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CASE REPORT

Wire-stem fretting and galvanic corrosion as an underrecognized cause of metallosis after hip arthroplasty: A rare case report

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ABSTRACT

Although metallosis after hip arthroplasty is most often attributed to bearing wear or trunnion corrosion, auxiliary fixation devices may also serve as a potential source. In this article, we report a rare case in which direct contact between a stainless-steel cerclage wire and a titanium femoral stem produced localized metallic debris and a peri-stem pseudotumor, consistent with fretting and galvanic corrosion. Ten years after index total hip arthroplasty complicated by an intraoperative femoral fracture treated with cerclage, the patient presented with groin pain and a cystic lesion with solid components adjacent to the femoral stem. Revision surgery revealed black-stained tissue concentrated at the wire-stem interface. Histological examination confirmed metallic debris with chronic inflammation. After extensive debridement and revision to a distally fixed stem, pain on the Visual Analog Scale (VAS) decreased from 5 to 1, and the Harris Hip Score (HHS) improved from 70 to 93 at six months. In conclusion, this case serves as a reminder that even auxiliary fixation devices, such as stainless-steel cerclage wires placed for intraoperative fracture stabilization, can generate metallic debris and lead to metallosis when they come into contact with titanium stems. Surgeons, therefore, should avoid direct contact between stainless-steel and titanium components, or otherwise interpose an insulating layer when cerclage fixation is required.

Keywords: Cerclage wire, dissimilar metals, galvanic corrosion, hip arthroplasty, metallosis, mixed-metal implants. pseudotumor.

Total hip arthroplasty (THA) is a highly effective treatment for end-stage hip disease, providing reliable pain relief and functional restoration. However, long-term complications related to wear and corrosion remain clinically significant, as metallic debris can provoke adverse local tissue reactions (ALTRs) and periprosthetic osteolysis.[1] Metal-on-metal (MoM) articulations, once widely adopted, have seen a decline in use because of concerns regarding cobalt and chromium ion release and the risk of systemic toxicity.[2] Current practice more often favors combinations such as ceramic femoral heads with titanium stems and polyethylene liners, which substantially reduce metal ion burden, compared with MoM bearings, also lessen the long-term financial and logistical burden of intensive follow-up.[3] Nevertheless, metallosis cannot be completely eliminated, as alternative sources, including fretting wear at the trunnion, polyethylene wear debris, mixed-metal contact introduced during revision, or even catastrophic ceramic liner fracture, may still generate biologically active particles leading to metallosis and osteolysis.[4,5]

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While corrosion at non-articulating interfaces has increasingly recognized as an additional source of debris,[6,7] the risk associated with auxiliary fixation devices remain underappreciated. Components such as cerclage wires, although not part of the primary prosthesis, may also come into direct physical contact with titanium femoral stems, creating both mechanical and electrochemical interfaces. When dissimilar metals are placed in proximity within a conductive environment, galvanic interaction can occur, initiating or accelerating corrosion processes and generating metallic debris that contributes to metallosis and implant-related complications.[2,8]

In this article, we report a rare case in which a stainless-steel cerclage wire placed at the time of the index THA gradually interacted with a titanium femoral stem over 10 years, leading to localized metallosis and pseudotumor formation.

CASE REPORT

A 65-year-old male patient presented with progressive groin pain and reduced walking tolerance 10 years after a primary THA that was previously performed for osteoarthritis. The index procedure was complicated by an intraoperative femoral fracture, which was stabilized with a cerclage wire. The patient reported no systemic symptoms, wound complications, or features suggestive of metal hypersensitivity. On physical examination, he had an antalgic gait and painful hip motion, while neurovascular status remained intact. Laboratory tests showed a normal white blood cell count of $7.48 \times 10^3/\mu L$, C-reactive protein (CRP) of 0.022 mg/dL, and erythrocyte sedimentation rate (ESR) of 2 mm/h, all within normal limits. Joint aspiration cultures were negative, leading to preliminary exclusion of periprosthetic joint infection. With infection preliminarily excluded, subsequent imaging studies were performed to explore alternative causes. Pelvic anteroposterior radiograph demonstrated the right femoral stem with a cerclage wire encircling the proximal femur (Figure 1a). A low-density lesion was observed in the trochanteric region, raising suspicion for an adverse tissue response, possibly due to metallic debris released from micro-motion-induced fretting at the wire-stem interface. A magnified anteroposterior view of the right hip further showed radiolucent lines along the stem-bone interface adjacent to the proximal cerclage, raising radiographic signs suggestive of loosening (Figure 1b). Magnetic resonance imaging (MRI) revealed an approximately 12-cm cystic lesion with solid components, adjacent to the femoral stem, with T2 hyperintensity and thick rim enhancement, without evidence of sinus tract or abscess formation (Figure 1c). These findings raised concern for an ALTR, and revision surgery was undertaken through a posterolateral approach.

Intraoperatively, gray-black stained tissue was sharply localized at the cerclage wire-stem interface along the medial aspect of the proximal femur, while the bearing couple and the head-neck taper showed no visible damage or discoloration. The femoral stem was grossly loose, and its proximal surface adjacent to the cerclage was contaminated by corrosion

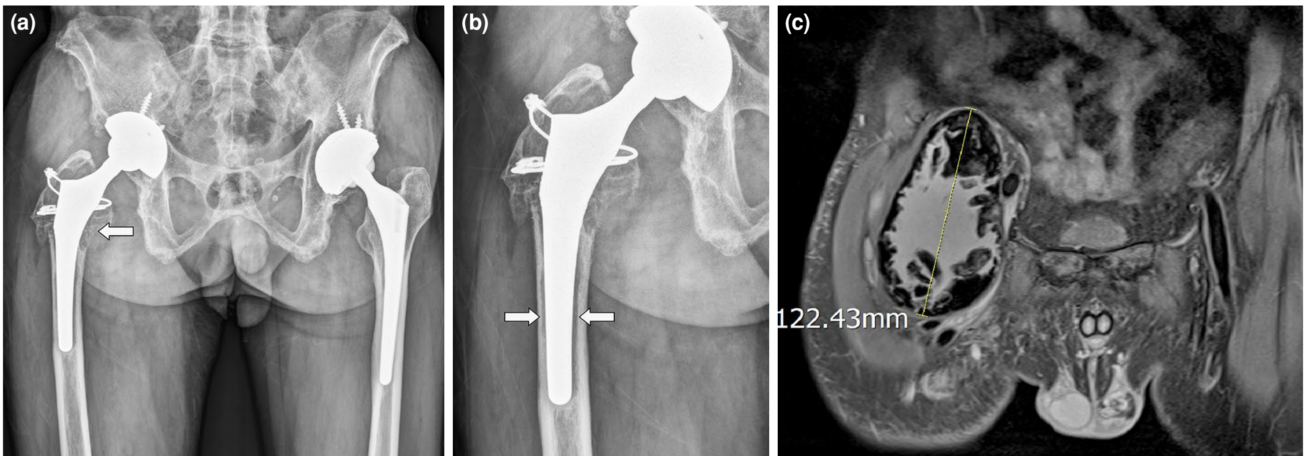

FIGURE 1. Anteroposterior radiograph. **(a)** A cerclage wire encircles the proximal femur, and a low-density lesion is visible in the trochanteric region adjacent to the cerclage wire (arrow). **(b)** Radiolucent lines are visible along the stem-bone interface (arrows), suggestive of loosening. **(c)** T2-weighted MRI of the right hip showing a large cystic lesion with solid components (122.43 mm) with high T2 signal intensity is visible within the proximal thigh musculature.

products. After extensive debridement, the stem was replaced with a long, distally fixed femoral component to remove all potentially involved interfaces and minimize the risk of recurrent metallosis. During the operation, the proximal femur showed marked osteopenia. After removal of the femoral stem, a lateral cortical crack was identified, which might have compromised proximal fixation of the femoral stem. To prevent further propagation of the crack and to reinforce proximal stability, a tension band wiring construct consisting of two Kirschner wires with proximally bent hooks and a tensioned figure-of-eight wire was applied, followed by placement of a stainless-steel cerclage wire circumferentially for additional reinforcement. The wire construct was positioned around the outer cortical surface, completely enclosing the host bone and fully separated from the titanium stem, which ensured that no direct metal-to-metal contact occurred. The acetabular metal cup was retained, and the polyethylene liner was renewed to improve long-term durability. Figure 2 shows the excised metallosis-involved soft tissue and retrieved

FIGURE 2. Excised metallosis-involved tissue and retrieved implants. Gross specimens show excised black-stained periprosthetic soft tissue together with the retrieved loosened femoral component.

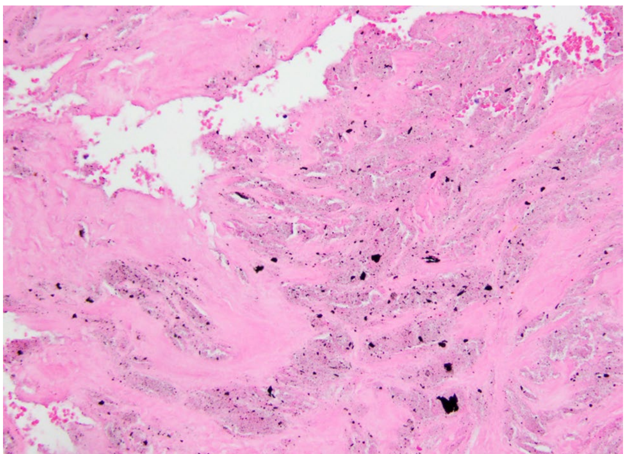

FIGURE 3. Hematoxylin and eosin staining of excised tissue. The section shows black metallic particles scattered within the interstitial tissue and within macrophages (H&E, ×200).

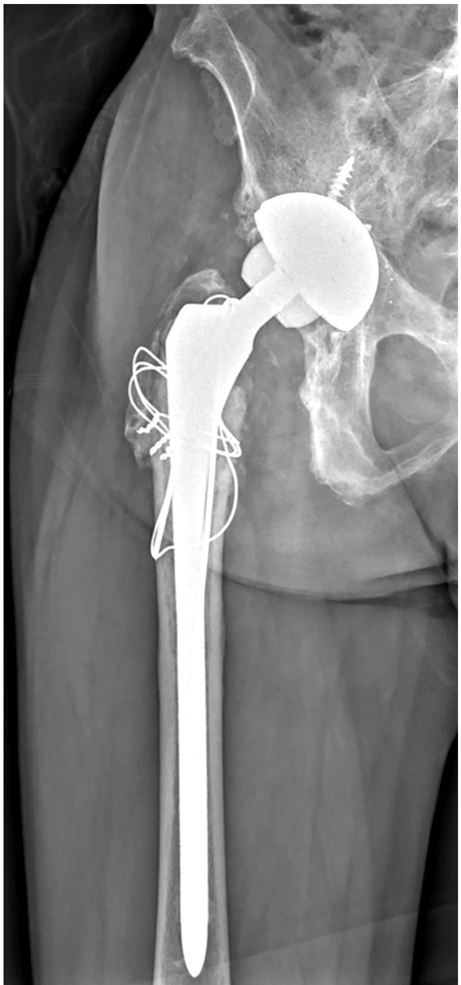

FIGURE 4. Post-revision anteroposterior radiograph. The image demonstrates a long, distally fixed stem. The tension band wiring construct and the cerclage wire are isolated from the stem by intervening host bone, with no direct metal-to-metal contact.

implants. Postoperatively, histological examination of the excised tissue revealed fibroadipose tissue with chronic inflammation, macrophages containing refractile metallic particles, and multinucleated giant cells, while Gram stain and cultures were negative (Figure 3). At six months of follow-up, his pain score on the Visual Analog Scale (VAS) improved from a pre-revision value of 5 to 1, and his Harris Hip Score (HHS) increased from 70 to 93. Post-revision radiographs showed a well-seated femoral stem, in which the wire construct and cerclage were separated from the stem by intervening host bone (Figure 4). No progressive osteolysis was observed. A written informed consent was obtained from the patient.

DISCUSSION

The present case illustrates a rare, but clinically important source of metallosis after THA, arising not from the primary bearing couple or head-neck taper, but from prolonged interaction between a stainless-steel cerclage wire and a titanium femoral stem. Over a 10-year interval, micromotion and galvanic corrosion at this auxiliary fixation site generated metallic debris that elicited localized metallosis and pseudotumor formation, while the articular and trunnion surfaces still remained intact. This unusual presentation highlights the underappreciated risk posed by non-articulating implant components and underscores the need to consider auxiliary devices among potential culprits when evaluating ALTRs following hip arthroplasty.

Total hip arthroplasty is one of the most common and successful orthopedic procedures, offering durable pain relief and functional restoration for patients with end-stage hip disease refractory to conservative treatment. It is most frequently performed for primary osteoarthritis, which comprises nearly 70% of the patient population.[9] Despite its overall success, long-term complications remain clinically relevant, particularly those related to wear and corrosion of implant materials.[10] Metallic debris in hip arthroplasty generated at bearing surfaces or modular junctions can trigger ALTR, periprosthetic osteolysis, and eventual implant failure.[10,11] Experimental and retrieval data indicate that fretting amplitude and frequency scale with patient activity, accelerating oxide disruption and electrochemical degradation and thereby modulating failure rates.[12] Historically, MoM bearings have been recognized as a major contributor, where direct cobalt-chromium (CoCr) articulation generates extensive particulate debris, leading to local pseudotumor formation and, via gradual accumulation of cobalt in the blood and subsequent deposition in body tissues such as the kidney, liver, heart, and brain, to systemic toxicity[13] manifesting as spasticity,[14] and cardiomyopathy.[15] With the shift toward metal-on-polyethylene (MoP) or ceramic-on-ceramic (CoC) bearings, complications became less frequent, but polyethylene or ceramic wear debris and associated third-body abrasion of the metallic head continue to induce osteolysis and ALTRs.[16] Furthermore, trunnion corrosion can occur at modular junctions such as the head-neck taper (trunnionosis), characterized by taper debris and synovial staining patterns extending into the periprosthetic capsule. However, the current case demonstrated a sharply localized distribution of metallic debris around the proximal cerclage wire, while the polyethylene liner and trunnion were intact. This pattern suggests that the source of metallic wear was most likely localized to the proximal wire-stem interface rather than the bearing surfaces or modular taper junctions.

Phagocytosis of metallic particles by macrophages triggers cytokine-mediated inflammation, which is central to ALTR, osteolysis, and periprosthetic bone loss.[1,17] Histological examination of periprosthetic tissue from this patient demonstrated black, refractile metallic particles within the macrophages, accompanied by multinucleated giant cells (Figure 3), consistent with an ALTR pattern. Clinically, ALTR commonly presents with groin pain and restricted range of motion and may be accompanied by radiographic peri-implant radiolucency (i.e., periprosthetic osteolysis). Our patient did report groin pain and had a focal peri-stem low-density lesion on plain radiographs (Figure 1). Furthermore, MRI revealed a cystic lesion with solid components, aligning with the established ALTR-osteolysis phenotype. Taken together, these clinicopathologic and radiographic findings supports metallic debris-driven ALTR with focal osteolysis. In conjunction with the intraoperative distribution of black-stained tissue, these results suggest that the corrosive process may have originated at the proximal cerclage-stem interface, where micromotion and dissimilar metal contact could have interacted to drive the local reaction.

Furthermore, as the retained femoral stem and the cerclage wire were composed of titanium and stainless-steel, respectively, CoCr bearing-related metallosis was unlikely. The patient's presentation was purely a focal peri-implant lesion, with no documented systemic manifestations of cobalt-related toxicity typically seen in MoM bearings. When cobalt toxicity occurs, it often involves neuro-otologic, cardiac, or endocrine systems[18,19] rather than remaining limited to a localized peri-implant process, and MoM pathology may also manifest as pseudotumor-related mass-effect syndromes such as sciatica.[20] In this case, the patient ambulated with an antalgic gait, was neurovascularly intact, and reported pain restricted to hip motion without radicular symptoms, further supporting that the corrosion originated from the local wire-stem interface rather than a bearing-related CoCr source.

Previous experimental studies have evaluated the electrochemical behavior of titanium-stainless-steel combinations under simulated physiological conditions. In a cyclic compression bending model mimicking spinal constructs, Serhan et al.[21] found that mixed stainless-steel-titanium interfaces exhibited only minimal corrosion, with no discernible galvanic effect even after five million loading cycles. Similarly, Høl et al.[22] investigated fretting corrosion between titanium screws and stainless-steel plates under tensile-compressive loading in both human serum and Hank's solution and found that galvanic coupling between titanium and stainless-steel exhibits electrochemical stability with minimal metal ion release, suggesting that galvanic coupling between titanium and stainless-steel is electrochemically stable and clinically acceptable. However, in the present case, after nearly 10 years of continuous mechanical loading, accumulated micromotion at the titanium-stainless-steel interface likely disrupted the titanium oxide layer, allowing fretting corrosion to develop first, followed by galvanic acceleration once bare metal contact occurred.

This long-term mechanical-electrochemical interaction provides a plausible explanation for why mixed-metal corrosion, although rarely observed in short-term experimental systems, manifested clinically evident in this patient. Mechanistically, fretting corrosion appears to be the initiating event, triggered by micromotion-induced mechanical abrasion, whereas galvanic coupling acts as a secondary amplifier that accelerates electrochemical degradation once the passive oxide film is breached.[22] Over years of cumulative stress, this synergistic process results in progressive metallic debris generation, macrophage activation, cytokine-mediated inflammation characteristic of ALTR with periprosthetic osteolysis and cystic pseudotumor formation.[23]

Furthermore, this case highlights a distinct pathophysiological process after THA, with localized metallosis originating at a cerclage-stem mixed-metal interface rather than at the bearing couple or the head-neck taper. In the post-THA evaluation of ALTR or focal peri-stem lesions, clinicians should look beyond wear at the bearing couple or the head-neck taper and explicitly consider adjacent auxiliary fixation devices as potential sources of debris. To illustrate, the cerclage in this report, as well as cables, plates, or wires inserted at the index arthroplasty or during prior surgery. Such auxiliary fixation devices may themselves act as a source of debris generation through fretting and galvanic interaction with titanium stems.[22] Therefore, when radiographs or MRI demonstrate peri-stem lesions adjacent to auxiliary fixation and the liner and head-neck taper appear intact, the differential should include device-stem fretting rather than attributing findings solely to MoP wear or taper corrosion, particularly when there is a history of intraoperative fracture fixation using metallic cerclage. In addition, if auxiliary fixation is required during THA, device placement should avoid direct contact with the stem and minimize mixed-alloy coupling. Applying these principles to the present case, the revision strategy was planned accordingly. In this patient, revision employed a long, distally fixed stem and avoided any new sites of dissimilar-metal contact by confining all supplementary fixation within host bone, thereby reducing the risk of recurrent galvanic coupling. Given the indolent course of corrosion-induced metallosis and the potential for delayed recurrence, long-term clinical and radiographic surveillance remains advisable to monitor for osteolysis or recurrent ALTR, particularly in patients with current or prior mixed-metal contact.

During revision surgery, irregular oblique and longitudinal cortical cracks were observed at the anterior aspect of the greater trochanter after the removal of the femoral stem. These cracks indicated that the structural integrity of the greater trochanter may have been compromised, creating a need for supplemental fixation. Given that the gluteus medius and minimus attach to the greater trochanter, its stability is essential for maintaining effective abductor function, particularly in patients after THA.[24] Instability of this region can reduce abductor tension and lead to lateral hip pain, fatigability, or a Trendelenburg gait due to insufficient pelvic support.[25] If cortical cracking occur in this region, it can further compromise structural support, particularly in the setting of diminished bone stock, and may adversely affect postoperative gait or hip stability if not adequately reinforced. In view of these concerns, a tension band wiring construct was selected to restore stability in our case. In clinical practice, it is well established for transverse or oblique fractures of the greater trochanter and converts tensile forces generated by the abductors into compression across the fracture surface, limits crack propagation, and provides stable fixation in fragile bone.[26-28] In this setting, tension band wiring construct offered reliable reinforcement of the compromised trochanter without introducing additional mixed-metal interfaces around the stem. No abductor weakness, Trendelenburg gait, or functional decline was noted during postoperative follow-up.

Nonetheless, certain limitations of this case report should be acknowledged. First, a magnified intraoperative close-up of the wire-stem interface was not captured, which precluded direct visualization of the fretting damage. However, overwhelming circumstantial evidence was provided by the topographical concordance between the position of the wire on imaging and the sharply localized zone of metallosis observed intraoperatively, supported by histologic confirmation of metallic particle-containing macrophages. Second, compositional analysis of the retrieved materials was not performed, which could have further verified the corrosion products and quantified the involved metals.

In conclusion, metallosis is an uncommon, but clinically significant complication that can occur outside of MoM bearings. While bearing wear and trunnion corrosion account for most cases, this case demonstrates that direct contact between stainless-steel cerclage and a titanium stem can generate fretting and galvanic corrosion, producing debris and localized ALTR and osteolysis. When auxiliary fixation is required, surgeons should avoid direct contact between dissimilar metals and, if cerclage is unavoidable, interpose an insulating layer.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: W.C.C.: Conceptualization, writing-original draft; W.C.C., H.J.Y.: Methodology; W.C.C., H.J.Y., W.Z.L.: Investigation, resources; W.C.C., W.Z.L.: Writing-review & editing; W.Z.L.: Supervision. All authors had full access to the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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