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Case report

Fracture of the femoral adapter bolt and taper adapter in a modern rotating platform knee arthroplasty

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ABSTRACT

A 58-year-old woman presented with onset of pain associated with a popping sound after a twisting motion 4 years after left total knee revision arthroplasty. She had a complex medical history, including a reported bone cement allergy, and presented to the hospital unable to bear weight. Plain radiographs revealed a broken femoral component, with the femoral metaphyseal sleeve separated from the distal articular component. During surgery, it was observed that the femoral adapter bolt and taper adapter had both fractured. Scanning electron microscopy of the fracture surfaces of the components confirmed that the implant had failed in fatigue, presumably due to high cyclic loads. Failure at this junction has not been described previously. In this type of knee design, we recommend supporting the distal articular component either with bone, augmentation, and/or bone cement to reduce the risk for this mode of failure.

Introduction

Modular components are widely used in both primary and revision total knee arthroplasty (TKA) procedures. Modularity allows for intraoperative customization, improved kinematic function, and improved fixation [1]. Porous titanium metaphyseal sleeves were introduced as a modular option to provide more advantageous fixation for challenging TKA surgeries [2]. These sleeves fit over a distal intramedullary stem that connects to the femoral component by a screw, bolt, and/or taper junction. The sleeves are intended to allow for load sharing across the joint and to provide stress relief for host bone [1].

Unfortunately, modularity has led to case reports of implant failure in both primary and revision TKAs. Early Optetrak designs (Exactech, Gainesville, FL) experienced failures at the male taper junction of the femoral component and the stem extension [3], and 5 cases of the Insall-Burstein II Constrained Condylar design (Zimmer, Warsaw, IN) were reported for failure of the stem-condyle junction because of loose bolt connections [4,5]. DePuy (Warsaw, IN) introduced the SIGMA TC3 Rotating Platform, which connects the femoral component to the distal femoral stem through a femoral adapter and corresponding femoral adapter bolt. These modular junctions may also have a possibility of failure, although modular junction failure has not been previously reported in the TC3 implant. No reported cases of bolt failure were found in the FDA's MAUDE database as of November 4, 2016. We report a case of a spontaneous, catastrophic fracture of the femoral adapter and corresponding femoral adapter bolt of a noncemented TC3 Rotating Platform knee.

Case history

The patient is a 58-year-old woman with a history of hypertension, hyperlipidemia, fibromyalgia, reflex sympathetic dystrophy, asthma, spine surgery, and multiple left knee surgeries. She had undergone a left primary TKA in June of 2009, 8 months before presenting to the hospital with pain and a reported infection after a

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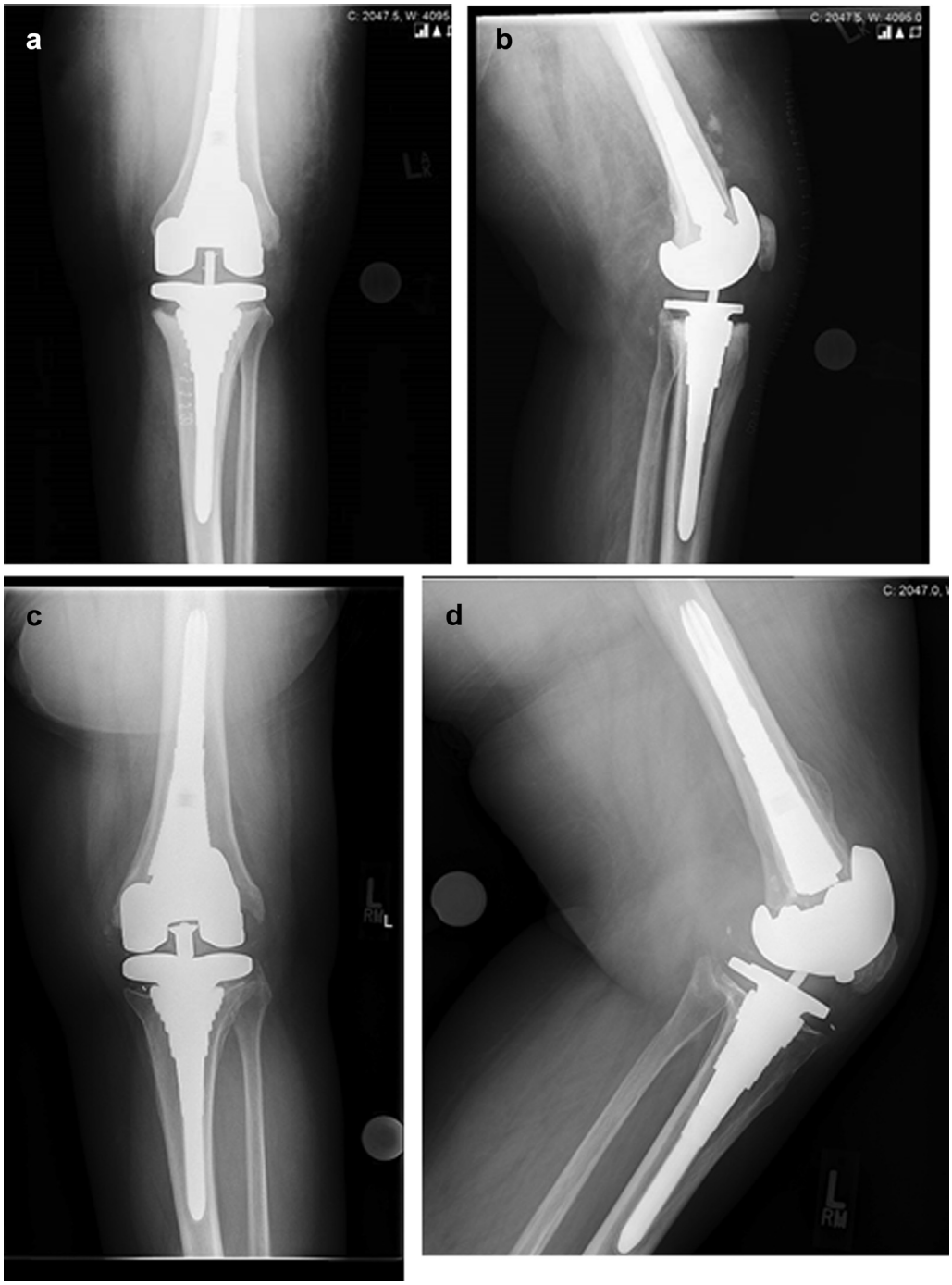

Figure 1. Anteroposterior (AP) (a) and lateral (b) radiographs obtained at revision surgery in 2010. 4.5 years later, the patient presented with onset of pain and AP (c) and lateral (d) views confirmed fracture of the implant and taper disengagement from the metaphyseal stem.

dental procedure. No evidence of bacteria was found, but the patient's pain continued to increase. All cultures were negative. Pathology found no histological evidence for infection despite the preoperative aspiration showing elevated white blood cell count, erythrocyte sedimentation rate and C-reactive protein. The negative aspiration results and inflammatory response at the cement-bone interface indicated a potential bone cement allergy. With this diagnosis, the initial 2-staged revision plan was abandoned in hopes of avoiding a second possible reaction to bone cement. A DePuy Press-fit TC3 Rotating Platform component was implanted with both lateral distal and medial posterior augments on the femur and stems and sleeves on both the femoral and tibial components (Fig. 1). At her 1-month follow-up visit, the patient had full range of motion with stable flexion and extension. At her 3-month follow-up, she reported feeling better and had undergone spinal surgery, which she believed benefited her outcome. In her recovery from spinal surgery, she suffered a fall, which initiated minor pain in the joint; however, radiographs and clinical examination revealed no abnormalities with the revision implant.

In November of 2014, 4.5 years after her revision TKA surgery, the patient presented after twisting her knee. At the time of the twisting injury, she experienced an accompanying sudden popping

sound. The patient was subsequently unable to bear weight. Anteroposterior and lateral radiographs (Fig. 1) revealed fracture of the femoral component of the implant. The radiographs showed that the distal femoral sleeve had disconnected from the femoral articular component and that a large metal fragment was freely floating in the intercondylar region of the joint space.

A second revision surgery was performed. Preoperative serological tests were not concerning for infection. A tourniquet was used during the surgery. The old incision was used, and the medial and lateral gutters were reestablished to gain exposure to the broken implant. The articular component was found to have broken at the taper connection. It was grossly loose and was removed. The freely floating broken piece of the bolt was removed from the joint space; the remaining broken fragment was retained inside the taper adapter. When attempting to disconnect the taper adapter from the femoral component, the broken fragment was observed spinning in the threads of the adapter. Therefore, the broken fragment was unthreaded from the taper adapter. The taper adapter could then be disengaged from the femoral sleeve by attaching a Winquist extracter (Shukla Medical, Piscataway, NJ) and backslapping the component. The metaphyseal sleeve was completely encased in bone with excellent ingrowth. Therefore, it was left *in situ*. A hinged femoral component was prepared and press-fit into place, which allowed for a one-piece connection, without any taper bolts, to the intact metaphyseal sleeve. The distal femoral bone was contoured using a barrel tip Midas Rex (Medtronic, Fridley, MN), and bone cuts were made to fit the extra small size femur. A 16-mm polyethylene insert permitted full extension. All other components in the tibia were intact and left in place. A lateral release was performed to improve patellar tracking.

Postoperatively, the patient was in a splint for ambulation only, given Coumadin for venous thromboembolism prophylaxis, and was allowed weight-bearing as tolerated. She spent 7 days in the hospital, had a long-term pain consultation, and was prescribed rehabilitation. Six weeks postoperation, the patient complained of occasional pain and inability to walk over 5 blocks without assistance. At her 3-month follow-up appointment, she reported feeling better than at any time during the past 5 years. She could flex her knee more than 90° and could achieve full extension, had subjectively improved patellar tracking, and her incision was well healed.

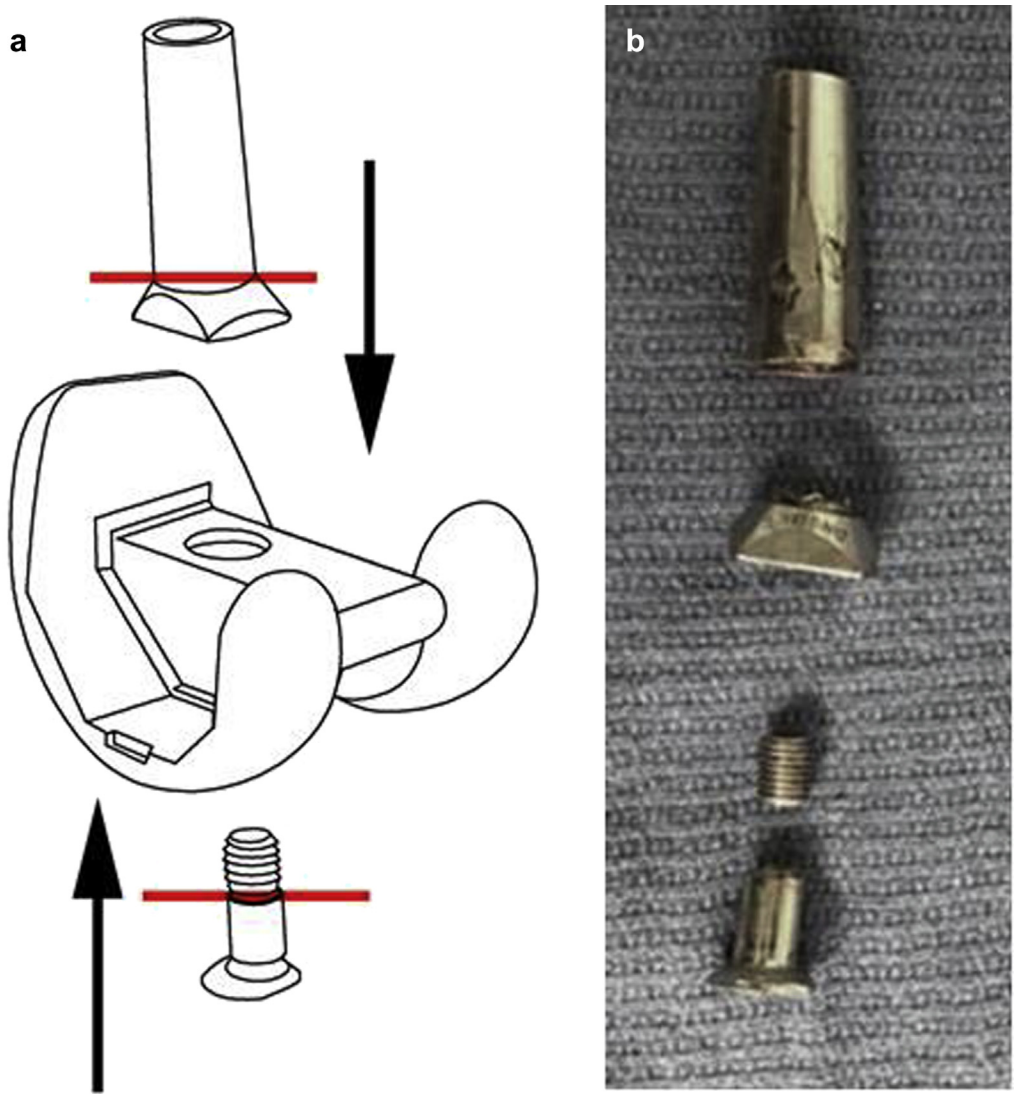

Figure 2. (a) Drawing displaying assembly of the femoral component. The red lines indicate location of implant fracture. (b) Intraoperative picture of the fractured segments after removal.

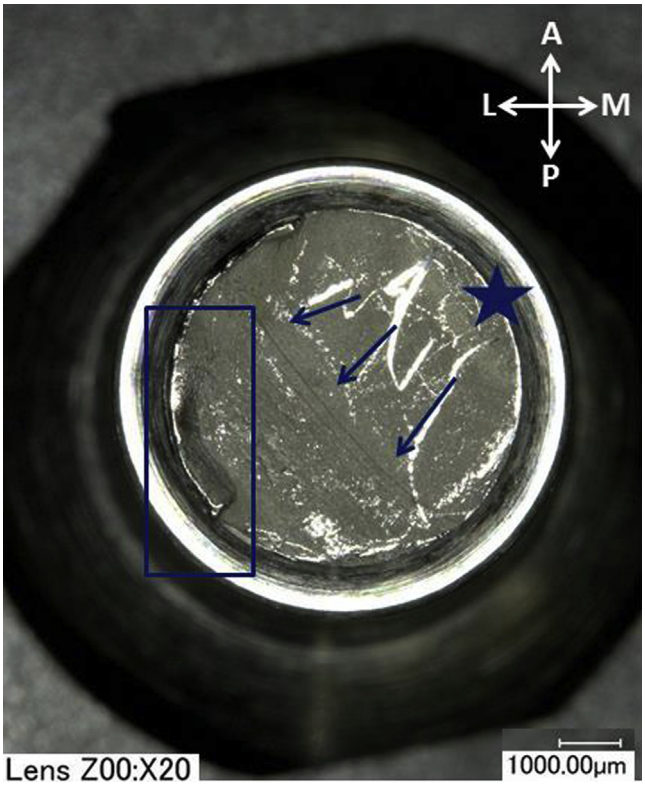

Figure 3. Magnified image of the fracture surface of the femoral bolt showing the point of fracture initiation (denoted by the star), beach or clamshell markings indicative of fracture progression posterolaterally across the surface (indicated by the arrows), and the area of final fracture (highlighted within the box at the posterolateral edge).

Biomechanical analysis

The retrieved DePuy TC3 Rotating Platform implant was cleaned and analyzed with both light and scanning electron microscopy (SEM). A drawing of the component accompanied by intraoperative images depicts the setup of the modular interfaces and the location of the failure (Fig. 2a and b). SEM examination of the fracture surface confirmed that the implant failed because of a fatigue fracture from cyclic loading. The flat shapes of the beach marks indicate a mild stress concentration near the origin of the fracture [6]. SEM images revealed beach marks propagating laterally across the surface, ending at the final fracture location on the posterolateral edge of the bolt (Fig. 3). The femoral component had no visible damage; the polyethylene insert had evidence of moderate pitting and scratching. The post of the femoral component was slightly damaged anteriorly, likely from hyperextension of the knee. This implant was uncemented, which could provide evidence for the high stress environment in the surrounding host bone and distal femoral stem [3].

Discussion

Failure of modular connections has been studied in depth in the hip, shoulder, and knee joint, in conjunction with corrosion, fretting, dissimilar metal coupling, and traumatic injuries [7,8]. Few cases have reported fatigue fracture of modular tapers [3], and none report the bolt fracture pattern described in this case study. Failures have been observed of threaded bolts that had dissembled from the femoral component because of loose implant fixation. This failure was observed in the Scorpio design (Stryker, Mahwah, NJ), but no further damage was observed at the threaded junction interface [9]. Similar to our report, 2 cases have been reported of disassociated bolts free-floating in the intercondylar joint space in the Total Condylar III design (DePuy Johnson & Johnson, Warsaw, IN), although importantly neither of the bolts fractured. These bolts were reported to disassemble because of loose femoral components likely giving rise to uneven loads throughout the joint and increased motion between modular components [4].

Rotating platform tibial inserts were introduced to reduce tibial wear by providing higher conformity and thus reduced contract stresses at the articular surface of the tibial insert. The rotating platform design is also intended to reduce loads at the bone-implant interface or the cement-implant interface that could decrease long-term implant loosening [10]. In our case, the implant was not fixed to the bone with cement because of the patient's reported allergy. This led to higher load transfer through the femoral stem taper to the metaphyseal sleeve, which was well fixed at the time of revision. The implanted metaphyseal sleeve had excellent ingrowth, but was unable to distribute load properly because of the fatigue fracture at the femoral adapter. The femoral sleeve and stem were kept in place, and the patient has had a successful outcome after her latest revision.

The patient's allergy to cement must be emphasized. This implant is recommended for use with cement and failed at an unusual junction likely because of high cyclic loads unevenly distributed through the joint. Whenever possible, we advise using cement to prevent the type of fatigue failure that occurred in this case. If the patient has a cement allergy, we would advise against using this implant to avoid the described implant failure. A custom implant designed with biologic fixation, either through bone ongrowth or ingrowth, would be a strong recommendation for similar cases, as most stems use hybrid fixation involving bone cement. An additional option might be a monolithic design, but the sacrifice in modularity makes a revision TKA more challenging.

Summary

The use of modular TKA implants have generally led to successful outcomes, but possible adverse consequences exist with modularity. This case highlights an unusual catastrophic failure in an attempt to revise a patient who suffered from additional medical conditions, namely cement allergy, affecting her options for revision surgery. The bolt fractured in fatigue because of high cyclic loading, which would have likely been reduced by use of cement fixation. As this mode of failure is atypical, this case was initially perplexing on radiographic examination and proved to be complex during component removal. Despite the fracture of one of the components, modularity allowed for an adaptable revision: the femoral component was replaced and attached to the existing metaphyseal femoral sleeve. This mitigated further compromising remaining bone stock that otherwise would have been necessary had the sleeve needed to be removed. However, we would recommend against using this implant without cement in future cases.

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