Arthroplasty Today 6 (2020) 988–992

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Case report

A Unique Case of Extra-articular Extravasation of Metal Into the Lower Leg Resulting From Oxidized Zirconium Wear Particles From Total Knee Arthroplasty

Amanda Purcell, MD [a, *], Shelby Buckner, MD [b], George Brindley, MD [a], Jerry Grimes, MD [a]

[a] Texas Tech University Health Sciences Center, Department of Orthopaedic Surgery and Rehabilitation, Lubbock, TX, USA
[b] Texas Tech University Health Sciences Center, School of Medicine, Lubbock, TX, USA

ARTICLE INFO

Article history:
Received 2 August 2020
Received in revised form
13 September 2020
Accepted 20 September 2020
Available online 20 November 2020

Keywords:
Oxinium
Metallosis
Total knee arthroplasty
Ceramic
Oxidized zirconium

ABSTRACT

With an increasing number of joint replacements and the evolution of orthopaedic implants and hardware, there is increased occurrence and awareness of metal-related sensitivity. This has resulted in the development of devices using a variety of different materials to coat the implant. One popular option is to cover the metallic surface with a ceramic. One commercially available ceramic-coated prosthesis is coated with oxidized zirconium, with the trade name Oxinium. Although pseudotumor and metallosis resulting from ceramic joint arthroplasty implants have been documented, there is limited information on the occurrence of metallosis resulting from ceramic-coated knee implants. The purpose of this case report is to discuss a potential differential diagnosis for lower leg mass after total knee arthroplasty and to present a novel case of catastrophic failure of an Oxinium-coated total knee prosthesis (Smith and Nephew) that resulted in metallosis with extra-articular extravasation along the extensor digitorum longus tendon.

Introduction

Total joint arthroplasty has become a mainstay in the orthopaedic field. These procedures provide the ability for patients to make vast improvements in their ability to move. It is estimated that more than 750,000 total knee arthroplasty (TKA) cases were performed in 2014 [1]. By the year 2030, the demand for TKA is expected to increase by 673%. The number of total knee revisions is expected to grow by 601% by 2030 [2]. In a study by Inacio et al [3] in 2017, this number is projected to increase annually 143% by 2050, which translates to a projected volume of 1.5 million TKAs in the United States alone. A common concern regarding the implants associated with joint replacements is metal allergy and the complications that are associated with such allergic reactions. Metal sensitivity typically occurs as a type IV lymphocyte-mediated hypersensitivity. It has been documented that about 10% among the general population, 25% among patients with well-functioning total joint arthroplasty, and 60% among patients with painful total joint arthroplasty may have metal sensitivity [4]. In an attempt to reduce the allergic response to the metal implants, manufacturers have made implants with ceramic coatings to reduce the likelihood of hypersensitivity reactions. Smith and Nephew's implants (Smith and Nephew plc, Watford, England, UK) use the oxidized zirconium coating, Oxinium. In addition to being less likely to induce an allergic response, ceramic-coated implants are considered to be more resistant to wear damage during mechanical testing [5].

There has been documentation of metallosis or pseudotumor resulting from ceramic-coated total hip arthroplasty [6] and documentation of extra-articular involvement of metallosis or pseudotumor resulting from TKA [7-13]. There are limited data on the prevalence of metallosis resulting after TKA; however, there are extensive data on metallosis after total hip arthroplasty. Data are especially extensive involving metal-on-metal (MoM) hip replacements. Metallosis, or metal-induced synovitis, can occur as a late complication after total joint arthroplasty. In knees, metallosis typically occurs late when there is catastrophic wear of the polyethylene. Metallosis in TKA tends to result most commonly from the use of metal-backed patellar implants or because of wear of the tibial polyethylene [8,14,15]. Although there is documentation of

* Corresponding author. 3601 4th Street, Lubbock, TX 79430, USA. Tel.: +1-806-632-5020.
E-mail address: amanda.purcell@ttuhsc.edu

https://doi.org/10.1016/j.artd.2020.09.008

intra-articular metal debris after knee replacement [14,16,17], there is limited documentation of extra-articular extravasation of metal down the lower extremity compartments. One such case involved a SMILES rotating knee hinge (Stanmore Modular Individual Lower Extremity System, Stanmore Implants Worldwide Ltd., Middlesex, UK) used in a tumor-resection case. This patient developed wear debris from the polyethylene liner and metallosis of the tissue surrounding the tibial megaprosthesis [10].

There are other cases with documented cystic cavities into the calf or popliteal fossa. One particular case report discussed a patient who had an Insall-Burstein II TKA complicated with periprosthetic fracture of the tibia leading to extravasation of metal debris along the lower leg [12]. Another documented case involved a patient who developed a paratibial cyst after uncemented TKA (AMK, DePuy, Warsaw, IN). Metallosis in this case was noted due to communication with the cyst via a tract along a tibial baseplate screw [7].

Metallosis is particularly concerning in that it is a sign of implant failure and eventual osteolysis. Osteolysis was found to be caused by debris rubbing together with the implant components, called third-body wear. Debris is stimulated by friction and abrasion of the metal prosthetic surfaces as a result of wear of polyethylene, typically in metal-backed patellar implants or with wear of the tibial tray. It has been concluded that a higher dose or concentration and smaller particle size may cause greater host response than do the larger particles because of their maintained location in the joint space [5]. The metallic debris stimulates an influx of cytokines and inflammatory cells, causing pain and osteolysis surrounding the implanted components. Metallosis is demonstrated histologically by extensive fibrosis, with the presence of histiocytes including macrophages, dendritic cells, Langerhans cells, and multinucleated giant cells [4,5]. Once the inflammatory cascade has been initiated, macrophages continue to indirectly cause osteolysis by releasing chronic inflammatory mediators and the activation of the RANK/RANKL pathway, which in turn manifests with further failure of the implant [5].

Ceramic-coated implants have been described to be stronger, albeit more brittle, with a lower incidence of wear and particle generation [5]. The total knee implants described in these articles use a surface of Oxinium, or oxidized Zirconium. If Oxinium ceramic wear particles are present, they can cause a similar inflammatory response to the MoM implants and polyethylene debris. Osteolysis associated with ceramic implants typically is noted to be secondary to an implant failure such as malpositioning, instability, or infection [5].

There is literature available reviewing the development of extra-articular extravasation of wear debris, and there is documentation of wear and metallosis resulting from MoM and Oxinium-coated hip replacements. However, we believe there has never been documentation of wear of the Oxinium-coated TKA with extravasation of metal particles to compartments outside the confines of the joint capsule. In this case report, we discuss a unique case of failed Oxinium-coated TKA with resulting metallosis along the anterior compartment of the left lower leg, thus offering an additional differential diagnosis for lower leg mass in patients who underwent TKA.

Case history

The patient is a 69-year-old woman who underwent left TKA in 2006. Owing to metal allergy, she underwent replacement with an Oxinium-coated implant. She presented to the emergency room roughly 13 years after TKA with a 6-month history of pain and swelling of the lateral aspect of her left lower leg extending to her ankle. She had no known injury to the leg but had fallen a few times without acute injury. She noted that pain had started insidiously and was only getting worse. She could identify no alleviating factors. Activities and the range of motion of the foot and toes made the pain worse. She endorsed a “squeaking” in the knee with the range of motion.

On examination, there was palpable swelling along the anterior compartment of the lower leg. There was no erythema or warmth

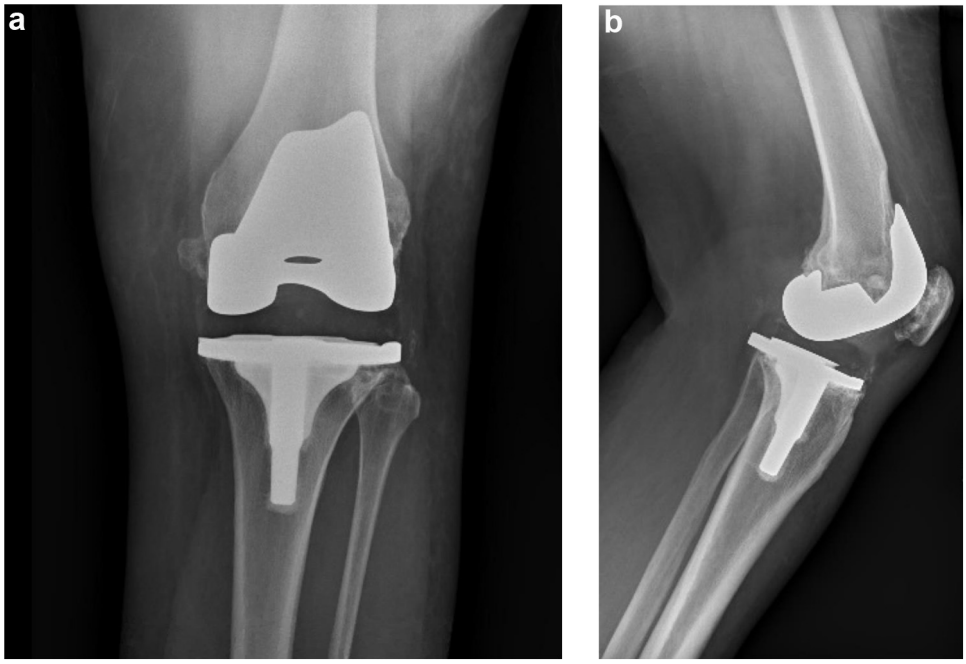

Figure 1. (a) In this anterior-posterior view of the left knee, the hardware appears intact, without significant lucency or osteolysis surrounding the implant. Along the medial femoral condyle, there is a “cloud sign” indicative of metal artifact. (b) In this lateral view of the left knee, there is no obvious sign of failure of the implant or osteolysis surrounding the implant. Subtle opacity within the limits of the synovium suggests metal artifact.

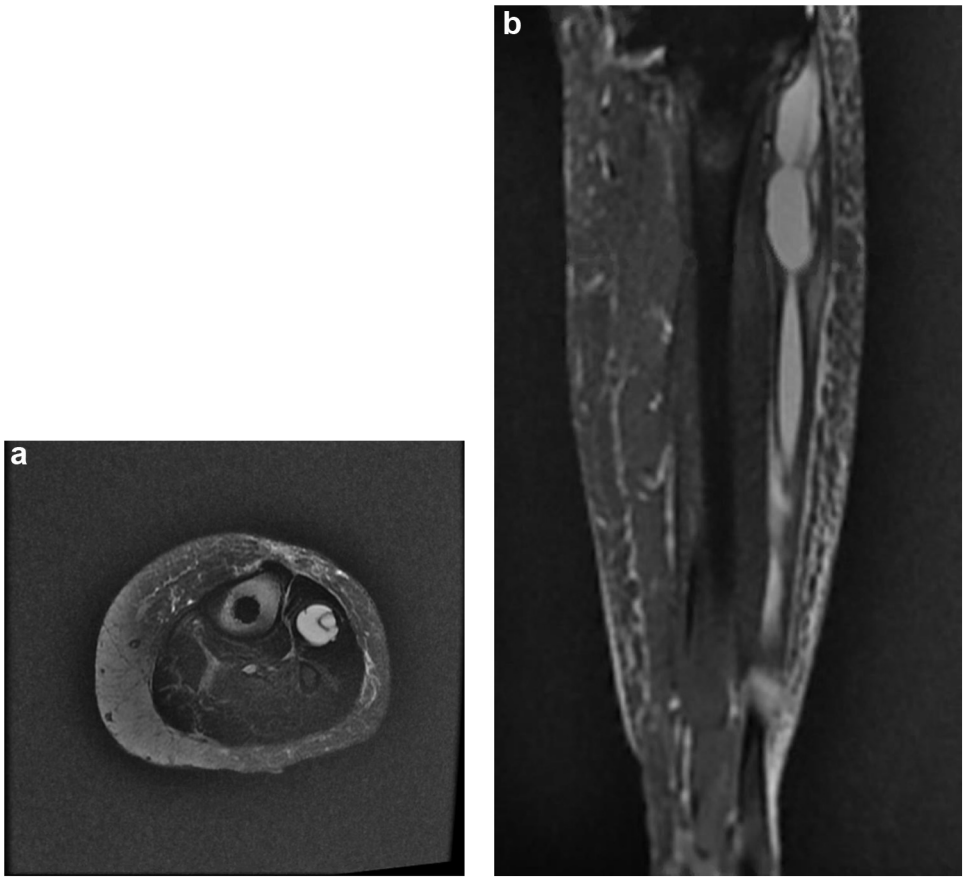

Figure 2. (a) In this T2-weighted axial cut MRI of the left lower leg, there is a loculated fluid collection within the anterior compartment. (b) The loculated fluid collection is seen extending along the anterior compartment distally in this T2-weighted coronal cut MRI of the left lower leg.

associated with the area. The knee itself was stable to stress, and the range of motion at the knee ranged from 0 to 110 degrees. She complains of subjective numbness over the entire foot, specifically along the course of the superficial peroneal nerve. Serum white blood cell count was slightly elevated at 12 K/uL (reference range: 3.98-10.04 K/uL), but C-reactive protein was 0.1 mg/dL (reference range: 0.0-0.5 mg/dL), and erythrocyte sedimentation rate was 13 mm/hr (reference range: 0-30 mm/hr), both of which were within normal limits, giving low concern for infectious etiology. Deep venous thrombosis was ruled out by ultrasound. Radiographs showed intact left TKA with notable "cloud sign" representing metal artifact within the synovium (Fig. 1a and b).

Magnetic resonance imaging (MRI) was scheduled outpatient. MRI demonstrated a loculated fluid collection along the extensor digitorum longus of the left lower leg (Fig. 2a and b). Technetium 99 bone scan verified that there was no obvious evidence of loosening of hardware.

Fine-needle aspiration of the mass labeled in the left lower leg was documented only as "30 cc of tan cloudy" fluid, negative for pathology. Gram stain of the fluid showed no organisms or white blood cells. Culture was negative for growth at 5 days. At this time, she elected to proceed with tenolysis and debridement of the extensor digitorum longus muscle and tendon. At the time of debridement, black pigment was noted to extravasate along the proximal fascia and muscle fibers of the extensor digitorum longus muscle (Fig. 3).

Histological findings demonstrated necrotic skeletal muscle and tendon with collection of macrophages with iron stain, consistent with hemorrhage, and black-pigmented metal particles. Also present were negatively birefringent crystals suggestive of polyethylene wear debris vs calcium urate crystals. This result was indicative of metal and polyethylene wear debris that had extravasated from her knee along the anterior compartment of her lower leg (Fig. 4a-c).

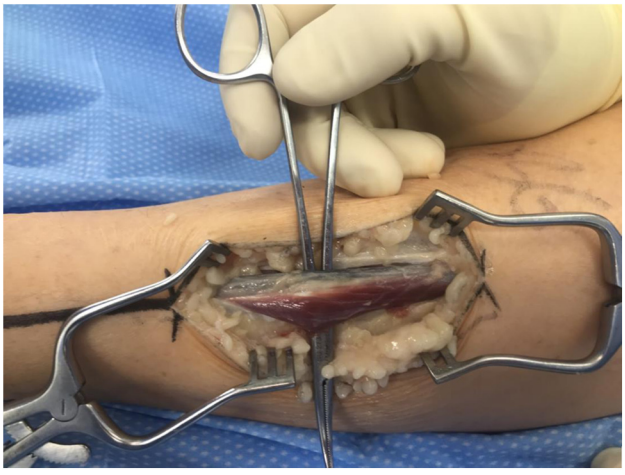

Figure 3. Intraoperative examination of the fluid collection along the anterior compartment of the leg yielded a large quantity of black-pigmented tissue along the extensor digitorum tendon and muscle within the anterior compartment of the left lower leg.

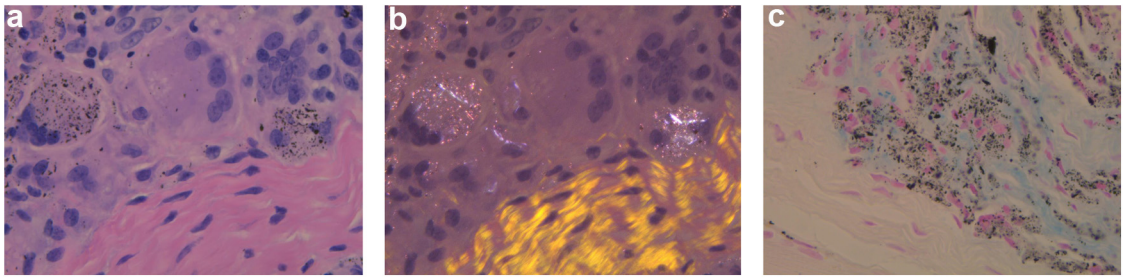

Figure 4. (a) This histology specimen was taken from the tissues of the anterior compartment of the leg. Within this high-powered field, there are multinucleated macrophages with phagocytosed black metal pigment. (b) This image is demonstrative of the presence of the same metallic particles within the multinucleated macrophages and the presence of birefringent crystals, suggestive of possible polyethylene debris. (c) This field demonstrates extensive infiltration of metallic particles within macrophages and within the skeletal muscle itself.

Based on the histology reports and clinical examination, it was determined that she had developed metallosis and metal sensitivity reaction as a result of the wear products of her failed Oxinium knee that subsequently extravasated down her lower leg. At a subsequent follow-up, she was evaluated by an adult reconstruction specialist. She underwent revision to an Aesculap total knee replacement (Aesculap Implant Systems, Inc., Germany). The Aesculap system uses a zirconium nitride ceramic coating reported to have resistance to scratches, low polyethylene wear, offering another option for patients with metal sensitivity. Microbiology results were negative for infection; however, the pathology images and report were positive for mononucleate and multinucleate macrophages, lymphocytic infiltrate, and the same black metallic particles previously documented from debridement of her lower leg (Fig. 5a-c).

She had a complicated postoperative course. She was initially noncompliant with knee immobilizer and walker use despite subjective episodes of instability over the 2 weeks postoperatively, although her knee was stable with intact extensor mechanism on examination. She subsequently had a fall with a small area of superficial wound dehiscence that was irrigated and closed primarily in the emergency room. The wound slowly improved and buckling resolved by the third week postoperatively. A few weeks later, drainage returned but was purulent in nature. Infectious indices were elevated at that time. She underwent irrigation and debridement with poly exchange and was placed on IV vancomycin and Rocephin. She developed a nonoliguric prerenal azotemia after being started on IV vancomycin and Rocephin. She also developed high anion gap metabolic acidosis. Cultures grew methicillin-sensitive *Staphylococcus aureus*, and she was transitioned to Rocephin for 6 weeks. Acidosis and acute kidney injury improved before discharge to a skilled nursing facility. She was seen in the clinic after completing her antibiotics with no sign of infection on clinical examination. She canceled her 3-month follow-up and has not rescheduled.

Discussion

We believe this is a unique presentation of metallosis with extra-articular extravasation of Oxinium wear particles along the extensor digitorum longus tendon. It is an unusual presentation in that prior cases with extra-articular involvement manifested with a fracture or cortical penetration of hardware. For this patient, the MRI of the lower leg with subsequent debridement and histology gave insight into the catastrophic failure of the implant. The aspirate and bone scan were less helpful. We believe that the cystic appearance on MRI was a result of metal artifact rather than a true collection of fluid.

Many conditions may result in lower extremity masses, and those should be ruled out at the time of presentation. Differential

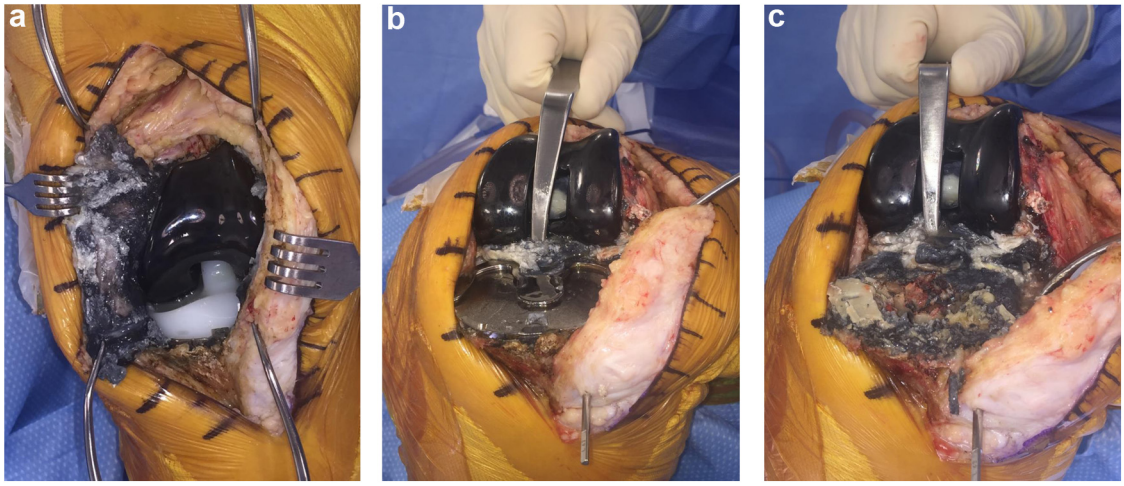

Figure 5. (a) Our initial evaluation of the knee once entering the synovium was indicative of the obvious metallosis occurring within the capsule itself, suggesting failure of the implant due to extensive wear particles. (b) Once the polyethylene liner was removed, there were signs of wear on the surface of the tibial baseplate and along the femoral condyles. (c) Metallic debris was noted within the cement mantle and within the cut surface of the tibia, indicative of the loosening that occurred, leading up to the failure of the implants.

diagnosis for patients developing cystic lesions or masses after TKA should include abscess or cellulitis, aneurysm, deep vein thrombosis, soft-tissue tumors, extravasation of wear debris resulting in a granuloma, or cyst.

Although it is documented that Oxinium-coated total hip arthroplasty components may fail because of metallosis and resulting wear particles, there is limited documentation of metallosis from Oxinium-coated TKA devices. We feel that this case highlights the importance of evaluating for metal allergy, as well as reviews the concern for metal-induced wear particles from ceramic-coated implants, specifically in this case using the Smith and Nephew Oxinium-coated knee implant. In patients with ceramic-coated implants, we recommend metal sensitivity testing and close monitoring of implants with follow-up imaging, including metal artifact reduction MRI or technetium 99 bone scan, to evaluate for loosening in those patients with an abnormal postoperative course or with local pain without an obvious clinical reason.

Summary

In summary, we feel that proceeding with ceramic-coated implants, such as those with the Oxinium coating by Smith and Nephew, has usefulness in patients with metal sensitivity. These patients should be closely monitored radiographically and clinically. In all patients who underwent TKA, it is of importance to rule out other possible causes of lower extremity masses, while keeping a high suspicion of local-tissue extravasation of wear particles associated with TKA. The extravasation of ceramic and metal particles should be considered as part of the differential diagnosis for symptoms of swelling and pain in compartments about the knee without other clinical causes.

Written consent was obtained from our patient for the use of her health information and medical records. Consent is available on request.

Conflict of interests

G. Brindley is a paid speaker for presentation for DePuy-Synthes (J&J) and is a co-investigator for Outcomes Research Project for DePuy-Synthes (J&J); J. Grimes holds stock ownership in ROM3 and is a board member in the Clinical Orthopaedic Society, Chairman of the American Academy of Orthopaedic Surgeons Foot and Ankle Evaluation Committee, and a member of the American Orthopaedic Foot and Ankle Society Physician Resource Committee and American Orthopaedic Society Abstract Review Committee; and A. Purcell and S. Buckner declare no potential conflicts of interest.

Acknowledgments

The authors appreciate the expertise of Dr. Mitchell Wachtel for the pathology images.

This case report is funded by Texas Tech University Health Sciences Center Department of Orthopaedic Surgery and Rehabilitation, Lubbock, TX, USA.

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