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Case Report

Bilateral Failure of Oxidized Zirconium Implants in Total Knee Arthroplasty

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A B S T R A C T

Oxidized zirconium was first introduced in total hip arthroplasty procedures to merge the strengths of metal and ceramic into one prosthetic. The subsequent adoption of oxidized zirconium (oxinium) for total knee arthroplasty is attributed to the theory of causing less wear on the tibial components compared to the alternative, cobalt chromium. However, the superficial layer of the femoral component is occasionally breached, exposing the softer zirconium substrate. Multiple mechanisms leading to zirconium substrate exposure have been explained, including collateral ligament instability and polyethylene wear. Such a failure may lead to damage to the periprosthetic tissues and often requires a revision procedure. In the current case report, we present a case of bilateral total knee arthroplasty with oxidized zirconium components that resulted in catastrophic failure and subsequent revision with hinged knee prostheses.

Introduction

One of the primary causes for revision of total knee arthroplasty (TKA) is wear and subsequent degradation of the polyethylene tibial component. In an attempt to diminish the polyethylene wear, oxidized zirconium (oxinium) prosthetics were introduced in total hip and TKA procedures by the Smith + Nephew medical technology company, Memphis, TN, USA [1]. When compared with the typical cobalt-chromium femoral prosthesis, oxidized zirconium produces less friction on the polyethylene tibial component, reducing wear by 25%-50% [2]. Specifically, the femoral component of the oxinium prosthetic has a 5-μm zirconium oxide superficial ceramic layer over a zirconium alloy substrate, combining the durability of metal with ceramic-like abrasion resistance [3].

Different types of polyethylene (PE) inserts have been introduced over the years. The conventional PE is an ultra-high molecular weight polyethylene (UHMWPE) [4]. Within the last couple of decades, crosslinking has been studied, which alters the chemical properties of polymers and has demonstrated successful results in total hip arthroplasty [4]. More recently, researchers have been studying the use of highly cross-linked PE in TKA procedures, which has demonstrated an improvement in wear properties compared to UHMWPE [4]. In fact, one biomechanical study found similar strength results between the 2 types of PE in both cruciate-retaining and posterior-stabilized designs [4]. In addition, the highly cross-linked PE demonstrated 64%-68% less wear compared with the UHMWPE [4]. Studies have also found that clinically there is not a significant difference in the rates of osteolysis, aseptic revisions, or survivorship when comparing the 2 types of PE [4].

Despite efforts to improve the durability and wear of these prosthetics, 20% of patients with a TKA report dissatisfaction postoperatively, even when no obvious wear or gross deformities to the prosthetic are present [5]. One proposed cause for this dissatisfaction is related to metallosis and metal hypersensitivity [6]. Metallosis, sometimes used synonymously with an adverse reaction to metallic debris, is a clinical term that describes metal debris deposition in periprosthetic bony and soft tissues and the resulting inflammation [7]. A similar phenomenon, mechanically assisted crevice corrosion, has been described in the corrosion of metal-on-polyethylene total hip arthroplasty. Like metallosis, mechanically assisted crevice corrosion has presented with periprosthetic inflammation and joint pain with the addition of unilateral lower extremity vascular compromise [8,9]. This has been shown to occur when periprosthetic soft tissue structures accumulate metal debris

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following a metal-on-metal reaction [8]. Typically, when metallosis is present, physicians will trend inflammatory markers due to the potential for the debris to stimulate an inflammatory reaction. This adverse response can ultimately lead to joint instability, osteolysis, and failure of implants [10]. Cases of metallosis have been demonstrated in total hip and TKA procedures with evidence of significant polyethylene wear and joint instability [11]. Although variable in its presentation, metallosis is visible on radiographs and often characterized by its cloud sign [12]. It is frequently documented in conjunction with metal-on-metal arthroplasties or dislocations leading to polyethylene degradation.

To date, research has not conclusively shown that oxinium femoral components result in a decreased occurrence of metallosis when compared with cobalt chromium prosthetics [5,13]. In the current case report, we present a case of bilateral TKA with oxidized zirconium components that resulted in catastrophic failure and subsequent revision with hinged knee prostheses. The femoral oxinium component of the prosthesis articulated directly with the titanium tibial baseplate, causing substantial medial compartmental collapse and varus alignment subsequent to the degradation of the tibial polyethylene constituent. To our knowledge, the current case report is one of the first recorded cases of TKA failure involving bilateral oxidized zirconium implants.

Case history

Written informed consent for publication of this case report was obtained from the patient prior to completion. The patient was a 62-year-old female who presented to an orthopedic clinic with bilateral knee pain, difficulty with range of motion, and persistent swelling. She reported that the right knee was more symptomatic than the left. Her past surgical history consisted of a right knee arthroscopy in 2004 and bilateral TKA procedures in 2013 using oxinium prostheses. Multiple comorbidities were noted in the patient's history, including obesity with a body mass index of 46.5 kg/m^2, hypertension, osteoarthritis, myocardial infarction, depression, and osteoporosis. The patient's primary complaint was bilateral knee instability that led to multiple falls over the past 5 years. During that time, her ability to ambulate independently had diminished from the use of a cane to a wheeled walker. Physical examination findings were positive for severe bilateral varus deformities and pain on palpation over both the medial and lateral joint lines. Valgus stress overlying the medial collateral ligament was stable, but varus stress demonstrated a 2+ laxity and substantial instability. The anterior drawer testing demonstrated a 1+ laxity. An infectious work-up and knee aspiration were not completed preoperatively. All other physical findings were unremarkable. Bilateral 2-view radiographs (Figs. 1 and 2) were obtained and indicated evidence of heterotopic ossification and severe medial compartment collapse.

Initially, the patient was treated conservatively with bilateral medial unloading braces. At her 1-month follow-up appointment, she reported no relief from the pain and a continued sensation of knee instability. Therefore, revision surgery with stem-hinged knee replacements was recommended, and the patient consented. The patient underwent bilateral revision TKA of the femoral and tibial components (Figs. 3 and 4) with autologous hematocyte bone marrow aspirate concentrate for its suggested antiinflammatory and immunomodulating effects. The procedure for each knee was performed separately, staggered 3 months apart, and the right knee was treated first because of the severity of symptoms in that knee.

During the right knee arthrotomy, a remarkable amount of metallosis was noted. It extended into the periprosthetic tissues and was excised with care (Fig. 5). No evidence of purulence was noted, and there was no foul odor associated with the black synovial tissue. After the oxinium component was excised (Fig. 6a), a large amount of bone loss was observed in the lateral femoral condyle. The patellar dome appeared intact with no signs of loosening and was subsequently left in place. The index tibial baseplate and polyethylene components were dislodged and removed without complications. Both implants showed severe wear medially (Fig. 6b and c). Smith and Nephew locking hinged components were chosen and fitted for the revision. A size 2 tibial baseplate and a 15-mm polyethylene spacer were utilized for implantation. Before closure, heterotopic ossification was noted in the popliteal recess; however, the risk of damaging the popliteal neurovascular structures was considered too great. Therefore, this was not excised. Final hinged prosthesis placement and closure were unremarkable.

During the left knee arthrotomy, findings were similar to the right knee with slight quantitative variations. A size 2 tibial baseplate was chosen. Intraoperatively, substantial bone loss was noted

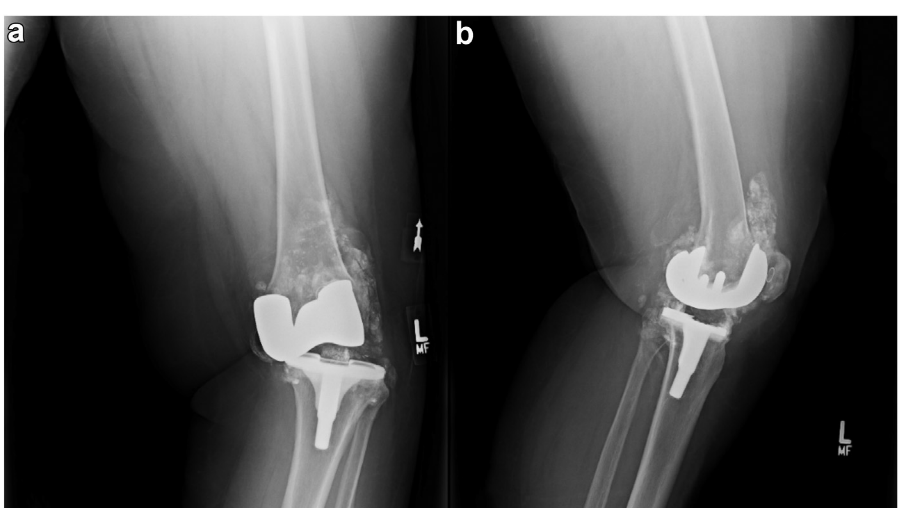

Figure 1. (a) Anteroposterior and (b) lateral x-rays of a skeletally mature left knee demonstrate metallosis and heterotopic ossification in the superior patellar pouch and the lateral gutter. The anteroposterior view shows complete medial compartment collapse, medial subluxation, and subsequent varus alignment. The femoral and tibial components were properly sized with no signs of loosening or fractures.

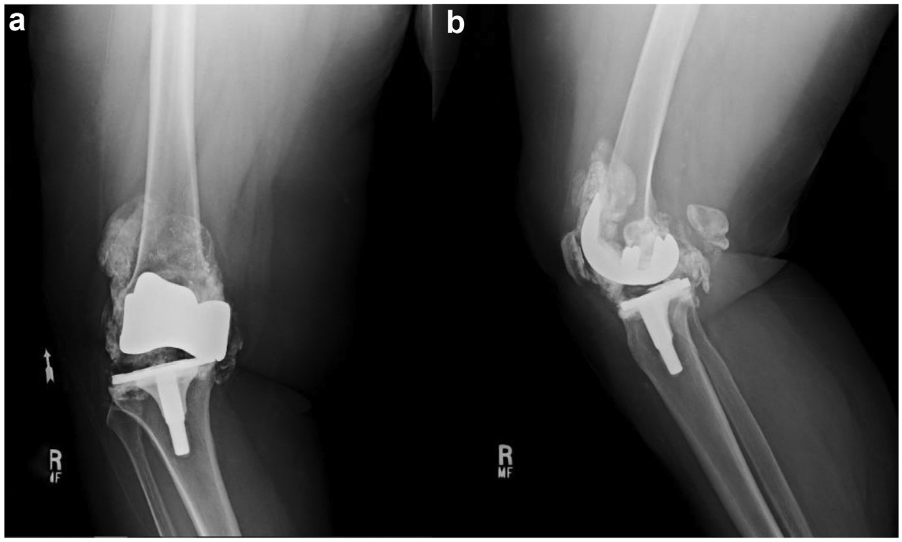

Figure 2. (a) Anteroposterior and (b) lateral x-rays of a skeletally mature right knee demonstrate metallosis and heterotopic ossification in the superior patellar pouch, lateral gutter, and popliteal recess. Complete medial compartment collapse, medial subluxation, and varus alignment are present. The tibial and femoral prostheses are well-sized without any apparent signs of loosening. No fractures are noted.

medially and laterally in the distal femur. Next, 10-mm bicondylar augmentations and an 11-mm tibial polyethylene insert were carefully placed to achieve a cumulative 21-mm of spacing. Once again, heterotopic ossification was palpated in the popliteal recess but was not excised because of the risk associated with dissection. Intraoperative radiographs showed that the final locking hinged prosthesis placement was well approximated. Like the right knee, Smith and Nephew implants were chosen for the left knee revision. Closure was once again unremarkable.

Both postoperative treatment courses were uneventful. Mobilization was initiated at the hospital 1 day after surgery, and the patient's pain was well maintained. She returned to the orthopedic clinic 5 days after surgery for a dressing change and cleaning; the incision site was noted to be healing well without complications. A course of physical therapy was prescribed and continued for 4 months, after which the patient was released for normal activities. The 6-month follow-up of the right knee was without complications. The patient presented with full range of motion to 120 degrees of flexion and reported little to no pain. Left knee recovery was prolonged due to a periprosthetic fracture just distal to the tibial stem, along the anterior crest of the tibia. The patient reported a fall in her home 2 weeks postoperatively, which was presumed to be the cause of the fracture. Intraoperative radiographs showed no sign of fracture. Open reduction and internal fixation were performed on the tibia without complications. During the 6 month follow-up appointment for the left knee, the patient's subjective history showed positive for pain in the vastus lateralis region, which was assumed to be due to chronic lumbar spine pathology. The patient was subsequently referred to pain management for injections to manage pain. Full active range of motion was demonstrated with complete extension and 120 degrees of flexion with the left knee.

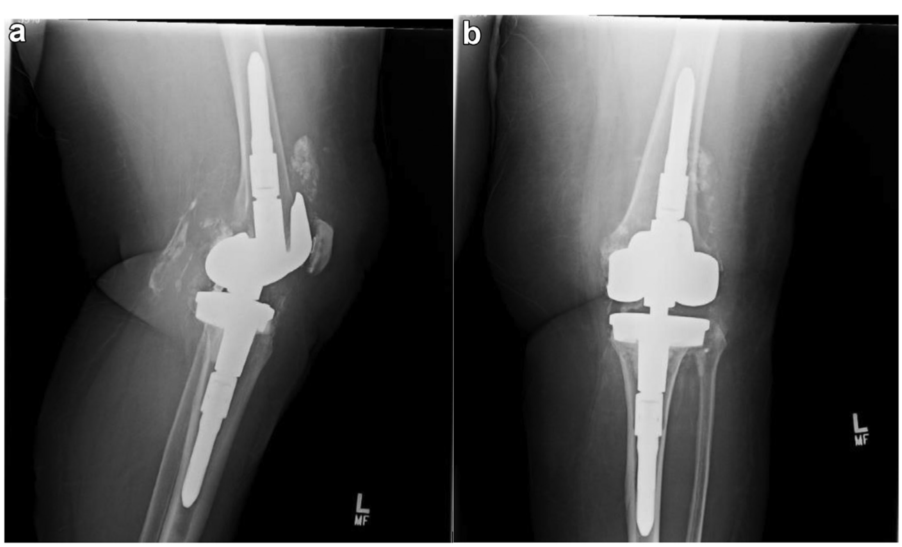

Figure 3. (a) Anteroposterior and (b) lateral x-rays of a skeletally mature left knee demonstrate the Smith + Nephew hinged knee prosthesis. Images were obtained at the patient's 5-day postoperative visit and showed a notable reduction in metallosis and heterotopic ossification when compared with previous images. Good bone stock and alignment of femoral and tibial hinged components are noted without signs of loosening.

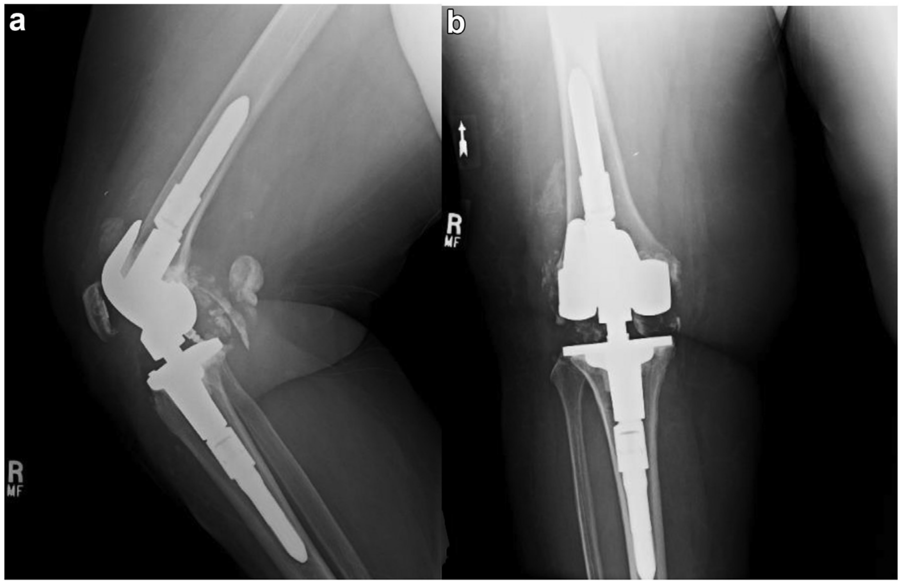

Figure 4. (a) Anteroposterior and (b) lateral x-rays of a skeletally mature right knee demonstrate the Smith + Nephew hinged knee prosthesis and a 15-mm polyethylene insert. The images were obtained at the patient's 5-day postoperative visit. Good bone stock and alignment of the femoral and tibial components are noted without signs of loosening.

Discussion

The current case report describes a case of bilateral TKA with oxidized zirconium components that resulted in catastrophic failure. Subsequent revision TKA with hinged knee prostheses was successful. After completion of physical therapy, the patient returned to weight-bearing status and reported diminished pain.

A similar case was reported by Purcell et al [14]. In that study [11], the female patient experienced insidious pain 13 years after receiving a TKA with oxinium prosthesis. As noted during surgical intervention, the patient did not have a breach of the oxidized zirconium layer; however, black synovial tissue was dispersed through the periprosthetic synovial tissue [14]. Further, Purcell et al. [14] did not consider their histological findings in relation to a cobalt-chromium failure. In the current case, tissue samples were not collected intraoperatively, so we were unable to quantify the extent of metallosis before the synovectomy. Therefore, future studies should compare the histological results of cobalt chromium and oxidized zirconium prosthetics after similar failure patterns.

Research investigating the longevity of oxidized zirconium suggests oxinium is a valid prosthetic alternative to the traditional cobalt chromium femoral component of TKA, especially when metal hypersensitivity is a concern [6] or the patient is younger than 75 years and wants to be physically active [15]. Oxinium is produced by heating zirconium alloy (97.5% zirconium, 2.5% niobium) [3], and the most superficial layer of this prosthetic is 5 μm of oxidized zirconium, which is black in color and twice as hard as cobalt chromium [2]. Conversely, the zirconium substrate of

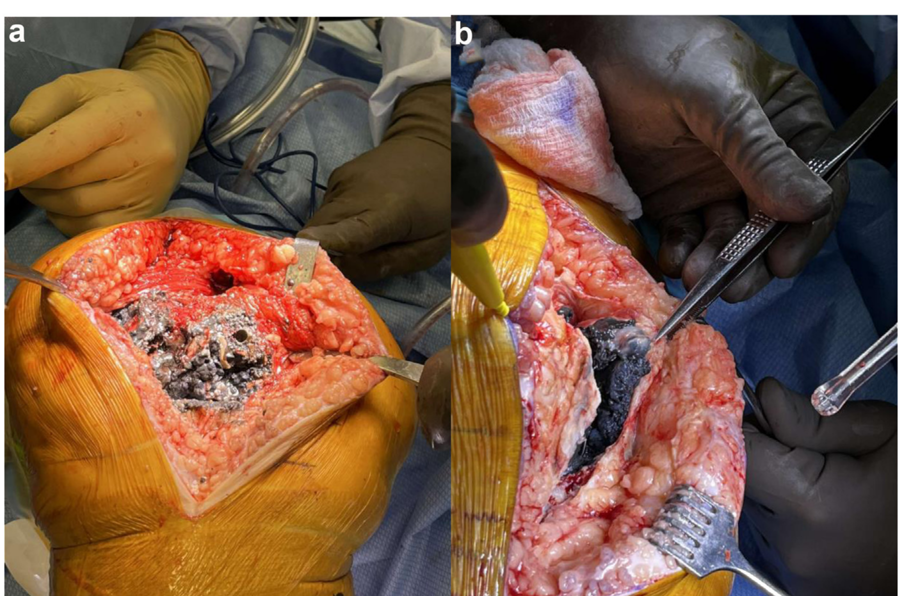

Figure 5. Intraoperative images of the right knee demonstrate (a) marked osteolysis and (b) metallosis in the periprosthetic synovial tissue.

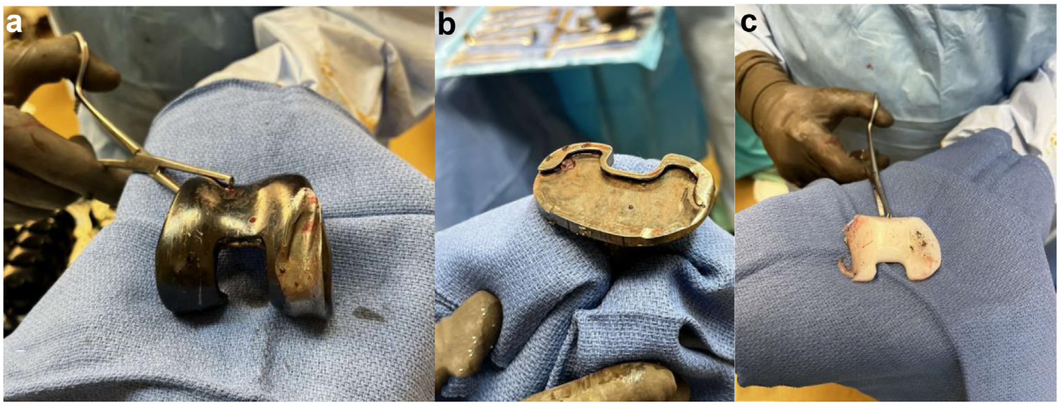

Figure 6. Intraoperative images of the removed oxinium implant. (a) Right oxinium femoral prosthesis after being removed during the revision procedure. The prosthetic medial femoral condyle demonstrated erosion of the oxidized zirconium layer that exposed the zirconium alloy substrate. (b) Right tibial baseplate after being removed during the revision procedure. Erosion of the medial tibial plateau indicated metal-on-metal articulation. (c) Right tibial polyethylene component of the prosthesis after being removed during the revision procedure. One-third of the medial aspect showed decimation.

an oxinium prosthetic is half as hard as cobalt chromium [3]. The mechanism of catastrophic failure of oxinium prostheses in total hip arthroplasty (THA) is much better understood [3,11,16] than the mechanism of catastrophic failure in TKA. Typically, THA failure is first noticed in radiographs, where eccentric positioning and dissociation of the polyethylene liner lead to failure [11,16]. According to Zou et al. [16], the 2 most common mechanisms of polyethylene liner dissociation in THA are dislocation of the hip joint and incomplete liner seating during the index procedure. To our knowledge, few TKA cases have been reported where the oxidized zirconium layer of the prosthesis was breeched, exposing the zirconium alloy substrate [11,17]. Further, the mechanism of catastrophic failure in TKA is less understood [11,13,15]. Unlike the common polyethylene liner dissociation seen in THA, Frye et al. [11] and Kore et al. [17] described atraumatic catastrophic failure in TKA without dislocation of the tibial polyethylene. More studies are necessary to better understand the mechanism of catastrophic failure in TKA with oxinium prosthesis.

Summary

The 5-μm oxidized zirconium layer of the oxinium femoral prothesis component offers exceptional scratch resistance and durability. Unfortunately, it simultaneously has a unique degradation pattern once compromised. The primary mechanism of compromise in this case report is polyethylene wear, which secondarily caused metallosis from metal-on-metal contact between the femoral and tibial components. It is believed that the patient's significant varus knee deformity likely accelerated the wear on her polyethylene insert, causing significant metallosis and further damaging the soft tissue structures surrounding her knee. It is probable that this reaction led to increased pain and joint instability, as the patient explained during her preoperative visit. Unlike previous cases of catastrophic failure with the oxinium prosthesis, the patient of the current case did not report a steep decline of function. Instead, she reported multiple falls over 5 years without a record of radiographs that corresponded with a steady increase in pain. The patient did not report an acute change in function or pain to either knee after each fall, but instead recounted a gradual worsening of symptoms after each subsequent event. Despite these differences in outcomes, we recommend that providers educate patients about the potential complications of the oxidized zirconium femoral knee prosthesis. Patients should also be urged to practice diligence during their rehabilitation and report any sudden onset of increased pain or rapid decrease in knee stability.

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Conflicts of interest

The authors declare there are no conflicts of interest.
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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).

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