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Case Report

Bilateral Femoral Component Fractures After Primary Total Knee Arthroplasty With Cruciate-Retaining Femoral Component

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A B S T R A C T

A 69-year-old male presented with atraumatic bilateral femoral component fractures at different time intervals after simultaneous bilateral total knee arthroplasty using the cemented Biomet Ascent Knee System. The right and left knee implant fractures occurred 12 and 17 years after primary arthroplasty, respectively. This patient was notably tall (190.5 cm, 98th percentile) and maintained an active lifestyle before implant fractures. Sequential, bilateral knee implant fractures in a system with a previously acceptable track record suggest that biomechanics, patient characteristics, and surgical factors can significantly influence the risks for fracture of an implant.

Introduction

Knee implant fracture is a very rare cause of arthroplasty failure and requires revision surgery [1-3]. Femoral, tibial, or patellar component fractures have been documented at rates of 0.13%-0.3%, which are low compared with other reported mechanisms of failure [1,2,4-6].

The mechanism for implant fracture remains difficult to describe and varies among prostheses. Common implant fracture mechanisms include defective implant design, severe osteolysis, aseptic loosening, component malalignment, and fatigue/stress factors [2,4,7-11].

We identified a case of bilateral femoral component fractures that occurred as separate atraumatic events in a patient who underwent simultaneous bilateral cemented cruciate-retaining total knee arthroplasty (TKA) 2 decades before. To our knowledge, this is the first case report describing bilateral cemented knee implant fractures.

Case history

The patient gave verbal consent to participate in this study. This case reports a 69-year-old male with history of hypertension and hypercholesterolemia who presented with moderate left knee pain 4 months ago after feeling a “crunch” in his knee prosthesis after walking and stair-climbing. He could not fully extend and sensed “something loose” within the left knee. His height measured 6’3” (190.5 cm) and was among the 98th percentile of reported height in the United States [12]. He weighed 100.2 kg and had BMI 28. He denied history of tobacco use, weight change, fever, or infection. Given a history of right knee implant fracture 5 years before, he believed he sustained a similar fracture contralaterally.

The patient recalls at least 3 knee surgeries bilaterally over 40 years ago for meniscus/cruciate injuries. Seventeen years ago, he underwent bilateral cemented cruciate-retaining TKA using the Biomet Ascent Knee System (Zimmer Biomet, Warsaw, IN). His initial primary arthroplasty allowed him to resume his active lifestyle, consisting of walking long distances, squatting, weight training, and golfing. Five years ago, he experienced sudden right knee pain during walking and could not fully extend. Radiographs demonstrated right femoral component fracture (Fig. 1). He subsequently underwent right revision TKA with the Stryker Triathlon Total Stabilizer system (Stryker Orthopaedics, Mahwah, NJ). Intraoperative images demonstrated posterior medial femoral condyle

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transverse fracture (Fig. 2). He successfully recovered and returned to normal activities until his recent left knee episode.

On physical examination, he exhibited antalgic gait and had full left knee extension and flexion to 100°. The left knee was stable in both sagittal/coronal planes. The right knee hyperextended 10° and flexed >130°. Bilateral lower extremities were neurovascularly intact.

On plain radiographs, the left lateral view showed clear evidence of osteolysis within the periphery of the posterior medial femoral condyle (Fig. 3). A sharp angle adjacent to the posterior condyle suggested implant fracture of the left Biomet Ascent femoral component. Bilateral radiographs showed a well-positioned stemmed revision arthroplasty on the right side. Given mechanical implant failure, the patient agreed to revision left TKA with constrained stemmed components.

Three weeks after injury, the patient underwent explantation of his left TKA and replacement with a Stryker Triathlon Total Stabilizer by the senior author. Intraoperative visualization of the flexed knee showed clear fracture of the femoral component's medial posterior condyle facing 180° backward. The component fracture was reduced to show the fracture line (Fig. 4). There was significant polyethylene damage without metallosis. The patellar component showed good fixation without significant wear and was retained. The remaining components were removed without remarkable bone loss. No complications occurred, and he was discharged home. His most recent office visit was 3 months after his revision left TKA (and 5 years after his revision right TKA). Bilateral active knee range of motion was 0°-120°, and he is ambulating with a normal gait.

Implant-retrieval analyses

After explantation, failed left TKA components were sent to an institutional review board–approved retrieval laboratory for detailed analyses. All components were imaged via white light microscopy (Keyence VHX-1000E, Keyence Corporation of America, Itasca, IL). Wide angle views (Fig. 5a) showed femoral medial condylar fracture, a tibial tray with ample adherent cement and

Figure 1. Radiographic right femoral component fracture. The right knee radiograph obtained after injury to the right knee 5 years ago. The lateral view demonstrates fracture of the right femoral component.

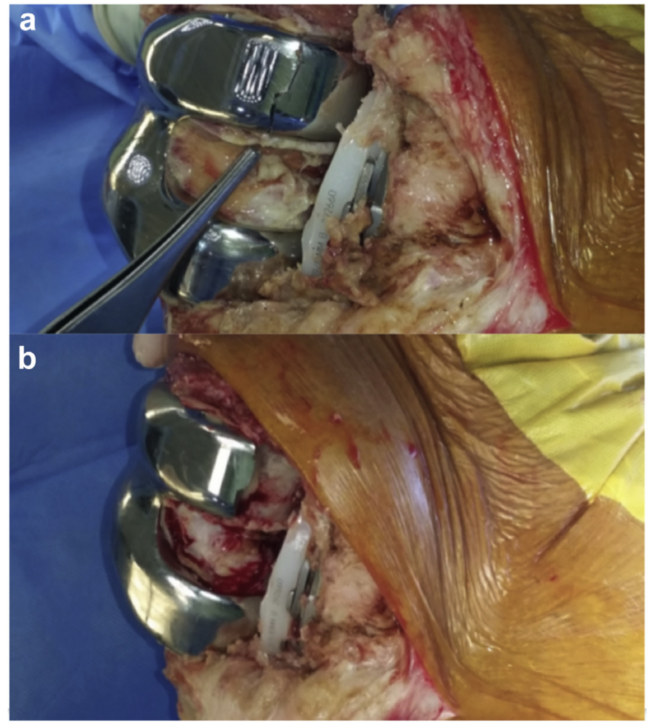

Figure 2. Intraoperative right femoral component fracture. Intraoperative images of a right knee femoral component fracture that occurred 5 years ago. (a) Transverse fracture of the implant at the medial posterior femoral condyle; (b) a broken piece of the femoral implant removed from the femur.

tissue, and a significantly damaged polyethylene tibial insert. The bearing (Fig. 5b) showed significant signs of articular surface delamination, adhesive wear, and abrasive wear secondary to femoral component fracture. Condylar wear areas (Fig. 5b, dashed ovals) showed ~14° relative femoral component external rotation.

Despite significant cement adhesion/bony interdigitation on the nonarticular anterior femur (Fig. 5a), the fractured femoral component (Fig. 5c) showed minimal residual cement on the posterior aspect, suggestive of a resorption gap between the posterior femoral condyle and posterior femoral bony tissue. Visual analyses of the condylar fracture surface (Fig. 5d) showed beach marks indicative of fatigue failure. Moreover, the faceted nature of the fracture surface is consistent with established grain structure/size of a cast CoCrMo alloy.

Discussion

We present a patient with atraumatic bilateral femoral implant fractures on the posterior medial femoral condyles at different long-term intervals, 12 and 17 years after primary arthroplasty. Medial-sided implant fractures have been explained by higher load share of the medial compartment, which increases with varus deformity [13]. Still, sequential, bilateral knee implant fractures have not been described. Therefore, the patient characteristics, implant-specific features, and associated surgical history present unique contributions to understanding mechanisms for implant fractures.

In the present case, the patient's above-average height would create a longer-than-average lever arm for any torque placed on the knee. This would exacerbate any deficits in the cement technique along the posterior condyle. A longer lever arm, combined with posterior medial femoral condyle osteolysis, would have led to implant fatigue failure under a cyclic condylar loading force. A

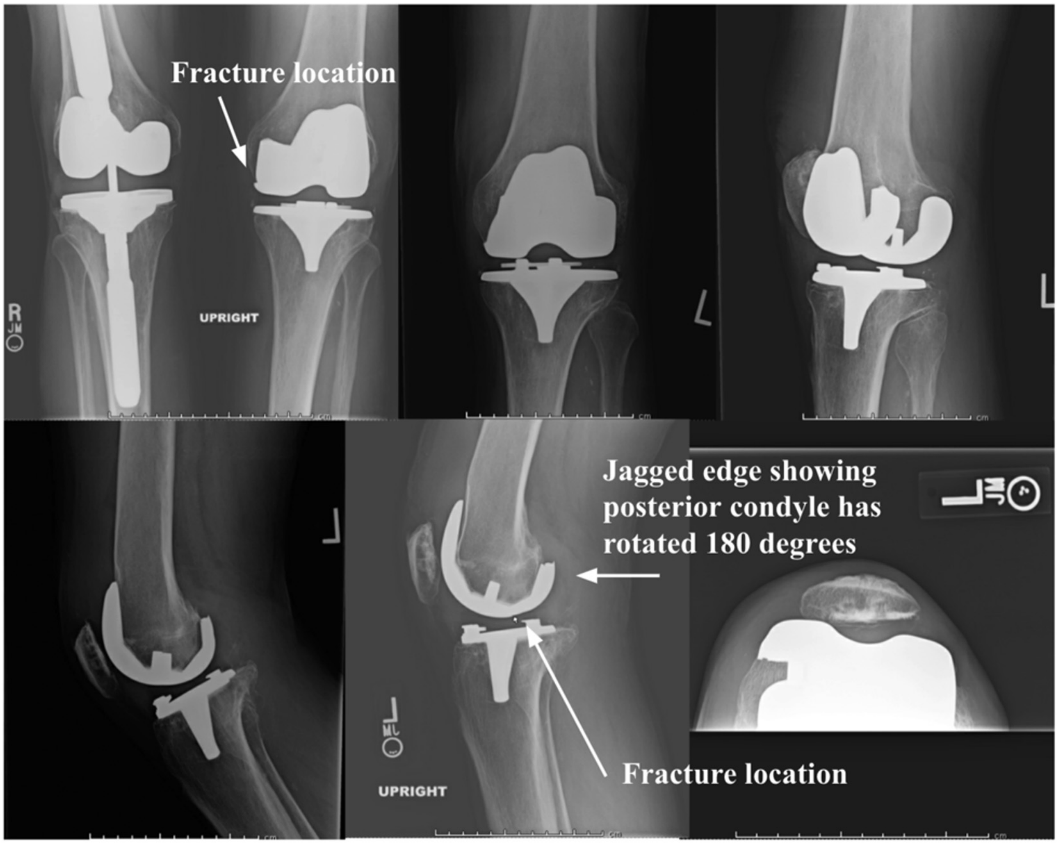

Figure 3. Radiographic left femoral component fracture. Multiple radiographs of the left knee demonstrating fracture of the femoral component after injury to the left knee 4 months ago. Arrows indicate fracture location on the anteroposterior view (top row, left) and lateral view (bottom row, middle). The lateral view (bottom row, middle) demonstrates that the posterior edge has rotated 180 degrees backward.

conservative solid-mechanics approach to estimate cyclic stress may assume 4000N force (4 × BW) during ~90° knee flexion, which has been documented during squatting, sit-to-stand, and stairs [14]. Using cross-sectional dimensions of the retrieval, and assuming equal load sharing between medial/lateral condyles, ~50-Nm moment would be applied at the fracture surface. With a

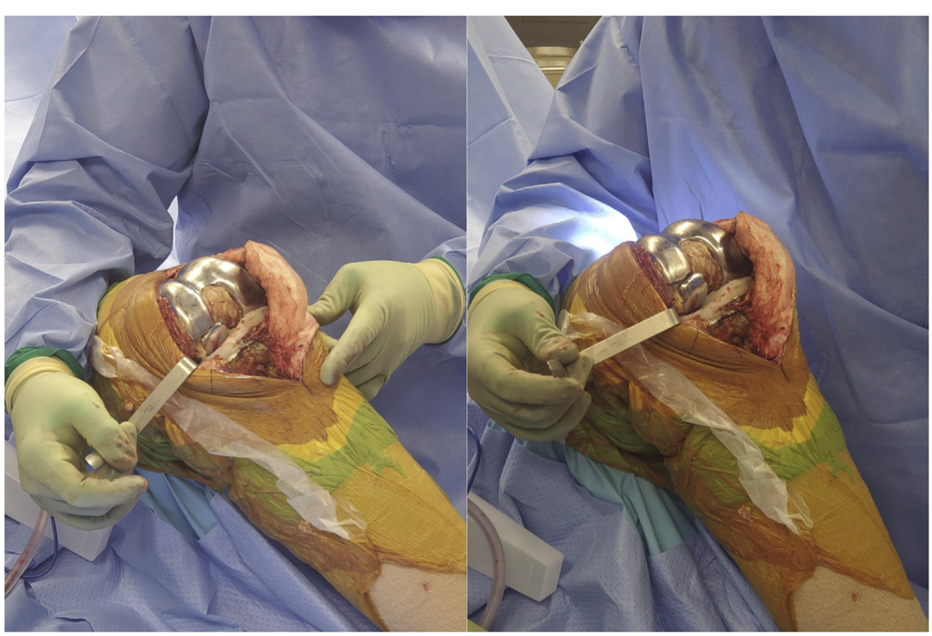

Figure 4. Intraoperative left femoral component fracture. Intraoperative images of a left knee femoral component fracture that occurred 17 years after primary total arthroplasty.

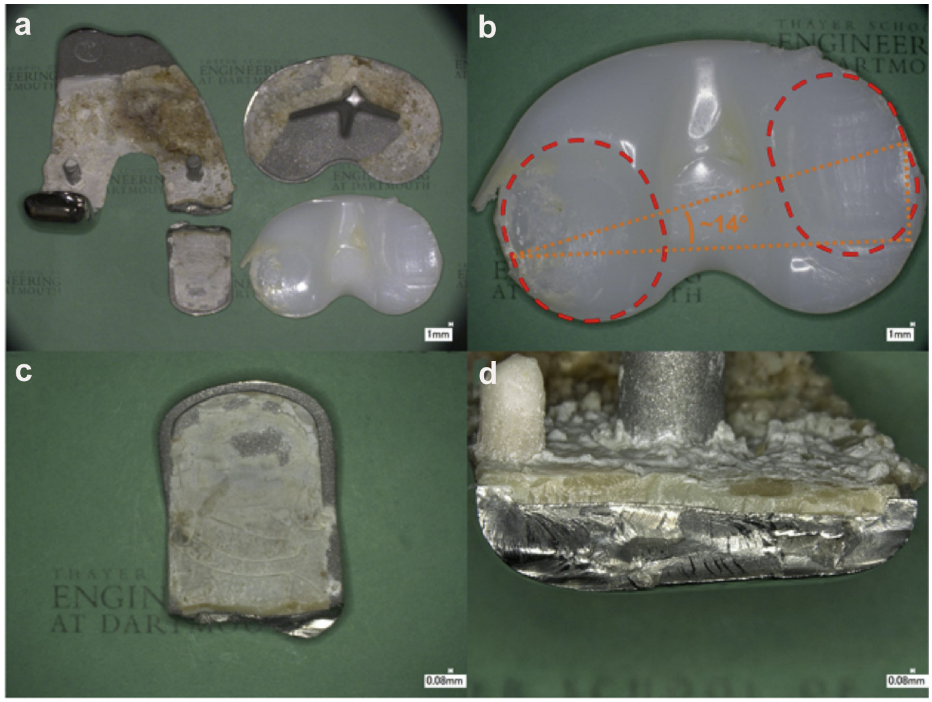

Figure 5. Biomechanical implant analysis. Explanted failed left Biomet Ascent TKA device including (a) a wide-angle image of all components, (b) damaged tibial polyethylene insert highlighting a significant adhesive/abrasive wear pattern (dashed) at ~14° external femoral rotation (dotted), (c) fractured medial posterior condyle showing little cement adhesion, and (d) the fracture surface with beach marking throughout.

condylar width/thickness of 26.25 mm/4 mm, respectively, the resultant stress would exceed 700 MPa. This stress is approaching upper thresholds for the yield strength (500-800 MPa) of cast CoCrMo alloys [15]. Loading conditions at this magnitude or during more intense biomechanical conditions may be hypothesized to place the fractured region in a low- or high-cycle fatigue regimen.

Implant fractures have been reported as high as 5% of all causes for revision TKA [1]. Gilg et al. (2016) identified 74 and 892 knee implant fractures recorded in clinical studies and national arthroplasty registries, respectively, between 1992 and 2016. The earliest reported knee implant fractures occurred at the femoral component because of design flaws in one primary TKA implant, the cementless Ortholoc II prosthesis (Dow Corning Wright, Arlington, TN) [4]. In this device, all implant fractures occurred at the medial femoral condyle because of insufficient metal thickness resulting in fatigue failure [4-6]. Thereafter, additional femoral and tibial component implant fractures were published in clinical studies of unicompartmental, primary, and revision TKA implants. Design-specific problems were the most common implant fracture mechanism [4,16-19]. Severe osteolysis with poor bone stock [20] and uncorrected mechanical axis malalignment [7,21-23] were other common factors attributed to implant fracture.

Femoral component stress fractures have also been described in case reports using the mobile bearing Low Contact Stress (DePuy, Johnson & Johnson, Raynham, MA) [24-26], fixed bearing Genesis (Smith & Nephew, Memphis, TN) [27,28], and Press-Fit Condylar (Johnson & Johnson, Raynham, MA) [29] prostheses. In addition, one case report describes bilateral knee femoral implant fractures in the uncemented Flexible Nichidai Knee system (Nakashima Medical Inc, Okayama, Japan) [13]. Most case reports of femoral component fractures occurred with uncemented implantations, suggesting that instability at the bone-implant junction leads to failed bone ingrowth/ongrowth and increased implant fracture risk [13,24-29].

This case is novel for several reasons. To our knowledge, this is the first report of atraumatic bilateral femoral implant fractures after primary cemented TKA. Although implant fractures have been recorded in other Zimmer/Biomet devices [30], none have involved the Biomet Ascent system. Moreover, femoral component fracture in a cemented environment presents a novel fracture pattern whose mechanism cannot be explained by micromotion and lack of bone ongrowth/ingrowth. Postoperative radiographs demonstrated acceptable alignment of the mechanical axis (Fig. 6), although intraoperative examination showed some fibrous tissue overlying the posteromedial condyle underlying the fractured fragment. On retrieval analysis, it was noted that the femoral component was externally rotated relative to the tibial insert (~14°), and the cement mantle on the medial condyle was absent. This was further compounded by surgeon-reported moderate osteolysis, permitting a gap between the nonarticular condylar surface and the underlying femoral bony tissue. The global result is a cyclically bent condyle allowing fatigue failure to occur via stresses approaching the femoral component material yield values.

Saito et al. (2011) noted that patients with knee implant fractures were younger than patients in most TKA cohorts (58.1 vs 70 years). Younger age, higher BMI, and increased participation in athletic activity were identified as contributing factors to implant fracture [13] and are similarly present in this case. Although casting defects or other metallurgical flaws might hasten failure, the supposition of high-cycle fatigue (based on in vivo duration and patient activity level) and the bilateral failures do not necessarily implicate material processing. This case likely represents an unpredicted multifactorial failure mechanism involving the implant design, patient biomechanics, surgical alignment, and osteolysis.

As this fracture was of the posterior condyle, it was likely caused by a cyclic force with the knee in deep flexion. However, due to the isolated number of reported cases of posterior condyle fracture, we would not implement any additional activity restrictions that would inhibit a potential patient's return to a functional activity

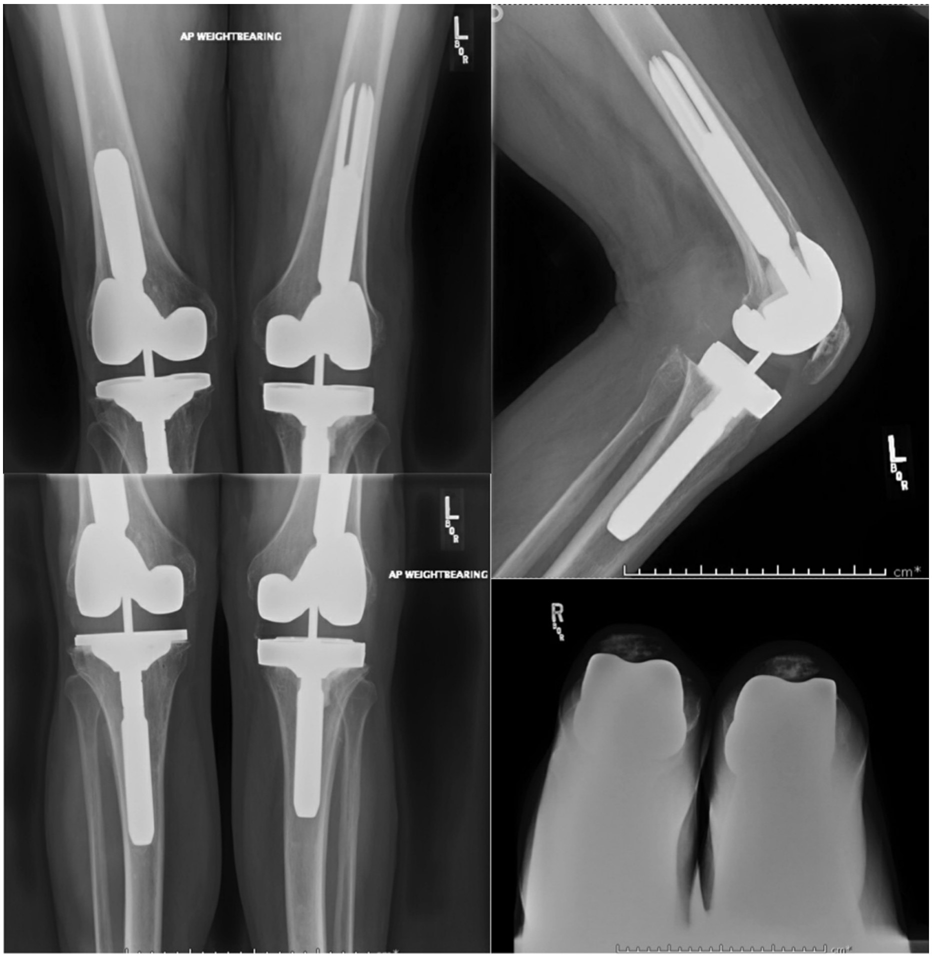

Figure 6. Radiographic revision knee prostheses. Multiple postoperative radiographs of the bilateral knees showing good alignment of the revision prostheses.

level. Furthermore, during cementation, arthroplasty surgeons often will try to minimize the cement placed on the posterior condyles of the femoral implant to prevent extrusion during implantation into an area that is difficult to visualize. By trying to avoid one complication, arthroplasty surgeons could be creating the potential for another. Micromotion between the bone-implant interface without adequate cement could weaken the bearing surface, leading to a late implant failure as seen in this patient. Thus, we recommend careful attention when applying cement to the posterior condyles to achieve adequate fixation while preventing large amounts of cement extrusion posterior to the femoral prosthesis.

The Ascent Total Knee System was redesigned in 2003 to the Vanguard Knee System with adjustments to femoral/tibial components to improve patellar tracking, flexion, durability, and medial tibial load transfers [31,32]. No Vanguard Knee system implant fractures have been reported [31,32]. Nonetheless, clinicians are encouraged to stay vigilant for lucencies in the posterior aspect of femoral components, particularly in larger active patients.

Conclusion

Sequential, bilateral knee implant fractures in a system with a previously acceptable track record suggest that the implant design, surgical factors (functional rotational malalignment), and patient-specific characteristics (age, activity level, stature, and osteolysis) may have greater influence on the risk of implant fracture than previously recognized.

Conflict of interests

R. M. Chapman receives financial or material support from OrthoSensor. D. W. V. Citters receives research support as a principal investigator from DePuy Synthes Joint Reconstruction, Orthosensor, Total Joint Orthopedics; and also receives financial or material support from ConforMIS.

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