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Case report

Catastrophic Failures of the Tibial Post in a Bicruciate Substituting Total Knee Prosthesis

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ABSTRACT

Failure of the tibial post in a bicruciate substituting total knee prosthesis is a rare but catastrophic complication. The authors report 2 cases of a fracture of the polyethylene tibial post with subsequent episodes of knee subluxation. Prompt recognition and early revision of these complications are associated with a favorable early outcome.

Introduction

Total knee arthroplasty is one of the most successful and reproducible procedures in the field of orthopedics. The evolution of orthopedic implants has ranged from cruciate-retaining, posterior cruciate stabilized, bi-cruciate stabilized, bi-cruciate retaining, and a variety of polyethylene (PE) options. The various implant designs aim to recreate normal kinematics with the option to supplement other knees that may require additional constraint. The goal of the bi-cruciate substituting (BCS) total knee prosthesis (Smith and Nephew, Memphis, TN) is to recreate the normal kinematics of the knee by replicating the posterior cruciate ligament and the anterior knee ligament.

The BCS implant was designed to allow deep flexion while recreating the native tibiofemoral axial rotation and allowing improved patellar tracking. However, mechanical wear of the PE may lead to instability of the knee and can result in a catastrophic failure of the implant through tibial post breakage [1,2]. Tibial post breakage has been described in the literature for posterior stabilized designs with other implants such as the Scorpio (Stryker Corp., Mahwah, NJ) and the NexGen (Zimmer Biomet, Warsaw, IN) [3]. To our knowledge, only one case report of an isolated patient details an atraumatic tibial post fracture in a BCS total knee prosthesis that required revision surgery [4]. Enhanced understanding of the physical examination, clinical history, and radiographic signs of this complication will improve recognition and treatment. Our institution reports 2 cases of a tibial post fracture in a BCS substituting total knee prosthesis from nontraumatic events. Written informed consent was obtained for 2 of the patients to disclose medical history. The compromised tibial PE materials were cataloged by a company representative and reported to the Advanced Surgical Devices Division of Smith and Nephew, 1450 Brooks Road, Memphis, TN 38,116, USA.

Case history 1

A 52-year-old female with a body mass index of 40.8 kg/m^2 presented to the office complaining of right knee pain and instability for 1 month. In January of 2008, the patient underwent a right medial unicompartmental knee arthroplasty for isolated medial compartment arthritis. The patient recovered appropriately from her surgery but described worsening knee pain at her 6-month follow-up. Radiographs taken in the clinic at 6 months confirmed an acute worsening of her lateral compartment arthritis. She underwent a conversion arthroplasty to a BCS Journey 1 TKA (Smith and Nephew, Memphis, TN) 10 months after her medial

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unicompartmental knee arthroplasty. The patient denied a history of trauma, instability, or malfunction after her revision TKA surgery. Twelve years after conversion surgery, the patient presented to the office with acute right knee pain and instability that started while attempting to squat to the floor 1 month before presentation. The patient was fit for a brace by her primary care physician at the time of injury. The brace provided minimal improvement of her right knee pain and instability. She was instructed to use a cane for assistance ambulating and urged to follow-up with an orthopedic surgeon.

Physical examination performed in the office revealed a painful and limited range of motion to eighty degrees of flexion. Varus and valgus testing of the right knee revealed global laxity. Passive flexion and extension of the right knee recreated an audible clunk of the right knee. A posterior drawer test performed in the office was limited because of patient discomfort and guarding; however, the surgeon identified a firm endpoint. Radiographs taken in the office showed the presence of a well-aligned and well-fixed cemented Journey 1 BCS total knee prosthesis without bony abnormality (Fig. 1). Laboratory workup for infectious etiology was negative. An extensive discussion with the patient included a potential fracture of her tibial post and the source of her right knee pain and instability. The patient consented to a revision of her right TKA with the possibility of performing an isolated PE exchange. The risks, benefits, and alternatives were discussed with the patient and included a detailed discussion of the potential future need for an extensive revision.

Five weeks after her presentation to the office, a revision arthroplasty was performed. After induction of a spinal anesthetic and before incision, the right knee was manipulated in ninety degrees of flexion. An anteriorly directed force to the proximal tibia produced an audible clunk and anterior subluxation in relation to the femur. A posteriorly directed force to the proximal tibia reduced the tibial subluxation without difficulty (Video 1). Our suspicion for a fractured tibial post was confirmed intraoperatively. Examination of the intercondylar notch revealed premature wear, oxidation of the medial and lateral compartments of a tibial PE, and a 1.2-cm defect noted to the tip of the tibial post (Fig. 2). The fractured tibial post was extracted from the intercondylar notch of the femoral component (Fig. 3). No significant coronal or sagittal plane malalignment was seen intraoperatively or on preoperative radiographs. The tibia and femur were externally rotated to an acceptable degree. The patella tracked midline and did not show any significant amount of wear. The 14-mm tibial PE was removed and replaced with a 15-mm PE. The knee was evaluated and found to be stable in the sagittal and coronal planes. In this patient, the BCS TKA has performed well for 12 years and was stable in the operating room with an isolated tibial PE exchange. The surgeon elected not to revise the femoral and tibial components and proceed with an isolated PE exchange in a well-performed TKA.

Four weeks after the operation, the patient complained of mild pain in the operative knee that drastically improved from the preoperative level. She ambulated free of an assistive device and denied instability of the right knee. The patient returned to cycling and completed a five-mile workout the week before follow-up. She achieved full extension and 115 degrees of flexion. Radiographs were taken and displayed a well-fixed and well-aligned right TKA prosthesis with no signs of loosening. At her 6-month follow-up, the patient continues to improve her range of motion, does not require a prescription narcotic or an over-the-counter analgesic, and has returned to her previous level of activity.

Case history 2

In July 2020, a 72-year-old female, body mass index 33.9 kg/m^2, that underwent primary total knee arthroplasty for a posttraumatic arthritic left knee in 2008 with a Journey 1 BCS prosthesis (BCS Journey; Smith and Nephew) presented to the orthopedic clinic complaining of severe pain, significant instability, and recurrent episodes of “subluxation” of her left knee. Symptoms began 4 weeks before her visit after a ground-level fall onto her flexed left knee that caused severe pain and a knee "subluxation." Six total events of “subluxation” and pain were reported from the time of her initial fall until her presentation to the office, including while wearing a brace provided by another orthopedic provider. She reports significant apprehension to knee flexion, as this recreates the instability and pain in her left knee. There is no history of additional trauma, instability, revision, or malfunction after her left primary total knee arthroplasty in 2009 until the day of her fall.

On physical examination, her left knee had instability with end points present to varus and valgus stress testing and apprehension of knee manipulation with her knee flexed beyond thirty degrees. With the knee flexed to ninety degrees, a posterior drawer test had a positive stop and firm endpoint, although pain was limited on

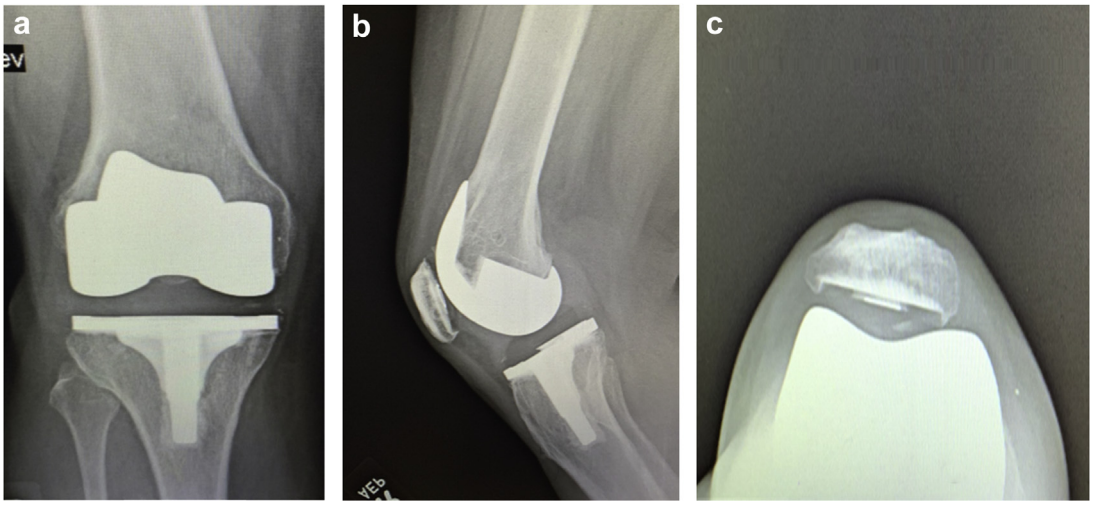

Figure 1. Anterior (a), lateral (b), and merchant (c) view of a right knee in a patient 12 years postoperative from a cemented BCS TKA.

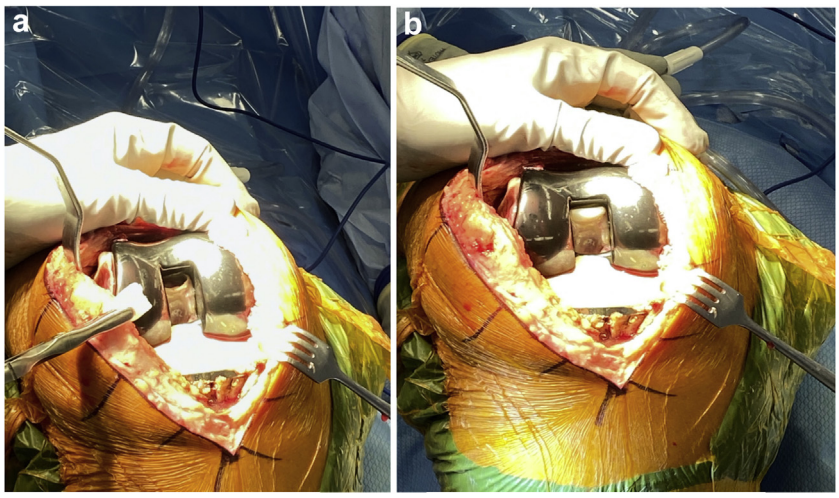

Figure 2. Intraoperative images from a revision Journey 1 BCS TKA. (a, b) Anteroposterior and oblique view demonstrating retained tibial polyethylene with the absence of a tibial post in the intercondylar notch.

examination. Radiographs taken in the office showed the presence of an acceptably aligned and well-fixed cemented Journey 1 BCS total knee prosthesis (Fig. 4). Concern existed for PE post fracture with her clinical story in addition to her examination.

Three weeks after the presentation in the office, a revision arthroplasty was performed. Before the surgery and after induction of anesthesia, a physical examination was performed. No firm endpoint was appreciated on a posterior drawer test when slight anterior force was applied to the femur. Intraoperatively, the tibial PE showed signs of oxidation and wear on both medial and lateral sides in addition to a one-centimeter defect of the tip of the tibial post (Fig. 5). The 1 cm missing tip of the post was found in the lateral gutter and removed. The 9-mm tibial PE was removed and reimplanted with an 11-mm size and found to be stable in all planes. The femoral and tibial components were evaluated and deemed acceptable with an appropriate amount of external rotation to the tibia and femur and no significant coronal or sagittal plane malalignment. The patella tracked midline and did not show any significant amount of wear.

Three weeks after the operation, the patient presented to the orthopedic clinic with mild pain in the left knee, improved range of motion and strength, and ambulated without an assistive device. She showed painless full extension and 120 degrees flexion of her left knee. Radiographs taken showed a well-fixed and well-aligned left TKA prosthesis with no signs of loosening. At the patient's 6-month follow-up, she has returned to her previous activity level and walks up to 10 miles a week. The patient denies the need for a prescription narcotic or an over-the-counter analgesic and is extremely satisfied with her operative knee's stability.

Discussion

The Journey BCS TKA system was introduced in 2005 and was designed to increase anteroposterior stability throughout knee flexion while restoring normal knee kinematics. The design included a dual cam-post mechanism that substitutes both the anterior and posterior cruciate ligaments. The anterior cam-post mechanism is designed to engage from full extension to twenty degrees flexion while the posterior cam-post engages beyond sixty degrees of flexion. The posterior cam facilitates the native knee's screw-home mechanism through its asymmetric shape to guide the femur into external rotation relative to the tibia during flexion and internal rotation during extension [4–7]. This guided motion had a theoretical advantage as it provides multidirectional sliding that limits tibial PE wear.

Several studies have assessed the kinematics of the Journey I implant as the manufacturers claimed that the design would provide more anatomic knee kinematics and improved patient outcomes. In a comparative study between the Journey I, Journey II, Genesis II, and native knees, Halewood et al. found that through 75-110 degrees of flexion, the tibia moved more anteriorly in Journey I than a native knee and other implants [7]. This was likely due to the more

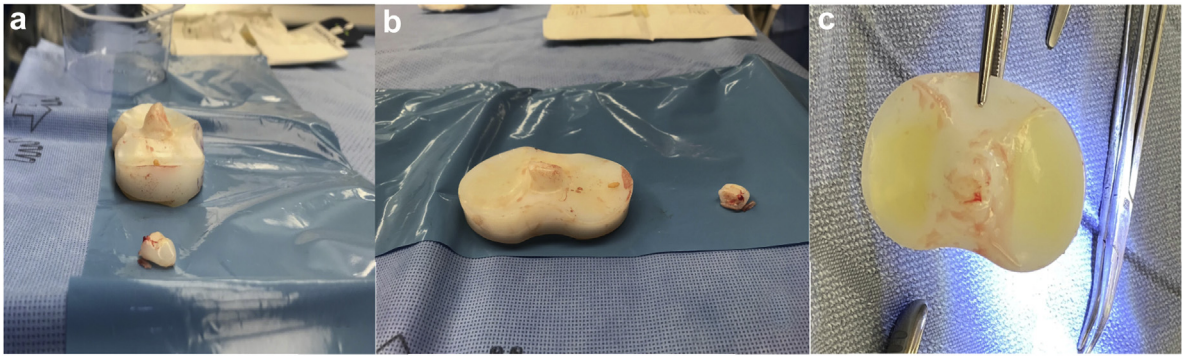

Figure 3. Intraoperative images from a revision BCS TKA displaying a 14-mm Journey 1 BCS explanted tibia polyethylene with a fractured tibial post and recovered post fragment (a, b, c).

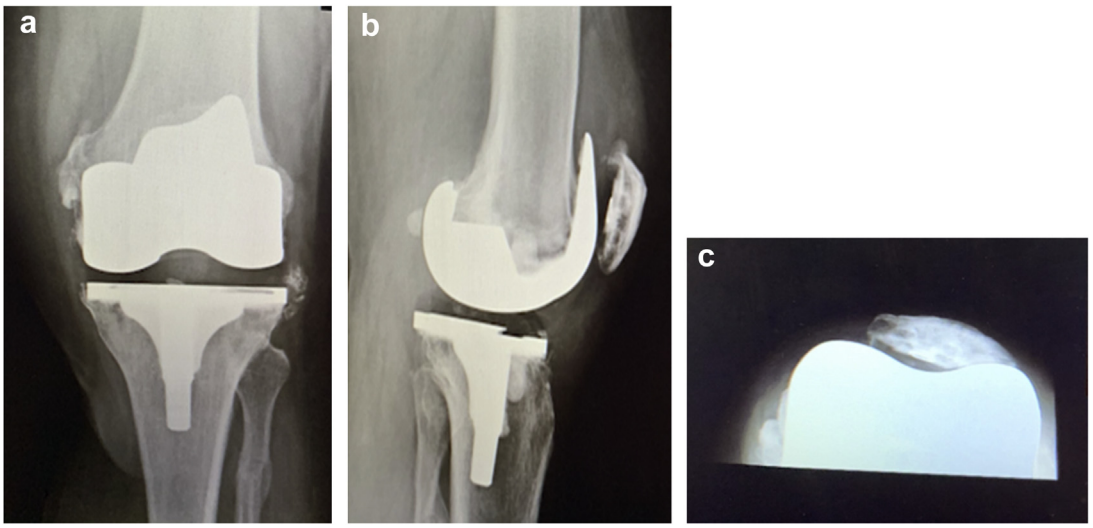

Figure 4. Anterior (a), lateral (b), and merchant (c) view of a left knee in a patient 12 years postoperative from a cemented BCS TKA.

posterior location of the tibial post. Similarly, Grieco et al. found that between 30 and 90 degrees, the JI-BCS experienced greater than 5 mm in posterior translation of the lateral condyle and approximately 3 mm in posterior translation of the medial condyle [8]. The brittleness of XLPE makes the tibial component more susceptible to failure as the kinematics of implant designs, such as the JI-BCS, put significant forces on the tibial component [9]. In the most severe tibial implant failure cases, tibial post fracture can occur, as seen at our institution, resulting from the JI-BCS design mechanics. Retrieved tibial inserts from fractured tibial posts have clinically confirmed the study by Gillis et al. and have a smooth fracture morphology adjacent to the tibial post base likely related to the poor ductility of the highly crosslinked polyethylene [10].

In comparison to the JI-BCS, the JII-BCS experienced less than 1.5 mm in posterior translation of the lateral condyle and less than 1 mm in posterior translation of the medial condyle [8]. In a retrieval analysis of PE wear in PS TKA implants, Puloski et al. found that the most predominant location of wear was the posterior surface with 40% of the posterior surface exhibiting some form of wear [11]. It was noted that remarkable posterior wear likely resulted in the post's subsequent fracture in one implant. In addition, another implant demonstrated significant anterior wear and was designed with a more anteriorly positioned post to resist hyperextension, which further illustrates that cam-post design ultimately effects the pattern of wear in each component [11,12].

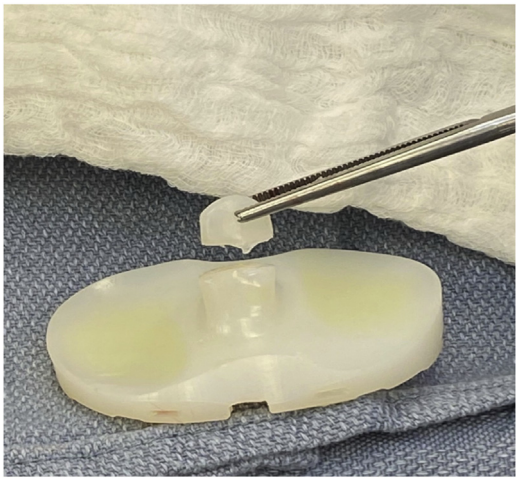

Figure 5. Intraoperative image of an explanted 9-mm Journey 1 BCS tibial polyethylene with a fracture of the tibial post and oxidation of the medial and lateral tibial compartments.

Arnout et al. performed an in vitro study to compare the post-cam mechanics and tibiofemoral kinematics of PS TKA designs [9]. They found a positive correlation between lateral femoral posterior motion and tibial rotation after post-cam contact with maximum contact forces on the tibial post [9]. Their findings suggest that TKA designs simulating natural knee kinematics have higher contact forces. Despite it being an in vitro study, their measurements of the JI-BCS kinematics are close to those measured in prior cadaveric and in vivo testing [13]. Of further importance was their finding that all designs, including the JI-BCS, demonstrated post-cam pressures that exceeded the yield stress of XLPE (22 Mpa), which was similar to prior studies involving post-cam mechanics [14,15]. Based on these findings, one would expect that an implant designed with a more posteriorly position tibial post may increase posterior wear and lead to postoperative complications, such as those seen with the Journey I BCS.

Tibial post wear and breakage is a rare complication of PS TKA and of great concern as it creates substantial wear debris and results in instability and the need for revision [16]. Retrieval analyses have demonstrated evidence of post wear on 100% of implants examined [11,17]. Post wear typically occurs anteriorly and results from TKA components being in net hyperextension resulting in impingement on the femoral box. Additional wear damage has been identified on the other 3 surfaces of the tibial post that are not intended to articulate with the femoral box, as suggested by retrieval studies. Dolan et al. found differences in both total wear damage scores and location of wear damage on tibial posts in 3 different PS designs, suggesting that tibial post wear damage is primarily determined by implant design [18].

Few cases of tibial post breakage in PS TKA have previously been reported. To our knowledge, 5 previous cases have been reported in the NexGen prosthesis (Zimmer, Warsaw, IN) [4,19–24]. Chiu et al. described a case of atraumatic tibial post fracture 3 years after TKA [19]. They believe post failure was due to repetitive anterior impingement resulting in accelerated wear and eventual failure during high flexion by a posterior lift-off force. Mauerhan reported 5 tibial post fracture cases in the Foundation (Encore Orthopedics, Austin, TX) PS TKA implant that presented with symptoms

resembling patellar clunk syndrome. Compared with other tibial post failure cases, it was found that tibial post wear began on the posterior aspect of the tibial post and high flexion ranges in patients were seen before the event [22]. Rodes et al. reported a case of tibial post fracture in the Genesis II (Smith and Nephew, Memphis, TN) implant 4 years after TKA. The implant failed while the patient was performing squats at the gym. On the post's intraoperative evaluation, there were no signs of significant wear due to post impingement. Similar to other post failure reports in deep flexion, the fracture likely occurred due to increased force on the post during squat exercises [23]. To our knowledge, there has only been one other reported case of tibial post fracture with the JI-BCS implant. Renson et al. reported post tibial fracture with the JI-BCS implant in a patient while crouching on their right knee when gardening [4]. Intraoperative examination of the tibial post showed a transverse fracture without excessive PE wear, suggesting that post fracturing during squatting may suggest increased posterior loading during deep flexion leading to failure [4]. However, Lachiewicz et al. described success with replacing a damaged tibial insert with a thicker component in PS TKA and avoiding the morbidity of a two-component revision [3].

The authors of this case report agree with the decision to revise only the tibial PE and limit the morbidity associated with a femoral and tibial component revision in a knee with well-fixed and appropriately positioned implants. The initial surgeries for the patients presented were all completed at an outside hospital before electronic medical record integration. We cannot comment on the technique performed for balancing the knee or the femoral component size implanted. However, a thorough preoperative radiographic evaluation and gross inspection revealed that the femoral and tibial components were well-fixed, well-aligned, and appropriately sized, consistent with a well-performed total knee arthroplasty. The 2 patients presented in this case report experienced an excellent short-term outcome and have returned to their daily activities without restriction or hesitation.

Owing to the high incidence of adverse events seen in the JI-BCS implant, the manufacturers incorporated several design changes to the JII-BCS design introduced in 2012. These changes were implemented to relax constraints associated with the JI-BCS cam-post mechanism and allow for more variability in patient dynamics while simulating native knee kinematics. Three design changes were made to the tibial component, which included: a more anterior tibial post with increased height to reduce the chance of dislocation from the cam “jumping” over it; the posterior slope was increased in the lateral compartment, and the posterior lip in the medial compartment was moved anteriorly. In the femoral component, changes included a reduced thickness of the medial femoral condyle and lateral anterior flange to reduce tension on the lateral retinaculum; reduced mediolateral width; and the posterior cam was decreased in size and moved more proximally to decrease anterior tibial translation in knee flexion. Grieco et al. found that in comparison to the JI-BCS, the new JII-BCS design reduced anterior-posterior motion throughout flexion as previously mentioned and ultimately delayed posterior cam-post engagement [8].

Summary

Clinical awareness and radiographic identification of the prosthesis and all possible complications associated with a particular implant allow an orthopedic surgeon to quickly and effectively recognize and treat the patient. A failure of the tibial PE can occur anywhere along the post. The diagnosis is easily missed when the proximal tip has sheared off, and a posterior drawer test is normal. Many patients will be difficult to evaluate in the office fully, and an examination under anesthesia may be warranted. In the relaxed patient, applying an anterior force to the femur while simultaneously performing a posterior drawer test may allow the post to subluxate posterior and enable the surgeon to diagnose this complication in the office setting. Coordination with the correct implant representative is recommended as a PE swap considerably decreases morbidity than a revision TKA. Our institution presents 2 additional rare complication cases to raise further awareness of this catastrophic complication associated with this prosthesis.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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