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Case report

Tibial tray fracture in a modern prosthesis with retrieval analysis

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ABSTRACT

Fracture of the tibial tray is a rarely observed complication of total knee arthroplasty (TKA), predominately in implants placed greater than a decade ago. This case highlights a case of baseplate fracture in a contemporary prosthesis. The patient presented 1 year after TKA with medial knee pain consistent with pes bursitis. The implant-cement-bone construct was intact and she was managed with corticosteroids. She had persistent pain, acutely developed new varus deformity, and presented with a tibial tray fracture. Retrieval analysis suggested fatigue fracture as the likely mechanism. At time of revision, necrotic bone was found at the medial plateau, which likely caused cantilever bending relative to the well-supported portion of the tray and resultant failure. The patient continues to do well 5 years after revision TKA.

Introduction

Implants for total knee arthroplasty (TKA) have evolved greatly over the past few decades. Through numerous advances in design and materials, the durability, longevity, and survivorship of TKA continues to improve. Presently, the most common reasons for failure and revision surgery are aseptic loosening, instability, malalignment, and periprosthetic infection [1]. Introduction of metal-backed tibial components presented a new mechanism of failure—fracture of the tibial tray, first described by Scott et al in 1984 [2]. Fracture of the tibial implant is a rare complication, and many of the documented cases occurred in those placed over a decade ago [2-14]. Several of the earlier reports were attributed to design flaws, and tibial tray fracture has rarely been reported in modern TKA [6,7,15]. We present a case of this rare complication in a modern TKA prosthesis.

Case history

Informed consent was obtained to publish deidentified information regarding this patient's TKA, tibial tray fracture, and subsequent care.

A 67-year-old women (weight: 109.1 kg, height: 179 cm, body mass index: 34.1 kg/m^2) presented to the outpatient clinic in 2008 with chief complaint of right knee pain that was severely limiting her activity. She previously underwent right total hip arthroplasty in 2007 and left TKA in September 2008 with uneventful postoperative courses.

Examination of her knee revealed a fixed valgus deformity of approximately 15°-20° and a range of motion of 0°-110°. Radiographs demonstrated right knee osteoarthritis with valgus deformity (Fig. 1a). The patient failed conservative measures for her symptoms and elected to undergo right TKA in February 2009, utilizing a PFC Sigma design (DePuy, Warsaw, IN) with a polished, chrome cobalt tibial tray. The prosthesis was fixed with cement, and a 12.5-mm polyethylene insert was used. The procedure was uneventful. Postoperatively, the knee was in 5° valgus alignment and knee radiographs demonstrated a stable implant (Fig. 1b). The patient did well after surgery and obtained complete pain relief.

At 1-year follow-up, she complained of recent onset medial knee pain in the area of the pes anserine bursa. Radiographs were unremarkable (Fig. 1c). She was diagnosed with pes anserine

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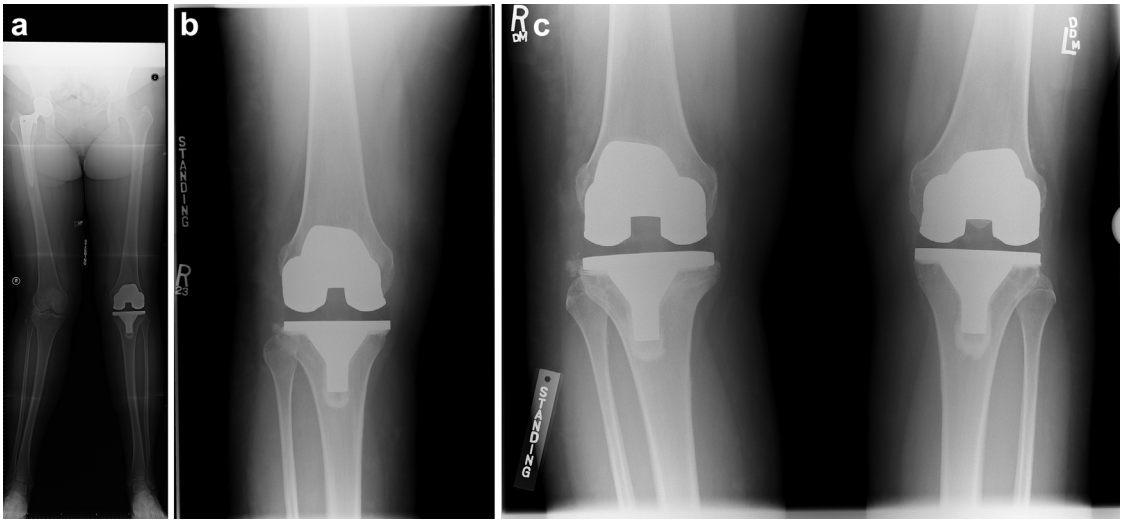

Figure 1. (a) Anteroposterior (AP) long leg preoperative radiographs from February 2009 (b) AP right knee at 6 weeks postoperative (c) AP bilateral knees at 1 year postoperative (d) AP and lateral radiographs first demonstrating tibial tray fracture in July 2010 (e) AP long leg radiographs 1 month after revision procedure (f) AP bilateral knees at 5 years after revision procedure.

bursitis and received a short course of oral corticosteroids. She returned 3 months later without improvement in her symptoms and she underwent a corticosteroid injection into the pes anserine bursa. The injection provided partial relief, but she returned 1 month later with progressive symptoms. At this time, the right knee was found to be in 15° varus. Radiographs were obtained and demonstrated a fracture of the tibial tray (Fig. 1d).

The patient underwent revision of the tibial component in July 2010. At the time of surgery, there was necrotic bone within the posteromedial aspect of the tibial plateau. High-speed burrs were used to debride the necrotic bone to healthy bleeding bone. A DePuy PFC Sigma revision tibial component was inserted and fixed with cement. No augments were needed, and the alignment of the knee was corrected. The patient tolerated the procedure well without complications (Fig. 1e). Intraoperative cultures and cell counts did not provide evidence of any underlying infection. She returned to full activity postoperatively and was asymptomatic at her most recent follow-up, 5 years later (Fig. 1f).

Implant analysis

The fractured tibial tray was first examined visually (Fig. 2). The fracture extended through the width of the tray in 2 primary directions (Fig. 3). The first extended from the corner of the posterior notch in the medial direction toward the outer rim. The second segment began at the anterior surface and travelled medially, initially with a similar contour to the outer rim. The segments met in the medial tray and separated the fractured component from the rest of the prosthesis. No indications of material defects, such as porosity, were observed nor were any witness marks from impact or tool damage.

The fractured tibial tray was then sent for analysis by scanning electron microscopy. Study of the component revealed both beach marks and striations. Beach marks are macroscopic indications on the fracture surface that resemble parallel lines, such as those created as water flows over sand on a beach, and indicate the position of the crack front at different times as it grows progressively across the component (Fig. 4). When variations in loading occur, the roughness of the fracture surface changes, creating these lines that can often be seen with the naked eye. Fatigue striations are similar parallel lines on the fracture surface that are observed on the microscopic scale (Fig. 5). As the crack grows under cyclic loading, the crack front progressively advances by a short distance with each or every few cycles. Each striation is an indication of the crack position after each individual or every few cycles. Fatigue striations were observed over the majority of the fracture surface, indicating the component was cracking for a considerable period of time under a relatively low loading scenario.

Because the crack grew by fatigue over most of its length, only small loads were likely present, allowing the 2 halves of the tray to remain attached by even a small ligament of cross-section until final failure occurred. Had the cyclic loads been larger, it would be expected that the remaining ligament of the cross-section holding the 2 halves of the tray together would eventually give way, creating a large area of the fracture surface indicative of ductile overload. Given the significant difference in direction of the 2 fracture segments, it is likely that each grew as separate cracks emanating from anterior and posterior points on the tray, eventually intersecting further out in the medial direction (Fig. 3).

In some small regions where the fracture surface was damaged by rubbing, the morphology of the fracture could not be determined. Such rubbing itself is often consistent with a fatigue mechanism, where partially fractured components are held in close proximity to each other while the crack continues to extend through the component. The opposing faces of the fracture surface tend to rub against each other as they deform under cyclic loading. Therefore, fatigue fracture was determined to be the most likely mechanism of failure.

Discussion

While TKA remains a highly successful procedure, rare complications still do occur. Retrieval analysis indicated fatigue fracture as the most likely cause of this tibial tray fracture, and there were no clear indications of manufacturing defect or damage to the implant during initial placement. Fatigue fracture is the method of failure for any metal structure facing high enough stress loads and/or number of cycles [8]. It has 3 phases: initiation, propagation, followed by sudden fracture [16]. We postulate that loss of proximal tibial bone support under the fractured area led to failure of this implant. Deficient bony support under a portion of the tibial plate can result in the loosened portion functioning as a cantilever, resulting in greater stresses at the junction between the supported and nonsupported segments of the prosthesis [4]. Chatterji et al

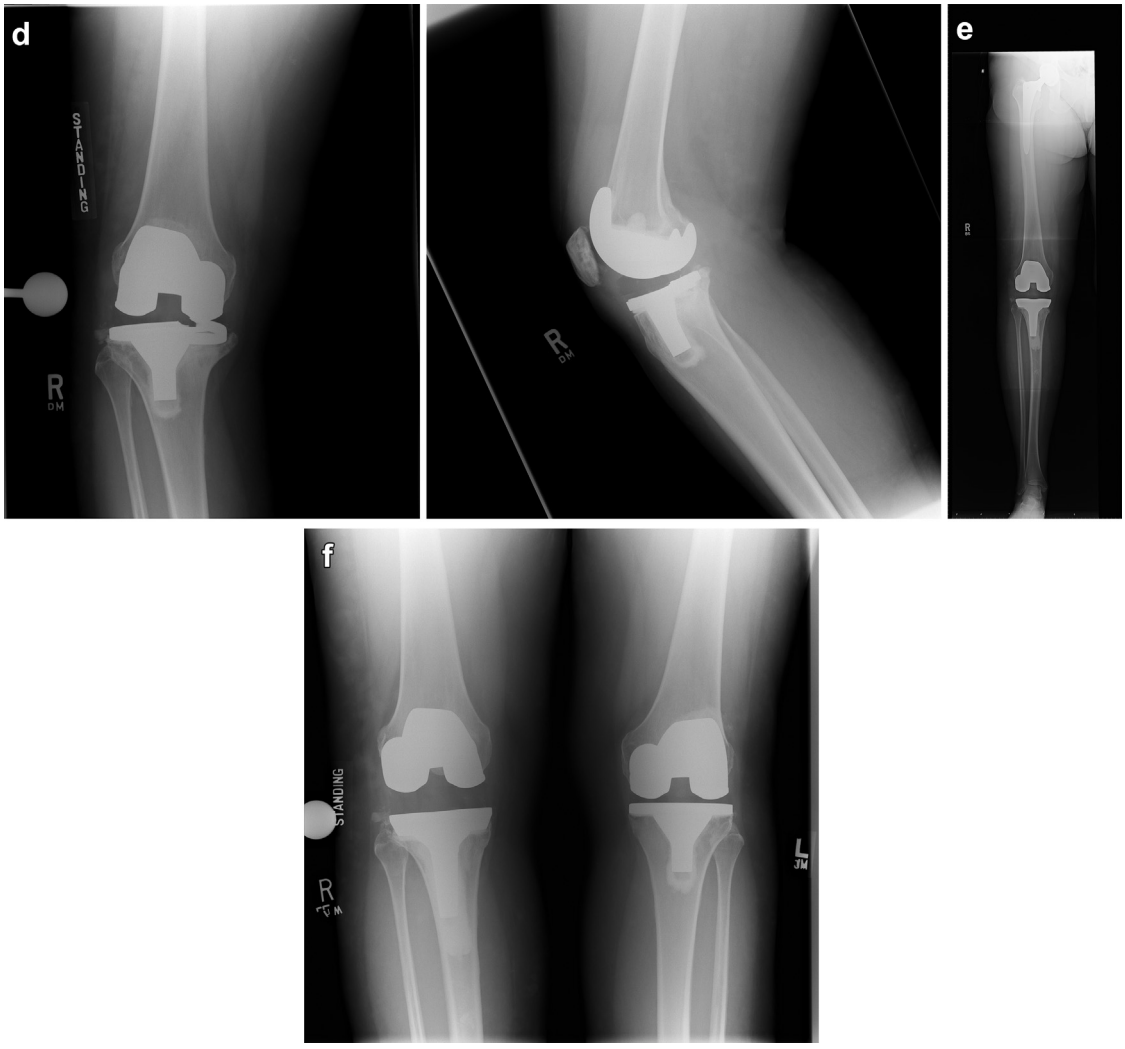

Figure 1. (*continued*).

postulated that this was the most important feature predisposing to eventual fracture [13]. Avascular necrosis, bone graft collapse, and osteolysis have been identified as mechanisms of bone loss in previous case reports [2,3,5-7,9-11,13]. This patient not did have evidence of osteolysis on serial radiographs leading up to the event, and bone graft was not used; however, this patient did receive an oral course and injection of corticosteroids in close proximity to implant failure. This may have led to tibial plateau bone loss, accelerated an ongoing process, or be unrelated. Acute treatment with corticosteroids has not been implicated in other reports of tibial tray fracture. At 109.1 kg (body mass index: 34.1 kg/m^2), the patient's weight could be considered a positive risk factor for tray fracture [2,5]. Fehring et al recently reported an increased incidence of varus collapse in obese patients after total knee replacement [17].

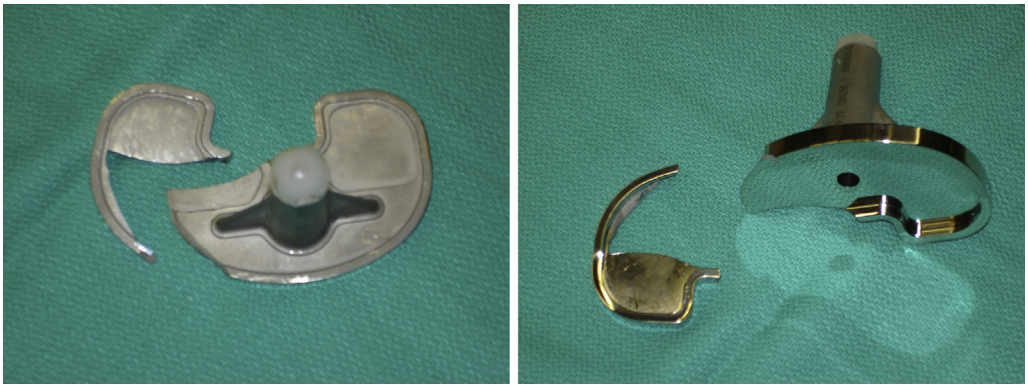

Figure 2. Fractured tibial tray.

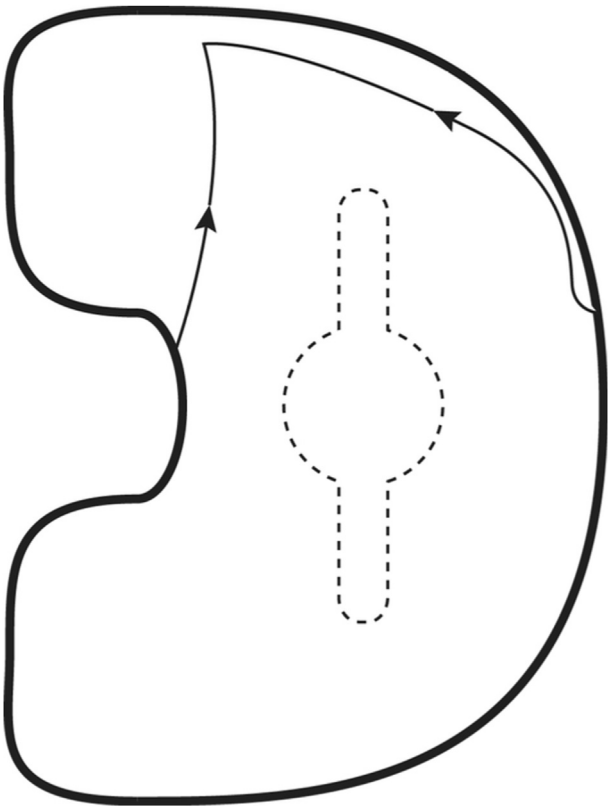

Figure 3. Schematic of tibial tray. The 2 fracture segments likely emanated from the anterior and posterior edges of the tray and grew in the directions indicated by the arrows. The approximate position of the post and flange support beneath the tray is indicated (not to scale).

This patient's weight, although excessive, is not uncommon in the joint replacement population today.

The failure occurred in a modern prosthesis, the PFC Sigma. A multicenter study of 1970 PFC Sigma knees demonstrated excellent midterm results with a 10-year survival estimated at 95.6% (95% confidence interval, 95.4-99.1) [18]. At an average follow-up of 7.2 years, there were 40 failures in the series: 17 from infection, 6 from wear/osteolysis, and 4 each for pain, instability, and component loosening [18]. There were no reported tibial tray fractures in this series or other follow-up studies for this implant [18-20]. In other cases with earlier generations of implants, design has thought to be a contributing factor to fracture. Ranawat et al noted that a thin bridge joining the medial and lateral segments was more susceptible to fracture [4]. Fenestrations in the tray portion of the PCA prosthesis (Howmedica International Ltd), intended to aid removal, were found to act as stress risers, predisposing these prostheses to fracture [6,7]. Fractures have been reported in porous-coated systems [4,5,8]. This can be attributed to notch sensitivity at the surface where the porous layer is bonded to the solid substrate and the sintering process, which can cause a 16% decrease in alloy strength [5,21]. These factors do not apply to the PFC Sigma and, to our knowledge, this complication has not been previously reported in this prosthesis. Failures of the Kinematic and PCA prostheses (Howmedica International Ltd) have been reported most frequently [10,13].

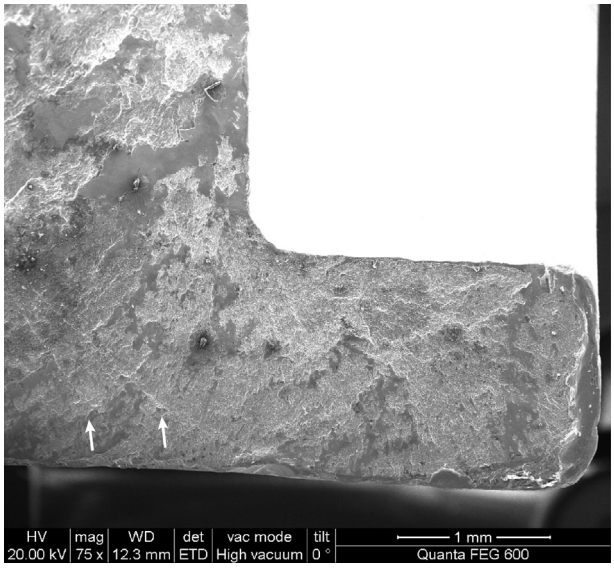

Figure 4. SEM micrograph of the tray fracture surface. Beach marks are indicated by the white arrows. Some areas of rubbing are also noted where the surface looks smooth. SEM, scanning electron microscopy.

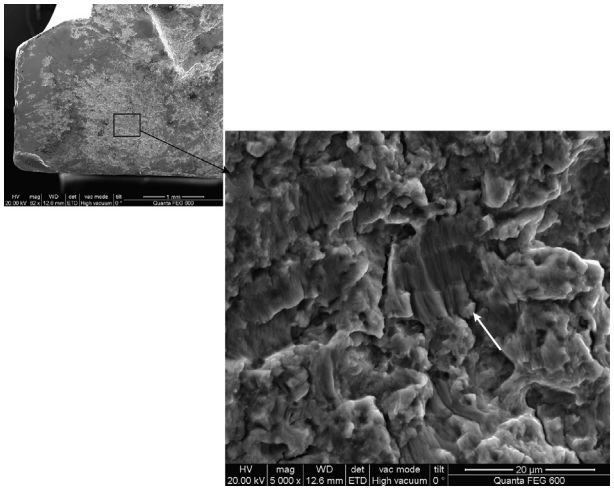

Figure 5. SEM micrograph of another region of the fracture surface. Inset shows fatigue striations (white arrow) at high magnification. SEM, scanning electron microscopy.

This case of failure, occurring at 17 months, was much earlier compared with other reports. The first cases reported by Scott et al, Dannenmaier et al, and Ranawat et al also occurred less than 18 months after the index procedure [2-4]. However, the majority of the cases occurred after 4 years, or even as many as 17 years as reported by O'Neill [7-14]. In addition, pre-existing or undercorrected varus deformities have been suggested as a cause [2,5,9,10]. In some instances, a progressively worsening varus deformity was noted before tibial tray failure [9,10]. Our case involved a patient with a preoperative valgus deformity, and there was no loss of alignment detected until the time when tibial tray fracture was diagnosed. In the case reported by Morrey and Chao and a series by Abernethy et al, poor tibial plateau bone stock and use of bone graft to obtain correction of alignment was associated with failure within the first 4 years [5,10]. There were no preoperative or intraoperative concerns about proximal tibial bone stock in our case. It has been reported once in a unicompartmental design owing to retained cement [22]. Kang recently described a case of tibial tray and polyethylene fracture in a 72-year-old woman after trauma from a fall [23]. These were not the factors in this case.

Summary

Fracture of the tibial tray is an uncommon complication after TKA, and it has not been previously reported with the PFC Sigma prosthesis. In this case, leg alignment was optimal, the patient's weight was somewhat excessive, and there was exposure to corticosteroids in close proximity to failure of the tibial component. Through analysis of the implant, the fatigue fracture was determined to be the reason for failure. This correlated with the intraoperative findings of necrotic bone at the medial tibial plateau with local bone cement loosening in an otherwise stable implant-cement construct. Loss of proximal tibial bone stock, leading to cantilever bending at the junction between the well-supported portion of the component and insecure posteromedial portion, likely led to fatigue fracture in this case.

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