Title

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Case report

Stress-Induced, Aseptic Osteolysis of the Mid-Tibia in a Revision Hinged Total Knee Arthroplasty Mimicking Infection

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ABSTRACT

In this report, we present the case of an 80-year-old female with pain located over the tip of her cemented tibial stem in a revision hinge total knee arthroplasty with localized osteolysis that looked suspicious for infection. A thorough workup was negative for infection. We postulate that the osteolysis at the end of her tibial stem was initiated by a modulus of elasticity mismatch at the stem tip, which generated a focal area of increased sagittal bone bending and microparticle generation. She was treated with lesional exploration, debridement, synthetic bone grafting, and tibial plating to distribute stress loads away from the tibial stem tip. Histologic analysis identified no organisms or neoplasm. Her pain ultimately resolved, and the patient returned to her customary activities.

Introduction

As more primary total knee arthroplasties (TKAs) are performed in the United States, the number of revision surgeries and complications surrounding total knee implants will continue to rise [1,2]. The causes of a painful TKA are broad, with infection, instability, component malpositioning, aseptic loosening, and stiffness all being common causes necessitating a revision surgery [1,3,4]. Osteolysis is a radiographic finding that clues the clinician as to an underlying pathologic process [5]. As more sophisticated revision procedures are undertaken, the radiographic changes may not be pathognomonic. In this article, we present the case of an 80-year-old female with a localized osteolytic lesion at the distal tip of her cemented revision right TKA tibial stem. Based on the temporal presentation, we presumed the lesion to be the result of a low-grade periprosthetic joint infection (PJI). After a thorough workup negative for infection and without evidence of other pathologic processes, we postulate that her osteolysis was a mechanical stress-induced osteolytic lesion initiated by the elastic modulus mismatch centered at the diaphyseal stem tip.

Case history

A 65-year-old female with a past medical history significant for atrial fibrillation, hypertension, and coronary atherosclerosis underwent staged, bilateral TKAs for osteoarthritis in 2004. She subsequently underwent single-stage bilateral revisions in 2014 because of extensive catastrophic polyethylene wear, osteolysis, and resultant instability of her bilateral primary TKAs. Since her bilateral revisions, the patient had been following up on a regular basis, with no major issues or complaints and was walking independently without any ambulatory aids.

She then presented at her 5-year postoperative visit, now 80 years old, with complaints of a new anterior mid-tibial mass on her right leg. It was locally painful with ambulation and tender to palpation at the apex of the mass. She denied fevers, chills, or problems with her left knee and was otherwise still ambulating well despite mild pain. On physical examination, she demonstrated full knee range of motion from 0° to 135° with no appreciable effusion, warmth, or erythema. Over her right mid anterior tibia, there was a soft mass measuring 2 × 1.5 cm that was locally tender to palpation. Plain films demonstrated a lucent lesion measuring

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approximately 8 mm in diameter just anterior to the distal tip of the tibial stem (Fig. 1). She appeared to have no other lucencies or suggestions of osteolysis surrounding the remainder of her implants. Given the concern for infection, inflammatory markers were drawn along with completion of a right knee aspiration to rule out infection. Serum inflammatory labs, including C-reactive protein, erythrocyte sedimentation rate, and D-dimer, were near normal. Synovial fluid analysis, including synovial cell count, alpha defensin, culture, and next-generation DNA sequencing (MicroGen DX, Lubbock, TX), was negative for infection.

At her subsequent visits over the next 3 months, her mild mid-tibial pain continued, and she remained independently ambulatory. Over 3 months, she underwent 2 additional arthrocenteses, which were again negative for infection. Table 1 summarizes all preoperative testing results. Given her negative infection workup, it was postulated that her osteolytic lesion was initiated by an elastic modulus mismatch between her cemented cobalt chrome stem above and her native tibial bone below. She was scheduled for a lesional tibial exploration and reconstruction, which was ultimately expedited because of patient complaints of increasing mid-tibial pain.

At surgery, under local tourniquet, an anteromedial incision was made over the tibial diaphysis, with subperiosteal dissection extended laterally and medially with mobilization of the tibialis anterior and medial soleus for planned advancement and soft-tissue coverage during closure. There was an area of reactive subcutaneous tissue measuring 2.5 cm in length over the anterior tibial crest lesion, a sample of which was sent for histologic analysis. No gross purulence was encountered. Soft-tissue debridement revealed a round hole in the anterior diaphyseal cortex of the tibia, measuring 1.2 cm and centered directly over the tip of the revision stem (Fig. 2). In the surrounding tissue, small (1-2 mm) fragments of necrotic bone and cement were found. All fragments were removed, and the bone was sent for culture. The remaining edges of the bone hole were debrided and curetted to a solid border. The defect was then filled with 5 cc of calcium sulfate/hydroxyapatite synthetic bone void filler (Cerament; BoneSupport AB, Lund, Sweden), which was injected into the region and spread flush with the anterior diaphyseal cortex (Fig. 2). A 14-hole 3.5-mm locking compression plate was placed centered over the defect to distribute bending stresses along the tibial diaphysis (Fig. 2). The tibialis anterior and soleus were then advanced over the plate and defect to provide a neovascular supply and additional soft-tissue coverage. The wound was closed in layers over a drain, and a soft compressive dressing was applied to the right lower extremity. The patient was made weight-bearing as tolerated, with oral doxycycline to

Table 1
Preoperative Laboratory Test.

	Index visit (IV)	IV+ 2.5 mo	IV+ 3 mo
Serum WBC (thousands/uL)	4.0 (≥10.0)	3.4	—
Serum ESR (mm/h)	9 (≥30)	6	—
Serum CRP (mg/L)	1.08 (≥1.0)	.82	—
Serum D-dimer (ng/mL)	1050 (≥860)	1150	—
Synovial WBC (cells/uL)	3370 (≥3000)	3062	1987
Synovial PMN (%)	38.8 (≥80%)	54.7	24.1
Synovial fluid cultures	Negative	Negative	Negative
Synovial alpha-defensin	Negative	Negative	Negative
Synovial DNA MGDX[a]	Negative	Negative	Negative

WBC, white blood cell; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; PMN, polymorphonuclear leukocytes.
Threshold levels based on previous consensus meetings and the report of Parvizi et al. are given in parentheses of the second column [6].
[a] MGDX = MicroGen DX—next-generation DNA sequencing for microbiota.

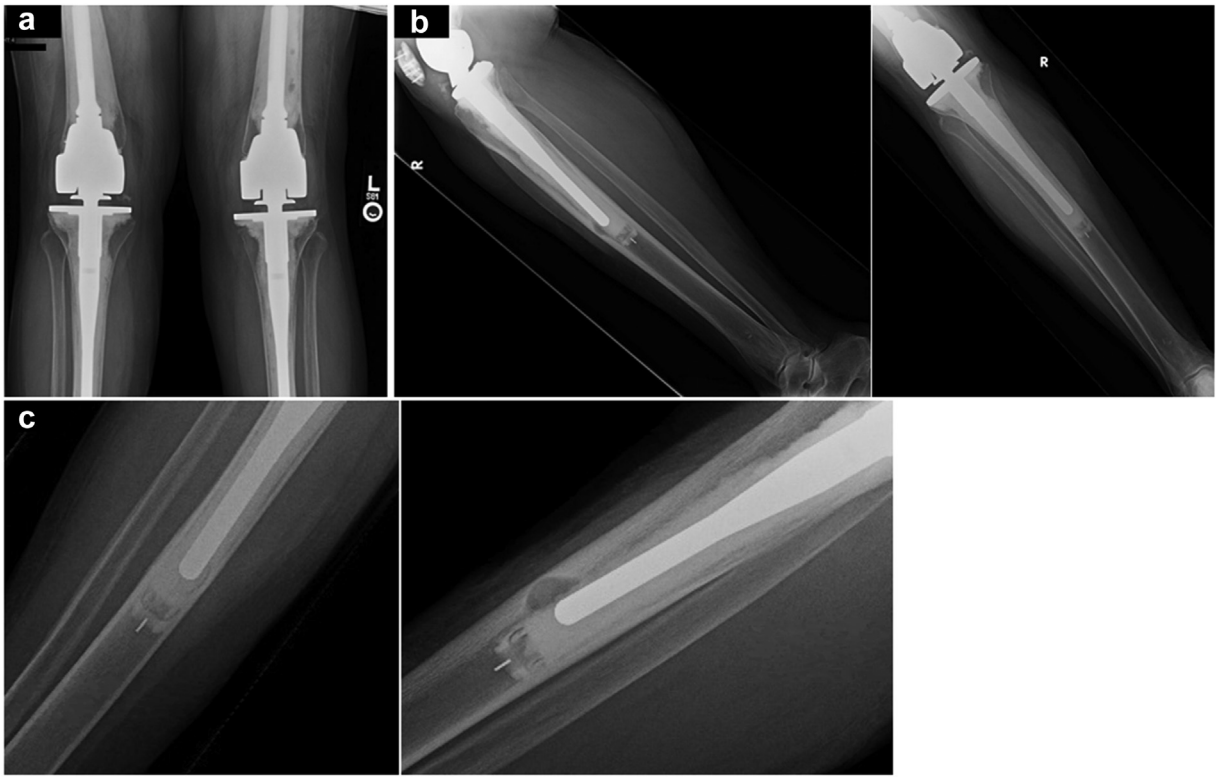

Figure 1. Five-year postoperative radiograph of revision right TKA. (a) Bilateral anteroposterior (AP) plain film of right and left hinged revision TKAs. (b) AP and lateral x-rays of the right tibia. (c) AP and lateral projections of distal stem tip in the right tibia. Mid-diaphyseal anterior tibial lesion can be seen at stem tip. Cement mantles other than the right tibial stem tip show no obvious erosions or debonding.

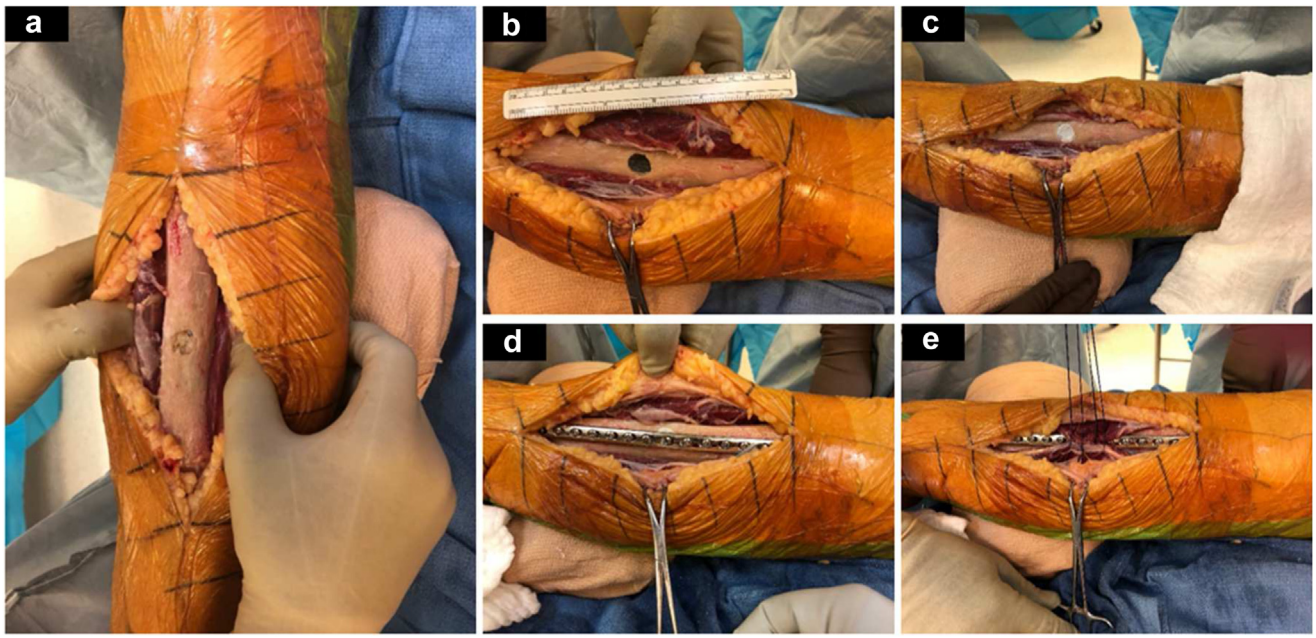

Figure 2. Intraoperative photographs of surgical exploration and reconstruction demonstrating (a) diaphyseal osteolytic lesion, (b) lesion status after debridement, (c) filling of the lesion with synthetic bone void filler, (d) plating across the defect with a 3.5-mm LCP plate, (e) mobilization of the tibialis anterior and medial soleus muscles for soft-tissue coverage.

continue until cultures and histology finalized. Radiographs are shown in Figure 3.

Intraoperative surgical tissues were sent for fungal, acid-fast, aerobic, and anaerobic bacterial cultures. All cultures finalized with no growth. Pathologic and histologic analysis of the tissue surrounding the osteolytic area demonstrated fibro-adipose tissue with evidence of chronic inflammatory changes, with staining negative for any evidence of organisms. After 3 years, in her most recent clinical follow-up visit, she reports that she is doing well with her right revision TKA. She has returned to her customary activities, walking 1-2 miles per day. Her shin pain has resolved, and she does not require any assistive devices for ambulation. The patient provided informed consent for publication of her case.

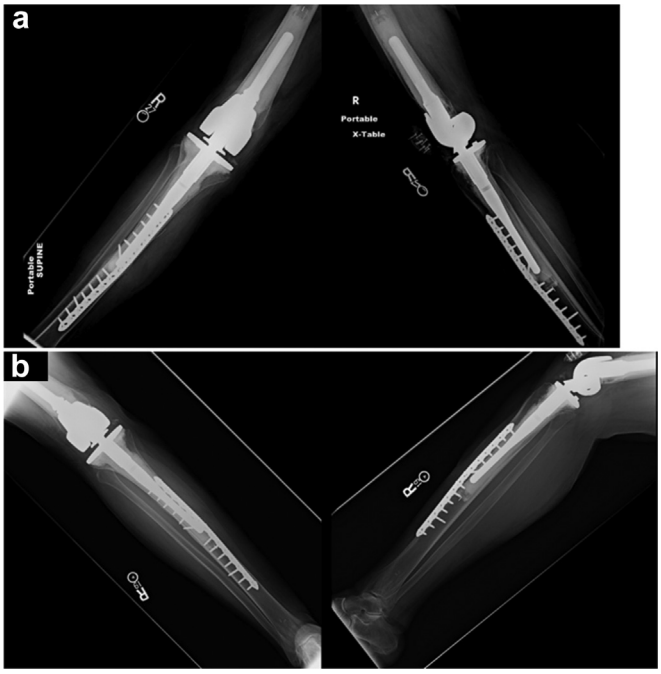

Figure 3. Post operative radiographs of right tibial reconstruction (a) showing tibial lesion filled with bone void filler and load-sharing bridge plate, and 2-year follow-up radiographs (b) showing density loss at the area of bone void filler. However, patient is pain free and customarily active.

Discussion

In this case report, we present an 80-year-old female with bilateral hinged revision TKAs with insidious onset of a tender and painful mass over the anteromedial right shin. This tenderness corresponded radiographically to the anteromedial cemented tibial stem tip, with a very discrete and isolated area of osteolysis about the anteromedial tibia. This case presented an interesting diagnostic and treatment challenge, with the differential diagnosis including infection, microparticulate debris-mediated osteolysis, and neoplasm. The temporal presentation at 5 years was very suggestive of PJI.

The differential diagnosis of a painful TKA can be quite broad, including a number of diagnoses extrinsic to the implant or limb, such as neurological or psychological causes, in addition to the more common intrinsic causes of loosening, instability, malalignment, and infection [7,8]. In the workup of the painful TKA, infection should be ruled out before definitive treatment given the potentially devastating, painful, and costly consequences of inappropriate treatment in the setting of missed infection. In 2018, Parvizi et al. validated updated criteria for the diagnosis of PJI, modifying previous criteria to include additional laboratory tests such as alpha defensin, D-dimer, and synovial C-reactive protein [6]. In addition, this new algorithm uses a stepwise approach to diagnosis that mirrors clinical workup and treatment [6]. Beyond the laboratory workup more formally defined by the Musculoskeletal Infection Society, the senior author of this article routinely sends synovial samples in suspected PJI cases for next-generation DNA sequencing. While next-generation DNA

sequencing can result in false positive results and presently has relatively low specificity, its high sensitivity and ability to isolate specific microbial strains holds promise in improving the workup and treatment of PJI [9,10]. Given this patient's unique presentation, her normal preoperative aspiration studies and the lack of intraoperative findings lent confidence to the treatment team that this case was not caused by infection, but rather an aseptic, mechanical etiology.

Periprosthetic osteolysis is a concerning finding in any arthroplasty patient. The cellular mechanisms of osteolysis involve numerous cytokines in the inflammatory cascade although the end effector of bone resorption and osteolysis is the osteoclast cell. Osteolysis secondary to microparticulate debris, infection, and neoplastic processes are common causes of periprosthetic osteolysis and have been well described in the orthopedic literature [5,11,12]. Given this patient's negative infectious workup, as well as her negative pathologic examination and the temporal presentation of both her pain onset and radiographic localized osteolysis (at 5 years postoperatively), we postulate that her tibial pain and adjacent osteolysis was likely initiated by increased sagittal mechanical bending stresses generated at the cemented diaphyseal stem tip. Specifically, a modulus of elasticity mismatch at the stem tip generated a focal area of increased sagittal bone bending at the anterior tibial cortex. In addition, because of a thin anterior distal cement mantle, the concentrated micromotion caused localized cement cracking, creating microparticulate polymethylmethacrylate debris. The microparticulate debris in turn initiated localized osteoclastic bone resorption. Gallo et al. described in detail the mechanisms of periprosthetic osteolysis that can occur secondary to high mechanical stresses at the bone-implant interface [5]. Over time, and with cyclical loading from daily weight-bearing and activity, the localized bending stress at the bone-cement interface can lead to microcracks and debonding of the bone-cement interface. Furthermore, it is known from examination of cemented hip stem retrievals that a cement mantle defect (defined as an area where the stem touches bone or the cement mantle is very thin as seen in this case) is a focal area where cement initially begins to fatigue [13]. In this case, we surmise sequential additive mechanisms to produce the tibial bone lesion. These include increased localized mechanical bending stress, cement mantle defect, polymethylmethacrylate microparticle generation, and a chronic inflammatory reaction [5,14]. Finally, we propose the patient's tibial pain started because of a further increase in bone bending resulting from the newly generated cortical hole from the osteolytic process.

End-of-stem pain in revision TKA is a well-known complication, thought to occur due to increased stress and modulus of elasticity mismatch at the stem tip, but it occurs early, usually noted within the first 3 months of implantation. Previous studies have demonstrated end-of-stem pain rates of up to 11% and 14% on the femoral and tibial sides in revision TKA [15,16]. End-of-stem pain is also well characterized after hip arthroplasty and an important differential in the workup of thigh pain after total hip arthroplasty [17,18]. The mismatch of the modulus of elasticity between the implant stems and the native bone leads to high local stresses, which are thought to cause painful endosteal and periosteal irritation and localized inflammation [15,17,19]. Over time, bone remodeling reduces the modulus mismatch, and in most cases, end-of-stem pain improves without surgical intervention. In contrast, the end-of-stem pain in this case started at 5 years and was associated with a localized progressive inflammatory process. We feel this case to be unique, and not related to classical stem tip pain pathology.

As high local stresses were thought to be the cause of the patient's aseptic bone resorption, the surgical treatment was aimed at reducing the modulus of elasticity mismatch between the stiffer cemented stem segment and the more-elastic native distal tibia. Treatment in this case consisted of lesional debridement, filling of the defect, and long plating centered at the stem tip lesion. Previous case studies have reported the use of cortical strut allografts, as well as plating across the implant-bone interface, to decrease the modulus mismatch and eliminate resultant pain [20,21]. In addition, using a finite element analysis model, Kimpton et al. demonstrated significant decreases in the amount of stress seen at the implant interface with the placement of a tibial plate at the level of the stem tip [19]. They noted the greatest decreases in stresses when the plate is placed on the medial side of the tibia, where compressive forces are greater because of the larger and more loaded medial compartment of the knee [19].

Summary

Treating surgeons should be diligent in the management of the patient with a painful revision TKA with radiographic isolated stem-tip osteolysis. Infection-induced osteolysis should always be ruled out before any additional surgical treatment. Once infection is ruled out, thought should be given to the pathogenesis of the osteolytic lesion including modulus of stress mismatch, excess bone-bending stress, microparticulate debris, and neoplasm. Treatment of stress-induced lesions and pain should be aimed at redistributing high stress concentrations, which was accomplished in this case through a bridging plate centered over the affected area.

Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: E. McPherson receives royalties from Zimmer Biomet; is in the speakers' bureau of or gave paid presentations for and a paid consultant for Austin Medical Ventures and Zimmer Biomet; is in the editorial or governing board of Reconstructive Review.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2022.01.030.

Informed patient consent

The patient gave full consent to have her deidentified information and case presented in article format.

KEY POINTS

- Osteolytic stem tip lesions around a revision TKA stem, presenting early in the life cycle of the implant, require first a thorough preoperative and intraoperative investigation for PJI.
- When infection is ruled out, the mechanism causing a localized osteolytic process should be carefully assessed. Factors include modulus of elasticity mismatch, cement mantle defects, and excess local mechanical bone bending. A tissue examination with cultures and histologic examination for a neoplastic process are always required.
- Treatment of stress-induced lesions and pain should be aimed at redistributing high localized bone stress concentrations.

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