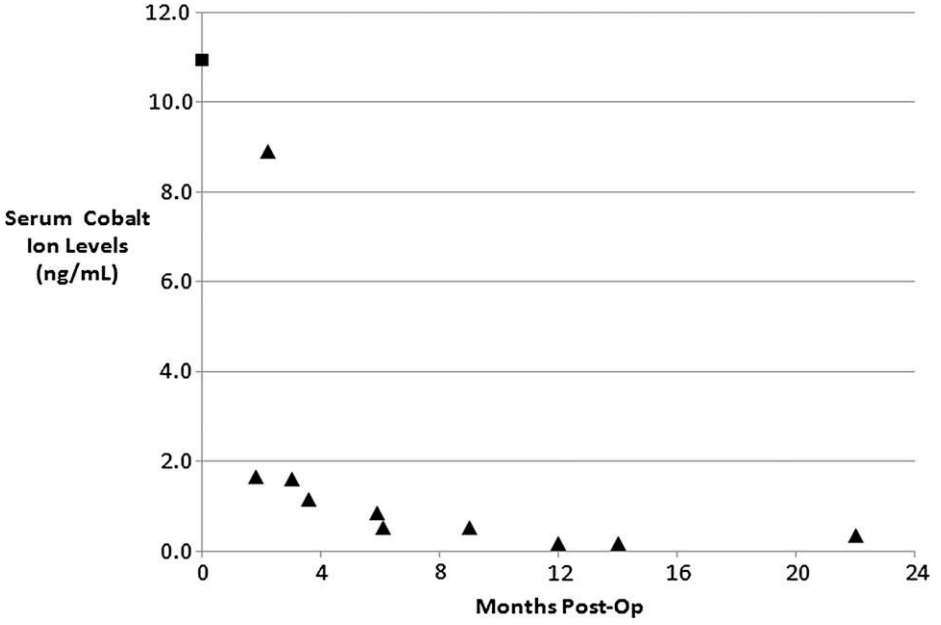

Fig. 4

Graph depicting the decrease in serum cobalt levels following revision surgery for corrosion at the modular head-neck taper. The square represents the mean of the preoperative values for the six patients who had measurement of postoperative metal levels. The triangles represent individual data points for different patients at various points during the postoperative course. As a reference, patients with a well-functioning metal-on-polyethylene total hip prosthesis have demonstrated a serum cobalt level of 0.16 ± 0.10 ng/mL at eighty-four months postoperatively[31].

pre-revision compared with 1.80 ng/mL post-revision) nor the chromium levels (mean, 1.62 ng/mL pre-revision compared with 1.38 ng/mL post-revision) demonstrated a significant change with the sample size available for study.

Complications included recurrent instability in a sixty-six-year-old woman who was noted to have moderate abductor necrosis at the time of the initial revision. After three dislocations, she underwent a second revision in which a constrained liner was placed and she had not had any more episodes of instability at the time of writing.

Discussion

The idea that corrosion might occur at the head-neck taper of the femoral component of a total hip prosthesis was first described in the early 1980s[30], and the concept that modular tapers are susceptible to mechanically assisted crevice corrosion, a combination of fretting and crevice corrosion, was subsequently introduced[6]. Since that time, there have been numerous reports of corrosion at this taper interface, documented primarily in retrieval studies[2-5,8,13-18] or, in rare cases, in association with catastrophic failure[2,7]. Although there have been concerns[9] that fretting corrosion at the modular taper may produce soluble and particulate debris that can migrate locally or systemically[19], to the best of our knowledge there have been only two prior case reports of corrosion at the head-neck taper as a cause of occult, ongoing hip pain or as a cause of adverse local tissue reactions[21,22].

In the present series, corrosion was a difficult diagnosis in most cases. The level of suspicion for an adverse metal reaction was initially quite low for patients with a metal-on-polyethylene bearing surface. However, as serum testing for metal is readily available at our institution, the role of these tests has expanded beyond patients with a metal-on-metal bearing surface. Our relatively low threshold for performing these tests, coupled with our confidence in the accuracy of our laboratory's results, likely enabled us to make this diagnosis more readily than we would have been able to do otherwise. The results of these tests suggested an abnormality in all ten patients, typically showing a greater elevation in serum cobalt levels than in chromium levels when compared with reference ranges for patients with a well-functioning metal-on-polyethylene total hip arthroplasty[28,31]. Notably, two studies of metal-on-metal total hip arthroplasties have also documented differential elevations in serum cobalt levels over chromium levels, and their authors attributed this to release of metal debris or corrosion at the modular taper[32,33].

It is clear from our series that, although it is uncommon, corrosion at the head-neck taper of the femoral component can produce substantial soft-tissue damage around the hip and should be included in the differential diagnosis for occult hip pain following total hip arthroplasty. On the basis of the type of tissue reaction and the presence of elevated serum metal levels, this process appears to be quite similar to adverse metal tissue reactions secondary to metal-on-metal bearing surfaces[23-26]. Further complicating the clinical picture, the primary process of corrosion has the potential to masquerade as a more obvious secondary process such as instability or component loosening, which has also been reported in the setting of adverse tissue reactions surrounding metal-on-metal bearings[25,26,34,35]. In particular, instability was a substantial problem in our series. Two

patients presented with recurrent dislocations, and in both cases there was extensive necrosis with gross deficiency of the abductor mechanism that necessitated a constrained liner to achieve stability. A third patient experienced recurrent instability after revision surgery and subsequently had a revision to a constrained liner. Although the literature has demonstrated an increased dislocation rate after isolated head and liner exchange[36,37], this problem is likely compounded in the setting of local tissue damage and severe abductor damage[38]. In view of this complication, the patient in this series who most recently underwent revision surgery for taper corrosion received a constrained liner despite having no history of instability, with the decision based on the amount of abductor damage seen at surgery.

Although the distribution of implants and manufacturers in this series may suggest a problem with a specific design, the distribution of implants is more likely related to the pattern of use in our institution than a design flaw of a single implant. Seven of the ten femoral components in this series were diaphysis-engaging cobalt-alloy stems with sintered beads. The findings in this series may be related to the preponderance of cobalt-alloy cementless stems that were used, as these devices had a greater-than-anticipated prevalence of intergranular corrosion on their trunnions in a separate series of 246 retrieved implants[39]. One of the stems in our study was a titanium femoral component with a modular neck and modular head. While modular neck stems may have some clinical benefits, this additional modular junction may increase the risk of corrosion and the types of soft-tissue reactions seen in this series; these complications may be more likely to occur in designs with a cobalt-alloy neck.

There was one acute infection in the setting of ongoing corrosion. This patient underwent two preoperative hip aspirations, several weeks apart. In both cases, no organisms grew on culture, and cell counts demonstrated fragmented cells and debris but no WBCs. The patient was scheduled for revision surgery on the basis of markedly elevated serum cobalt levels (42.45 ng/mL), after which he reported developing a sinus infection and subsequent worsening of hip pain. At the time of revision, gross purulence was found in the setting of a large, avascular soft-tissue mass and capsular hypertrophy, with cultures positive for Peptostreptococcus, an anaerobic organism commonly associated with sinus infections[40]. Although uncommon, the presentation of a superimposed infection has been reported in the setting of a pseudotumor associated with a metal-on-metal total hip arthroplasty[41]. It is possible that the avascular and necrotic nature of these large soft-tissue masses make them a susceptible site for infection in the setting of transient bacteremia. As this was thought to be an acute hematogenous infection with prompt treatment, irrigation and debridement with head and liner exchange was performed, with no evidence of recurrence to date.

The revision consisted of a modular head and liner exchange in eight of the ten patients (with the remaining two having a concomitant revision of the acetabular component), with reasonably good results at the time of early follow-up. This allowed retention of well-fixed components while still addressing, at least in part, the underlying problem at the taper junction. While extensive damage to the retained trunnion was not observed in these patients, there was likely some degree of damage. In a large retrieval study, corrosion was found to be more advanced in the head than on the trunnion[8]. The dilemma faced by the revising surgeon is whether to expose the patient to the potential morbidity associated with revision of a well-fixed femoral stem (particularly a distally fixed, fully porous-coated stem) in the setting of mild-to-moderate fretting corrosion on the trunnion. Our approach in this small series involved converting the cobalt-alloy/cobalt-alloy and cobalt-alloy/titanium-alloy head-neck interfaces to titanium-alloy/cobalt-alloy or titanium-alloy/titanium-alloy interfaces. This may be sufficient to prevent recurrence of the adverse local tissue responses, as was demonstrated in another case report[42]; however, longer-term follow-up is required to determine if the favorable results observed at a mean of 13.0 months postoperatively are maintained.

This study had several limitations, the most notable being an unknown denominator as not all patients had the primary arthroplasty performed at our institution. Nonetheless, we believe that this complication is relatively uncommon as it accounted for only 1.8% of the hip revisions performed at our institution over this time period. Furthermore, this is a relatively small series of patients with a short duration of follow-up, and it is unclear how these patients will fare over time. Despite the small size of this series, given the difficulties in diagnosis and the severity of the soft-tissue damage noted, we think that sharing our experience is important. Additionally, metal levels were available for all patients prior to revision, but these levels were inconsistently collected postoperatively.

In conclusion, adverse local tissue reactions can occur secondary to metal debris resulting from corrosion of the modular head-neck taper of metal-on-polyethylene total hip prostheses; these reactions appear to be quite similar to those reported in patients with metal-on-metal bearing surfaces. Serum metal levels were abnormal in every case, with an elevation of cobalt levels that was differentially higher than that of chromium levels. We recommend consideration of these tests for patients with a painful total hip prosthesis without an obvious cause, particularly if evidence of a fluid collection or tissue damage is detected by advanced imaging modalities. ■

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