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Case Report

Sister, Sister! Siblings With Simultaneous Early Femoral Insufficiency Fractures After Total Knee Arthroplasty

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ABSTRACT

Early periprosthetic fractures after total knee arthroplasty are rare but devastating complications which require revision surgery and lead to poor patient satisfaction. We present 2 siblings who underwent primary total knee arthroplasty on the same day and then both presented 2 weeks after surgery with atraumatic periprosthetic femur fractures. The first patient underwent revision for a cemented distal femoral replacement with stemmed tibial fixation. The second patient underwent an isolated femoral component revision with a stemmed femoral component and distal augment. Histological evaluation identified significant peri-implant osteoporosis. The variation in complexity associated with early periprosthetic femoral insufficiency fractures is highlighted by these 2 cases. Surgeons may consider using stemmed femoral components in similar patients if poor distal femoral bone stock is encountered intraoperatively.

Introduction

Periprosthetic fractures after total knee arthroplasty (TKA) are a rare but significant complication and most often involve the distal femur [1]. The majority of these fractures occur several years after the operation [2], are often traumatic in nature, and can also be secondary to age-related decline in periprosthetic bone mineral density (BMD) [3]. The prevalence of distal femoral fractures around a primary TKA ranges from 0.3% to 2.5% with both patient [4-7] (osteolysis, chronic steroid therapy, rheumatoid arthritis, osteopenia, frequent falls, neurological disorders) and surgical risk factors (anterior femoral notching, use of canal-filling components, use of constrained implants) being associated with their occurrence [1,8-10].

However, the early atraumatic periprosthetic femoral insufficiency fracture is a less well-understood phenomenon. We present 2 cases of early femoral insufficiency fractures occurring simultaneously in 2 siblings with similar risk factors who underwent primary TKA on the same day with nearly identical implants. The purpose of this case report and review of the literature is to highlight the potentially synergistic interaction between patient and implant-related risk factors that may have contributed to this devastating complication. The 2 patients involved in this report have provided consent for publication.

Case history

Two sisters underwent unilateral primary TKA on the same day in our institution by the senior author (P.K.S.). Patient #1 was 87 years old, had a body mass index (BMI) of 22, and had a past medical history of hypothyroidism, transient ischemic attacks, nonalcoholic cirrhosis, and hypertension. Patient #2 was 89 years old, had a BMI of 26, and had a past medical history of mild dementia, myocardial infarction, and hypertension. Conservative management of their knee osteoarthritis had been unsuccessful,

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and both patients presented with reducible varus deformities and radiographic evidence of thin cortices and osteopenia (Fig. 1a and b). Patient #1 and #2 underwent unilateral mechanically aligned TKA procedures, both receiving a cemented Persona posterior-stabilized knee (Zimmer-Biomet, Warsaw, IN) with patellar resurfacing and 30-mm tibial stem extensions because of their bone quality. An 11-mm and 14-mm posterior stabilized polyethylene insert was used in each case, respectively. Patient #1 received a size B tibial baseplate and a size 3 narrow femoral component. Patient #2 received a size C tibial baseplate and a size 4 narrow femoral component. Of note, the femoral sizes used (3 and 4) have identical anteroposterior dimensions to the 2 smallest femoral sizes available in the Sigma (DePuy Synthes, Warsaw, IN), Triathlon (Stryker, Kalamazoo, MI), and Vanguard (Zimmer-Biomet, Warsaw, IN) systems [11]. Furthermore, the smallest femoral components (sizes 1 and 2) and tibial components (A and B) are only available on special request and not part of the standard Persona size offerings. Two bags of medium-viscosity cement (Simplex P; Stryker, Mahwah, NJ) was used in both cases, with one bag warmed up to 37°C before use to hasten polymerization time.

The femoral size was determined through posterior referencing. No femoral notching or other adverse events occurred intraoperatively, and excellent implant stability, ligamentous balance, and range of motion were achieved. No notable distal femoral or proximal tibial bone defects, excessive porosity, or fragility was noted intraoperatively. Both patients began to mobilize on the day of surgery, had cleared physical therapy, and were mobilizing up and down stairs by postoperative day 3, when they were discharged home under family supervision.

On postoperative day 14, a visiting physical therapist contacted the surgeon's office to report that patient #1 had increasing difficulty bearing weight and had developed noticeable deformity in the operated knee. No traumatic event had occurred. The patient was seen urgently by the on-call surgeon (A.V.C.), and radiographs revealed a periprosthetic fracture that affected both femoral condyles and resulted in collapse and valgus angulation of the distal femur. The tibial component was still well fixed (Fig. 2a). The patient was admitted and consented for revision surgery, which occurred the following day. At surgery, both condyles were found to be displaced with catastrophic collapse of the osteoporotic metaphyseal bone. Bone excised during revision arthroplasty showed histologic evidence of osteoporosis and recent ischemia (Fig. 3a). Owing to massive bone loss on the femur, the patient had to be converted to a stemmed distal femoral replacement with cemented fixation and revision of the tibial component to a rotating hinge with a long press-fit stem with hybrid fixation (Fig. 4b). Postoperatively, the patient was permitted to fully weight bear and instructed to use a walker at all times for stability.

Upon speaking with the niece of patient #1 (and daughter of patient #2) to report the successful revision procedure, the niece stated that patient #2 had begun to develop progressive pain and a similar atraumatic deformity in the operated knee. The patient was evaluated the following day, and, similar to patient #1, the radiographs revealed a periprosthetic fracture that affected the lateral (unloaded) femoral condyle and resulted in collapse and valgus angulation of the distal femur. As with the other case, the tibial component appeared well fixed (Fig. 2a). A subsequent CT scan confirmed the fracture affecting only the lateral condyle with preservation of the osteoporotic medial condyle. At revision surgery, the cancellous distal lateral condyle was found to be severely impacted inside the intact lateral cortical shell. The lateral collateral ligament insertion was intact. Histologically there was evidence of an insufficiency fracture with associated necrosis in the underlying femoral bone (Fig. 3b). The medial condyle and medial collateral ligament were both intact, so an isolated femoral component revision was performed converting to a Zimmer-Biomet Persona revision stemmed femoral component with hybrid fixation and a long press-fit stem (Fig. 4a). A 10-mm distal lateral augment was necessary to compensate for the femoral bone loss, and a 10-mm mid-level constraint liner was used. The patient was instructed to limit weight bearing to toe-touch for 6 weeks.

Owing to the COVID-19 pandemic, both patients were hospitalized for a longer-than-usual period to receive physical therapy and avoid discharge to inpatient rehabilitation facilities. Patients were discharged home on postoperative day 8 and 10, respectively. Their caregiver reported good pain control without the need for

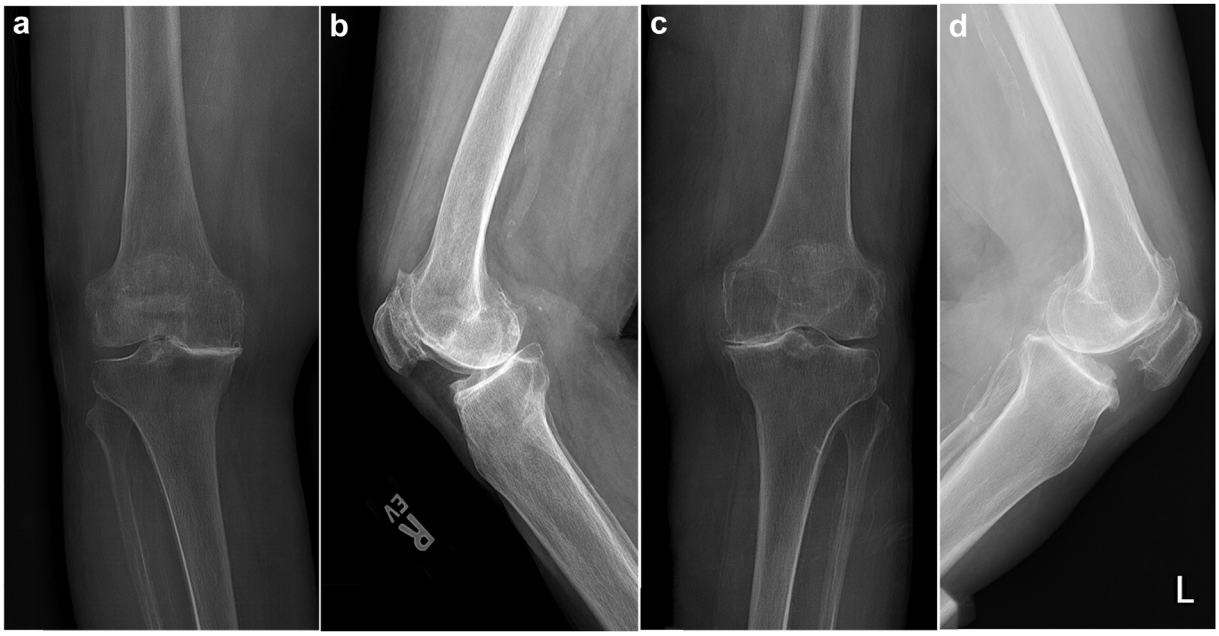

Figure 1. Preoperative anteroposterior radiographs of patient #1 (a, b) and patient #2 (c, d) demonstrating osteoporotic bone, varus alignment (6° and 16°, respectively, according to the hip-knee-ankle angle) and unloaded lateral femoral condyles.

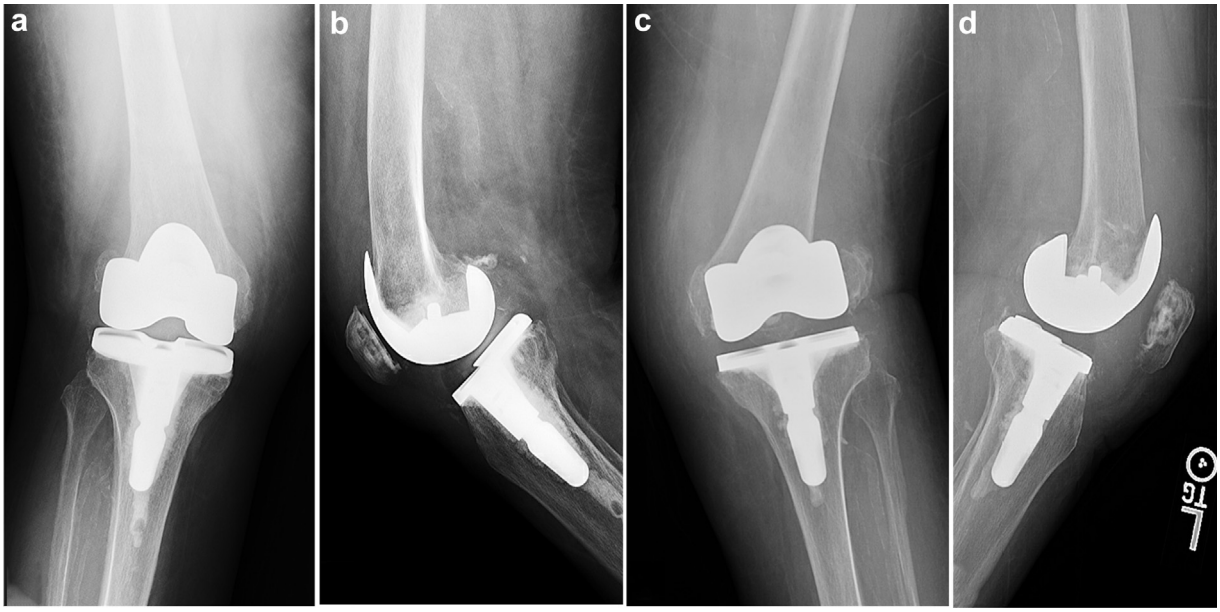

Figure 2. Three-week postoperative anteroposterior radiographs of patient #1 (a, b) and patient #2 (c, d). Both knees are in marked valgus. Patient #1 presented with a displaced lateral femoral condyle fracture. Patient #2 presented with a bicondylar fracture, with compression and displacement of the lateral condyle and avulsion of the medial condyle.

narcotic analgesics after 1 week. Patient #2 was hospitalized at an outside institution at 2 weeks postrevision for altered mental status but was cleared and discharged home. The surgical wounds healed without complication. On subsequent postoperative visits, both patients denied that they had been previously screened for osteoporosis or had taken calcium or vitamin D supplementation. They were both counseled to take vitamin D and referred to endocrinology for osteoporosis management. Follow-up imaging at 6 months revealed preservation of implant alignment and stability (Fig. 4a and b).

Discussion

This case report highlights the need for wider investigations into the prevalence of early insufficiency fractures and to determine if preoperative and intraoperative measures are needed to reduce the occurrence of this catastrophic early complication. In these 2 cases performed by the same surgeon in the same operating room with the same team on the same day, 2 siblings of the same sex (female) and nearly same age (89 and 87 years) underwent primary TKA for the same preoperative deformity (varus osteoarthritis) with nearly

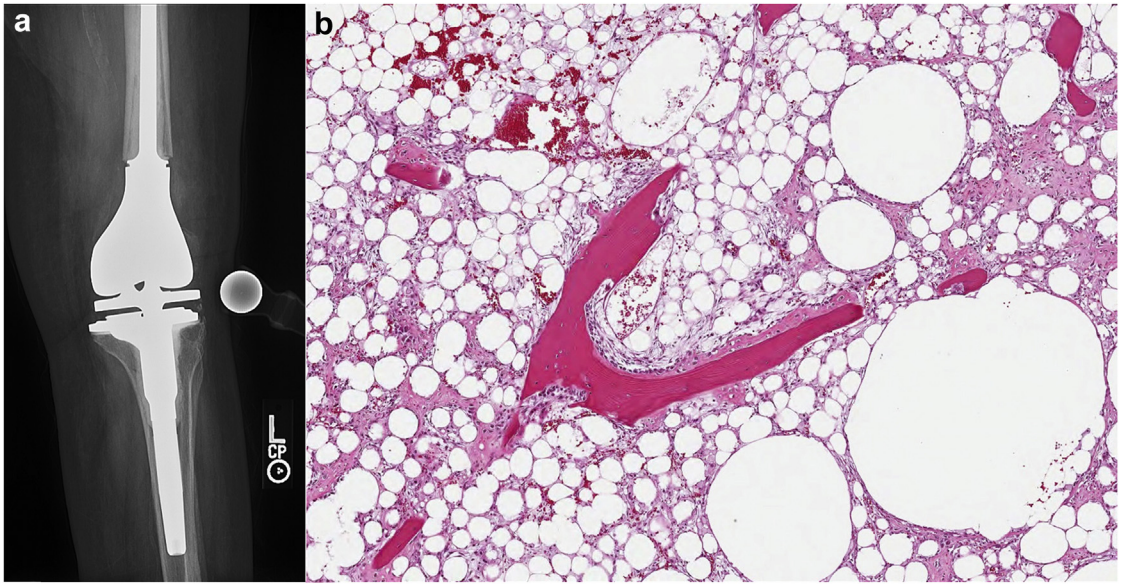

Figure 3. (a) Six-month postrevision radiograph of patient #1, who underwent revision for a distal femoral replacement with a rotating hinge, 80 × 15-mm cemented femoral stem, and extra-small tibial component with a 102 × 10-mm press-fit stem. (b) High-magnification image of cancellous bone retrieved from revision surgery. The low trabecular bone area reflects osteoporosis. Areas of hemorrhage and microvesicular and macrovesicular fat in the marrow reflect recent ischemia (50×, H&E).

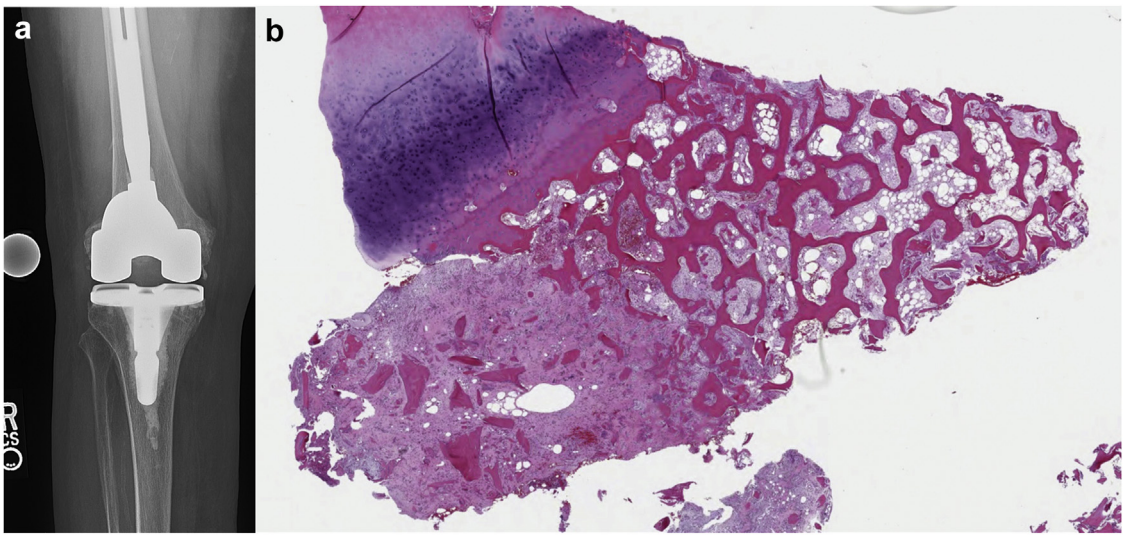

Figure 4. (a) Six-month postrevision radiograph of patient #2, who underwent an isolated femoral component revision with a size-3 revision femur, a 10-mm lateral distal femoral augment, a 5-mm posterior augment, and a press-fit 15 × 135-mm stem. (b) Low-magnification image of articular cartilage and subchondral bone excised during surgery. The disrupted trabeculae reflect an insufficiency fracture (10×, H&E).

identical small-sized femoral and tibial implants and the same level of constraint (posterior stabilized). They went on to experience the same type of atraumatic femoral fracture at the same postoperative time point (2 weeks).

Previous reports have found the unloaded condyle in a patient with a varus or valgus preoperative deformity combined with osteoporosis to be at risk for developing early insufficiency fractures [12,13]. The unloaded femoral condyle, as evidenced in our cases and 2 prior case series [12,13], appears to be at risk because of decreased focal BMD. Ishii et al. [14] found on 116 consecutive osteoarthritic patients that the BMD of the medial femoral condyle had 30% greater density than the lateral femoral condyle. Similarly, Akamatsu et al. [15] determined that the ratio between medial and lateral condylar BMD was positively correlated with increased femorotibial angle and the presence of medial osteophytes. Interestingly, correction of the coronal deformity after TKA equalizes the medial-lateral BMD ratio, not through improving the bone density in the unloaded femoral condyle but instead through decreasing the density of the preoperatively loaded condyle [16,17]. Pharmacological agents, such as bisphosphonate, can improve the BMD in the proximal tibia for the first 6 months after TKA [18], but the use of pharmacological agents preoperatively to increase femoral condylar BMD has not been described to date. Despite a limited understanding of treatment efficacy and timeline for improvement, these cases highlight the importance of identifying untreated osteoporosis in patients considering knee replacement surgery, a goal that orthopedic surgeons have historically struggled to achieve [19-21]. Furthermore, preoperative optimization of untreated osteoporosis may be one strategy to reduce the risk of insufficiency fractures. However, to date, there are inconclusive data regarding treatment strategies and long-term outcomes proving their efficacy.

The use of posterior stabilized knee replacements has also been suggested as a possible risk factor for intraoperative periprosthetic fractures, but its role in acute insufficiency fractures is less clear [22]. Despite excellent long-term performance, posterior stabilized TKA requires removing additional bone from the central portion of the distal femoral metaphysis to accommodate the box-shaped housing. Graceffa et al. [23] reported significant differences in the volumetric box resections among several posterior stabilized designs, raising the theoretical concern that a larger resection for a smaller femoral component size could place more tension-based strains on the femoral condyles and lead to a unicondylar or intercondylar fracture [24]. This concern could logically be extended to our 2 cases, which used the 2 smallest femoral component sizes available within the Persona implant system. We were surprised to find that this implant system had the lowest box resection volume of all the designs in the study by Graceffa et al. [23]. However, insufficiency fractures have occurred when no box resection was performed because the largest case series of insufficiency fractures, comprising 15 cases (over half of all reported cases), involved cruciate-retaining implants only [12]. In addition to the reduced bone stock after femoral box resection, our patients had small component sizes. To our knowledge, the effect of femoral component size on catastrophic bone collapse has not been investigated. However, Fehring et al. [25] reported that 72% (25 of 35) of catastrophic collapsed tibial components were in the lower half of tibial sizes in patients with high BMI. Smaller femoral components should be expected to result in larger burden placed on the bone, although a reduction in component size entails a less-than-proportional increase in component stresses because the load transfer is not homogeneous over the entire implant surface. Additional biomechanical investigations into the effects of bone resection and other implant variables that affect bone strains, such as implant constraint and liner congruity, are needed before definitive implant design recommendations can be made. The latter topic of implant constraint is becoming more clinically relevant as most major manufacturers offer a constrained posterior-stabilized insert for primary knee replacements [18], raising a possible biomechanical concern because greater varus-valgus constraint increases bone-implant load in the coronal plane, which may contribute to focal lateral condylar bone overload and consequent insufficiency fracture. An additional intraoperative consideration is the occurrence of thermally induced bone necrosis secondary to excessive cement polymerization temperatures, a factor which has been linked to osteocyte necrosis and speculated to possibly lead to implant loosening at the bone-cement interface [26].

Historically, a great deal of emphasis has been placed on the impact of increased BMI and constraint on tibial component

loosening. This has led to the near-universal option of adding a tibial stem extension to a primary tibial baseplate for patients with larger BMI and when mid-level constraint inserts are placed to decrease the risk of tibial loosening. However, in most primary TKA systems, the femoral component does not allow for a stem extension to be placed, and adding a femoral stem extension requires conversion to the revision system with an even larger box resection to accommodate a fully constrained polyethylene insert. For this reason, femoral stems are rarely used in primary TKA. The findings in this case report should cause a reevaluation of the importance of additional femoral fixation and development of criteria to help define which patients would be best served with femoral stem extension even if it means converting to a revision system. We believe that the simultaneous occurrence of this early postoperative femoral fracture after TKA is concerning and suggests that an updated treatment algorithm on when to use femoral stems to offload the distal femoral condyles is required. These 2 cases of elderly female patients with poor bone quality who required small-sized implants represent the ideal candidates for additional femoral stem fixation, at least when using this implant design.

Treatment of early insufficiency fractures invariably involves revision arthroplasty surgery which, as seen in the current cases, can present with different levels of disability and complexity. For this case report, both patients presented with marked angular deformities and an inability to weight bear, necessitating urgent surgical intervention. However, rapid intervention may not always be advantageous. Vestermark et al. [13] successfully delayed surgical management for 6 of 7 insufficiency fractures for an average of 6 weeks, permitting the fracture to heal before performing an isolated femoral component revision. Allowing the femoral condyle to unite before implant removal could prevent iatrogenic worsening of the femur fracture during implant removal. Shahi et al. [12] pointed out the challenge in revising implants in the osteoporotic bone of such patients, noting the regular need to use metaphyseal cone fixation to account for bone loss that occurred when removing the implant components. Both of those case series included at least one severe fracture presentation where a rotating hinge or distal femoral replacement was necessary. Furthermore, both reports found that patients took time to regain mobilization and motion, an understandable observation due to the physiological burden of 2 surgeries in a short period of time, especially in elderly patients.

Conclusions

The 2 cases presented in this report highlight the burden and complexity associated with early periprosthetic femoral insufficiency fractures. The concurrent presence of osteoporosis and preoperative angular deformities appears to be consistently present in the cases reported here and in the literature. The combination of small implant sizes combined with the use posterior stabilized articular inserts may also represent implant-related risk factors. Based on these cases, arthroplasty surgeons should consider optimizing at-risk patients for osteoporosis management through calcium and vitamin D supplementation, with endocrinology consultation for additional pharmacotherapies as needed. Furthermore, additional research is needed to determine which implant designs reduce the risk of early fractures and if specific intraoperative strategies, such as adding a stem extension to the femoral component, could prevent this complication from occurring.

Conflict of interest

P. K. Sculco is in the speakers bureau/received paid presentation from and is a paid consultant for DePuy Synthes, Intellijiont Surgical, and EOS imaging and obtained research support from Intellijiont Surgical. T. M. Wright received royalties from Exactech and Mathys; has stock or stock options in OrthoBond; received research support from Lima Corporate; and is a board member for Knee Society (Educational Committee), AJRR (Data Committee), and OREF (Research Grants Committee). T. W. Bauer is a paid consultant for Leica Biosystems and Moximed Corp; received research support from BioFire, Inc.; and is in the editorial/governing board of Journal of Bone and Joint Surgery (Deputy Editor for Research) and JBJS Case Connector (Co-Editor).

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2019.12.004.

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