

Case report

Complete wear-through of a metal-backed acetabular cup in an ambulatory patient

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ABSTRACT

We present a rare case of a patient who presented with complete and rapid wear-through of a ceramic femoral head through a polyethylene liner and titanium acetabular cup. In addition, this patient exhibited significantly elevated serum titanium ion levels, which may serve as a marker of severe metallosis in cases where the preoperative plain radiographs underestimate signs of periarticular metal debris. The unique findings of this case include the rapid (less than 1 year time) wear-through of the femoral head in interval radiographs and the dramatic progression of metallosis and pelvic and femoral osteolysis that required both component revision. In addition, the markedly elevated titanium levels secondary to cup wear-through are also of interest and demonstrate a systemic manifestation of abrasive wear of a titanium alloy component.

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Introduction

Polyethylene wear leading to subsequent periprosthetic osteolysis remains a common reason for reduced total hip arthroplasty (THA) longevity [1]. Efforts to limit the generation of polyethylene wear debris have focused on improving wear through decreasing polyethylene oxidation and increasing polyethylene cross-linking and on exploring alternative bearing surfaces (ceramic-on-polyethylene [CoP], ceramic-on-ceramic, and metal-on-metal [MoM]) [2]. The major advantages of a ceramic femoral head bearing include its hardness, scratch resistance, eliminated risk of taper corrosion, low coefficient of friction, increased wettability for improved lubrication, and superior wear

resistance [3]. Ceramic's higher resistance to scratching compared to chromium cobalt (CoCr) and its inert qualities in an aqueous environment contribute to the polyethylene wear rates seen clinically in CoP compared with CoCr-on-polyethylene bearings [4]. Tribology of CoP coupling compares favorably with that of metal-on-polyethylene implants because of its lower wear rate [5,6], while new generation highly cross-linked polyethylene had very low wear rates regardless of the bearing surface material (ceramic or metal head) [7,8].

Despite the favorable tribologic characteristics, catastrophic polyethylene failure and cup breakage have been reported even in THAs with ceramic head and conventional polyethylene bearing surfaces [9]. The main risk factors include increased patient activity, nonarticular backside wear, foreign body debris, a thin polyethylene cup, degree of cross-linking, removal of oxidation, polyethylene processing and sterilization technique, component malposition, and femoral head size [10]. The signs and symptoms of catastrophic wear-through failure include pain, noise with joint motion, and eccentric positioning of the femoral head with progressive leg length discrepancy [11–13]. Most patients with advanced wear are discovered at routine follow-up and are indicated for revision arthroplasty [14].

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Figure 1. Non cemented right total hip arthroplasty with eccentric position of the femoral head within the acetabular component indicated significant polyethylene liner wear.

We present a patient with a complete wear-through of a polyethylene liner and titanium acetabular cup resulting in a catastrophic ceramic-on-polyethylene THA failure. This case highlights the importance of routine interval radiographic follow-up and early liner exchange in asymptomatic ambulatory patients with radiographic signs of advanced polyethylene wear, since the initiation of wear-through can proceed to catastrophic failure in less than a year. Furthermore, in patients with radiographic signs of wear-through of the acetabular liner and the titanium cup, highly elevated blood or serum metal ion levels, including titanium, can serve as a systemic marker for severe metallosis and implant failure.

Case history

A 74-year-old female patient (former smoker, body mass index 20.4 kg/m²) underwent a noncemented CoP primary THA (REFLECTION Acetabular Cup System with conventional polyethylene; Smith & Nephew, Andover, MA and SL-Plus Femoral Stem; Smith & Nephew) for osteoarthritis on her right hip in 1996. Her medical history included hypertension and cataract. Her surgical history was noncontributory.

The patient reported that she went on to do well until May 2017 when she started noticing trouble walking further distances due to a right limp requiring the use of a cane. She was evaluated in July 2017 by a physician at an outside hospital, and radiographs at that time showed an eccentric position of the femoral head within the

acetabular component indicative of significant polyethylene liner wear (Fig. 1). Moderate osteolysis was identified in the periacetabular region and proximal trochanter, but both components appeared to be well fixed.

Although she was advised to undergo revision THA at that point, the patient did not proceed with surgery, and she continued to experience buttock and groin pain. Her symptoms significantly worsened in December 2017. At that point, she visited the emergency room of another hospital (no radiograph available from this visit) where she was given a brace and advised to start some physical therapy to treat low back pain, which unfortunately aggravated her symptoms.

She was first examined in our department in August 2018. At that point, she reported increasing pain and functional limitation and was now using 2 canes to ambulate. She noted that she was in good health overall and that she had been previously walking 4–5 miles per day and liked to remain quite active. On clinical examination, she had a well healed lateral incision without any skin discoloration, significant leg length discrepancy, with right shorter than left, and a severely coxalgic gait with guarding with gentle right hip range of motion.

Her anteroposterior standing radiograph revealed complete erosion of the ceramic femoral head through the acetabular superior dome of the component with marked periacetabular and proximal femur osteolysis. In addition, a large amount of metal debris could be radiographically identified throughout the right hip (Fig. 2). She underwent a computed tomography scan with 3D reconstruction of her right hip to better assess the extent of the acetabular osteolysis. Inflammatory markers drawn in preparation for surgery were within normal limits (C-reactive protein <0.7 mg/dL, reference range: 0.0–1.0 mg/dL; estimated sedimentation rate 16 mm/h, reference range: 0–20 mm/h), and she denied any recent infections or antibiotic use. Due to severe metal debris observed on the plain radiograph, serum was collected for analysis, which showed highly elevated titanium ions at 620 ppb (normal limit: <10 ppb).

Surgical technique

Surgery was performed through a posterolateral approach. Black metallic wear debris and a gross synovitic reaction was noted in all soft tissue layers (from subcutaneous tissue through to the joint capsule), and it was excised in its entirety (Fig. 3). Later pathologic examination showed that the amount of particulate metallic debris was quite high, while inflammatory infiltrates usually associated with infection were not identified.

The liner (44-mm external diameter) and the metal cup (48-mm external diameter) were completely worn through, while the



Figure 2. Complete wear-through of polyethylene liner and metal-backed acetabular cup resulting in THA catastrophic failure. (a) Anteroposterior radiograph view. (b) Lateral radiograph view.

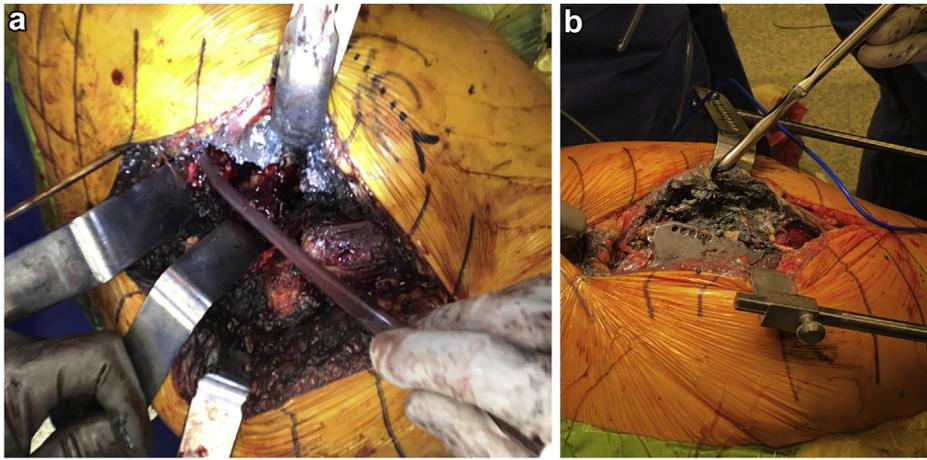


Figure 3. Black metallic wear debris (a) with gross synovitic reaction in all soft tissue layers (b).

ceramic femoral head (28 mm) had dislocated superiorly through the cup and appeared scratched (these scratches were titanium transfer to the ceramic head) but not fractured. On intraoperative assessment, the liner as well as the acetabular component was grossly loose and dislodged during the dislocation maneuver to reveal a severe lysis of the medial wall and ischium (acetabular defect of the Paprosky type IIc). The acetabular component and the femoral head were removed first with no difficulty. No trunnion corrosion was noted. Then the polyethylene liner was easily removed as well. Once the components were removed the hip was gently dislocated.

In addition, the remaining greater trochanter was a small cortical shell with abductor and vastus lateralis attached. Once the proximal femur was debried from the osteolytic lesion, it was noted that it was completely unsupportive and very thin. Severe proximal metaphyseal bone loss with intact femoral diaphysis (femoral defect of the Paprosky type IIIa) was found, so that the stem (14 cm length) was easily removed without any need for extended trochanteric osteotomy.

Allograft consisting of 60 cc cancellous bone chips was placed and reverse reamed in the deficient acetabular medial wall. Consecutively, a dual mobility cementless acetabular component (G7 OsseoTi DM 52 mm, hemispherical, standard offset; Zimmer Biomet) with multiple screws was inserted under computer-assisted navigation (IntelliJoint Surgical, Kitchener, ON, Canada), and a dual mobility liner (G7 DM 28 mm × 42 mm; Zimmer Biomet) was applied. A cementless taper splined revision stem (ARCOS Revision Stem 3° taper blunt spline; Zimmer Biomet; 150 mm length × 13 mm diameter; 50 mm body cone, standard offset) with a 28-mm Biolox G7 femoral head (Zimmer Biomet) was implanted into the femur, and a prophylactic Dall-Miles cable (Stryker Corp., Mahwah, NJ) was placed around the femoral diaphyseal isthmus area prior to stem preparation and insertion. Reattachment of the remaining trochanteric sleeve on the stem was performed with the use of No. 2 Ethibond sutures. The patient tolerated the procedure well without complications. Postoperatively, the patient was rehabilitated as per standard protocols and discharged on postoperative day 4. At 6-month follow-up, gradual restoration of the bone loss was observed in the anteroposterior radiograph (Fig. 4), while the patient was able to walk 2 miles a day without an assistive device.

Surface analysis

The implant was retrieved from pathology and analyzed with digital light microscopy. Following pathology protocols, the

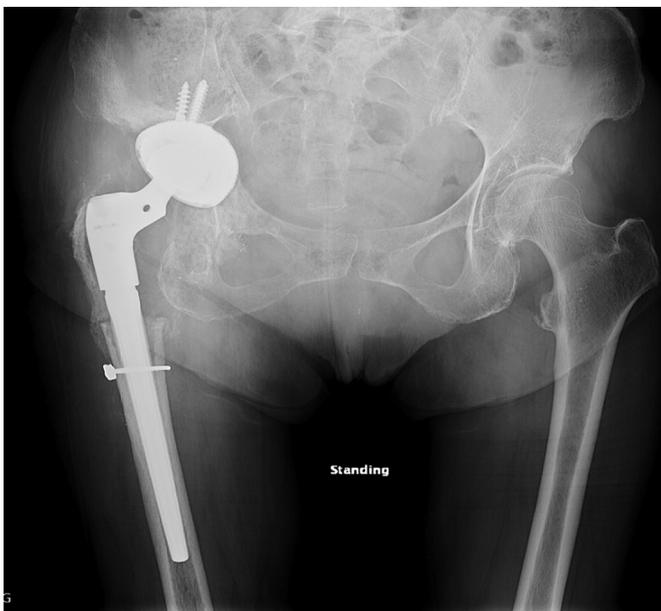


Figure 4. Six-month follow-up anteroposterior radiograph. A prophylactic Dall-Miles cable was placed around the femoral isthmus area.



Figure 5. Retrieved implant from pathology with retrieved components from acetabulum and femur.

implant was placed in formalin for 1 week and was then soaked in 10% bleach solution and cleaned with soap and water, following standard procedures in our Institutional Review Board-approved implant retrieval program (Fig. 5). The femoral stem and head catastrophically wore through the polyethylene liner, fracturing the liner, and wearing through the titanium alloy shell. The female head and taper of the femoral head had severe metal transfer from the SL-Plus trunnion. The trunnion of the femoral stem had deformed to become more elliptical in shape and toggled within the female taper of the femoral stem with clear evidence of material loss (Fig. 6). The polyethylene locking mechanism was partially worn but the polyethylene liner was completely disengaged from the cup and free floating since there was a lot of metal debris between the cup and the liner.

Discussion

This case presents complete wear-through of a polyethylene liner and titanium acetabular cup in an active ambulatory patient with a CoP primary THA. A hole in the acetabular liner existed with partial significant superior destruction of the titanium acetabular component secondary to ceramic head wear-through. Although rare, this mechanism of failure was reported previously [15–18]; however, what is unique and remarkable in this case is the rapid progression and massive acetabular and femoral osteolysis, marked metallosis, and markedly increased systemic titanium levels over a 1-year time interval.

Eight case reports have documented wear-through of the polyethylene liner and the metal-backed cup in non-MoM THA [14–21] (Table 1). All patients were younger than the patients reported in this paper (74 years vs a range between 36 and 65 years in the other papers). The time from index surgery to wear-through and revision was 22 years in this case compared to 6 years [16] to as long as 17 years [20] in cases from the literature. In all cases, a non-cross-linked conventional polyethylene liner was used suggesting that this wear-through phenomenon may no longer occur in the era of highly cross-linked polyethylene liners. Wear-through can occur with either a CoCr or ceramic femoral head. A ceramic femoral head was used in 5 studies [14–18], and CoCr heads in 3 patients [19–21]. Four studies documented failure of the locking mechanism with dissociation of the liner from the cup [19,20] or liner fracture

[14,18], while the remainder of the studies described an intact locking mechanism with direct liner wear-through [15–17,21]. Three patients also underwent a femoral stem revision [14,17,20], similar to the patient in this case report, whereas the remaining 6 stems were retained [15,16,18,19,21].

Similar to this case report, Lanting and Springer [20] documented catastrophic wear of a modular titanium acetabular component with complete wear-through of the acetabulum in an obese man with symptoms that started 1 year before revision surgery. They noted that patients should be routinely monitored to prevent catastrophic complications associated with older generation implants [20]. In addition, they concluded that the amount of metallosis and bony destruction is underestimated on plain radiographs, so surgeons must be prepared to deal with massive bone loss that can be caused by metal debris [20]. Similar to Lanting and Springer [20], Knudsen et al [19] described a case of THA failure where a CoCr femoral head completely wore through the polyethylene liner and the titanium acetabular cup, and in this case the liner's locking mechanism was dissociated. In another study, Engh et al [21] noted that excessive head penetration was not evident radiographically with S-ROM acetabular components. The authors recommended additional measures to diagnose wear-through, such as repeat radiographs at a higher kilovoltage to visualize the outline of the femoral head and a hip aspiration to diagnose metallosis [21].

Simon et al [16] were the first to show penetration of the acetabular liner from a ceramic femoral head that continued to erode through the acetabular shell, causing metallosis of the joint lining. In contrast to the previous studies, both cases that were presented by Simon et al [16] had wear-through of the acetabular component noticed relatively early after the primary surgery (6–7 years). Potential reasons of failure were reported to be both the thin polyethylene liner (3 mm in both cases) and the activity level of the patients [16]. According to Berry et al [11], who described 10 cases of catastrophic polyethylene failure in THAs with a metal-polyethylene bearing that occurred in a patient population of 4220 patients, no failures were noted in patients whose liners were thicker than 5 mm.

Furthermore, Manzano et al [15] suggested that the failure of a CoP liner in their patient was due to the use of a non-cross-linked polyethylene liner in combination with a highly active lifestyle and

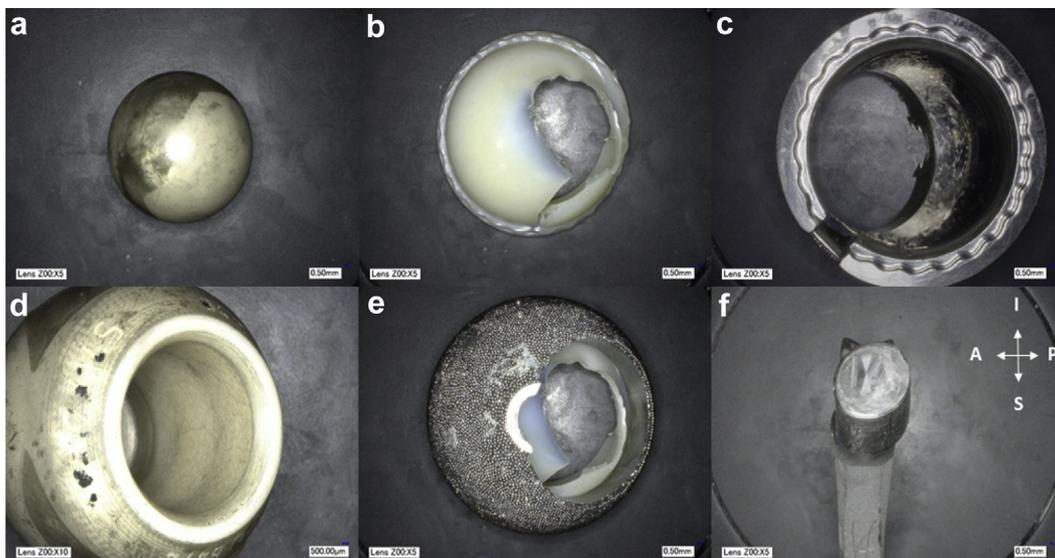


Figure 6. Magnified images of each component revised. Femoral head (a) shows extreme wear and metal transfer observed in female taper as well (d). Fractured liner (b, c, e) and acetabular shell worn through by femoral head. Femoral stem trunnion with material loss (f).

Table 1
Demographic, clinical, and radiographic characteristics of case report papers dealing with wear-through of acetabular polyethylene liner and metal-backed cup leading to catastrophic THA failure.

Author(s)	Age	Gender	Femoral head	Locking mechanism	Type of PE	Metal ion levels	Osteolysis	Stem revision	Time from first surgery	Time since onset of symptoms	Cup design	Radiograph finding of metallosis	LLD
Knudsen	51	Male	CoCr	Dissociated	Conventional	N/A	Yes	No	13 y	8 mo	REFLECTION V titanium	Suspicion of bubble sign	1.3 cm
Lanting	49	Male	CoCr	Dissociated	Conventional	N/A	Yes	Yes	17 y	1 y	Harris-Galante 1	No	1.5 cm
Engh	63	Male	CoCr	Intact	Conventional	N/A	No	No	14 y	6 wk	S-ROM	No	N/A
Manzano	57	Male	Ceramic	Intact	Conventional	N/A	Yes	No	10 y	N/A	Wright Technology Interseal Ceramic-on-Non-Crosslinked Polyethylene Hip System	No	N/A
Needham	49	Female	Ceramic	PE not dislodged. Complete wear-through of the superior PE and Ti shell	Conventional	N/A	Yes Severe (pelvis/femur)	Yes	16 y	3 wk	OptiFix	Suspicion of bubble sign	N/A
Simon: case 1	65	Male	Ceramic	Intact	Conventional	N/A	Minimal around the screws	No	7 y	N/A (no delay for revision)	OptiFix press-fit	No	N/A
Simon: case 2	36	Female	Ceramic	Intact	Conventional	N/A	Yes (trochanteric area)	No	6 y	22 mo	OptiFix	No	N/A
Malizos	38	Male	Ceramic	Intact	Conventional	N/A	Yes	Yes	14 y	1 y	OptiFix	Yes Bubble sign	N/A
Mariconda	50	Female	Ceramic	Intact	Conventional	N/A	Yes	No	11 y	6 mo	Expansion acetabular cup	No	N/A
Current Study (Malahias et al)	74	Female	Ceramic	Intact	Conventional	High elevated	Yes Severe	Yes	22 y	15 mo	REFLECTION Acetabular Cup System	No	Yes

PE, polyethylene; LLD, leg-length discrepancy; N/A, not applicable.

poor follow-up. In contrast, Mariconda et al [18] considered increased inclination (60°) of the Expansion acetabular component (Zimmer Biomet, Winterthur, Switzerland) as the main reason of wear-through failure in a CoP bearing. Needham et al [14] also attributed increased cup inclination to a superior breakage of the liner locking mechanism in a CoP bearing.

Finally, Malizos et al [17] reported another case of CoP catastrophic wear-through failure. They were the first to notice the radiographic “bubble sign” in this kind of bearing surface as a result of extensive soft tissue metallosis [17]. A thin polyethylene shell, a suboptimal locking mechanism, gamma in air sterilization for polyethylene, multiple screw holes that reduce the contact surface between the shell and the polyethylene, a rough surface on the inside of the shell, nonarticular wear at the metal polyethylene interface within the acetabular component, and the high demands of an active young patient may all have contributed to catastrophic failure [17].

In our case, the placement of the primary cup was optimal without any increased inclination, and most of the previously mentioned risk factors could not be confirmed. The patient was free-of-symptoms for almost 2 decades. Although there should have been progressive polyethylene wear throughout these 20 years that the hip was implanted, the turning point came when the plastic wore completely through and metal debris was generated from the titanium shell leading to THA catastrophic failure within a year from the onset of symptoms. In this case, some specific factors existed that might have played a critical role to the accelerated polyethylene wear. The patient was young at the time of primary surgery and remained active until recently. In addition, the primary THA contained old-generation implants with a conventional, relatively thin polyethylene liner. However, the most crucial factor associated with catastrophic wear was undoubtedly the delay in revision surgery after the initial diagnosis of moderate to severe polyethylene wear. The patient had clear radiographic signs of polyethylene wear with moderate periacetabular and proximal femoral osteolysis (Fig. 1) 1 year prior to catastrophic wear-through (Fig. 2). She was mildly symptomatic at that time, but she decided against proceeding with revision surgery. As a result, the ceramic head continued to wear-through the polyethylene liner until it completely penetrated. At that point, the ceramic head started to articulate with the metal cup and resulted in complete and rapid penetration of the ceramic head through the metal cup. One year after the initial radiographic diagnosis of polyethylene wear, the patient was found with complete wear-through of the polyethylene liner and the metal cup and severe metallosis and osteolysis of both the acetabulum and proximal femur. If the patient had decided to undergo a revision surgery 1 year earlier, when the initial signs of polyethylene wear were diagnosed, she would probably have undergone a much less invasive operation including implant retention and exchange of the liner and the femoral head. Instead, the patient required a complex revision surgery that required both components be revised and loss of the majority of her proximal femur secondary to osteolysis.

Interestingly, although no trunnion corrosion was found, the trunnion of the femoral stem was severely damaged with clear evidence of material loss. Specifically, in the retrieval analysis, the trunnion was found deformed into an elliptical shape. Our theory is that once the femoral head was locked into the acetabular shell the trunnion started spinning into the femoral head with subsequent deformation. The polyethylene locking mechanism was partially worn but the polyethylene liner was completely disengaged from the cup.

Another interesting finding in this case is the highly elevated serum titanium ion levels, which might be a useful marker of severe metallosis and periprosthetic osteolysis in cases where the

preoperative plain radiographs underestimate signs of periarticular metal debris. None of the previous non-MoM wear-through case reports included serum or plasma metal ion levels. The titanium level in this case was 620 ppb, much above the normal limit of <10 ppb. Of note, the severe metallosis led to the extensive proximal femoral metaphyseal bone loss through a different type of adverse local tissue reaction (ALTR) than that seen in CoCr MoM or trunnionosis cases. In contrast to MoM ALTR, in our case particulate metal debris was large (submicron), acting like particulate debris. Therefore, the ALTR observed in our case was similar to submicron polyethylene debris (although they are black rather than clear; Fig. 3) and cause bone loss and granulation. On the contrary, CoCr MoM cases are ionic and atomic reactions to crevice corrosion debris and cobalt ions (trunnion failure cases or MoM runaway wear) which cause cystic pseudotumors and necrosis of soft tissue and bone. Overall, in cases of suspected wear-through not completely evident on plain radiographs, elevated serum titanium levels may indicate that liner wear-through had occurred with femoral head articulation with the titanium acetabular component generating increased titanium metallosis and systemic absorption of titanium ions.

For the acetabular reconstruction, our decision was to go with a high hip center because that is where the best acetabular bone stock was located. The prior acetabular component was placed in that same position so the decision was made to keep it in that location. In addition, there was severe ischial osteolysis, so bringing the cup down was not going to be beneficial, since there was no ischial bone stock to pinch the cup against. As for the modular stem without support for the taper junction, while technically these implants are meant to have proximal support, recent modular fluted tapered stem junctions have shown no evidence of fracture at the taper junction [22,23]. Our goal was to leave the bone shell/soft tissue sleeve for gradual bone reconstitution as has been reported when using these implants in the setting of periprosthetic fracture [24,25]. As it can be noted in most recent follow-up radiograph (Fig. 4), bone reconstitution has occurred and now overlays the modular junction. This is the benefit of leaving vascularity alone and not over instrumenting or placing a large structural allograft in this area.

Summary

We present a case of rapid catastrophic wear-through of a conventional polyethylene liner-alumina ceramic bearing that is notable for the rapid progression over a 1-year interval. Routine interval radiographic follow-up and early liner exchange in ambulatory patients with radiographic signs of polyethylene wear and mild symptoms are the most crucial factors from preventing catastrophic wear-through and rapid massive osteolysis. In patients with radiographic signs that are suggestive but not definite of wear-through of the acetabular liner with subsequent articulating of the femoral head with the titanium cup, a highly elevated blood or serum titanium ion levels may help indicate that liner wear-through has occurred and act as a marker of severe metallosis. Although severe titanium metallosis does not lead to adverse tissue reaction and muscle necrosis, it can generate massive periprosthetic osteolysis that may require more complex reconstruction techniques.

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