

Case report

Nontraumatic tibial polyethylene insert cone fracture in mobile-bearing posterior-stabilized total knee arthroplasty

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ABSTRACT

A 72-year-old male patient underwent mobile-bearing posterior-stabilized total knee arthroplasty for osteoarthritis. He experienced a nontraumatic polyethylene tibial insert cone fracture 27 months after surgery. Scanning electron microscopy of the fracture surface of the tibial insert cone suggested progress of ductile breaking from the posterior toward the anterior of the cone due to repeated longitudinal bending stress, leading to fatigue breaking at the anterior side of the cone, followed by the tibial insert cone fracture at the anterior side of the cone, resulting in fracture at the base of the cone. This analysis shows the risk of tibial insert cone fracture due to longitudinal stress in mobile-bearing posterior-stabilized total knee arthroplasty in which an insert is designed to highly conform to the femoral component.

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Introduction

Posterior-stabilized (PS) total knee arthroplasty (TKA) prostheses have been used extensively and have shown excellent long-term results [1,2]. On the other hand, there are some reports of tibial polyethylene insert fracture because in PS knee prostheses, the stress tend to concentrate in post-cam mechanism [3]. However, tibial polyethylene insert cone fracture has never reported before. We report the case of nontraumatic tibial polyethylene insert cone fracture. Written informed consent was obtained from the patient for the publication of this case report and accompanying images. Approval was obtained from the ethics board of Otemae Hospital (Osaka, Japan) before the start of the examination.

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Case history

The patient was a 72-year-old male, with a height of 165.7 cm, body weight of 75.9 kg, and body mass index of 27.6. He visited our department in October 2010 because of worsening pain on the right knee due to severe osteoarthritis (Fig. 1). The preoperative range of motion (ROM) on the first visit was -15° and 115° of extension and flexion, respectively, and radiographic imaging findings revealed Kellgren-Lawrence grade III osteoarthritis of the medial compartment, grade IV osteoarthritis of the lateral compartment, and Iwano stage 1 of the patellofemoral osteoarthritis [4]. He also presented with genu valgum deformity with a femorotibial angle (FTA) of 166° and the Mikulicz line (mechanical axis) passing through 90° of the lateral compartment. The tibial posterior declining angle was 5° . The patient's medical history showed cerebral infarction, hypertension, and paralysis but without sequela causing a decrease in activities of daily living (ADL), such as muscle weakness, or systemic disease, such as rheumatoid arthritis. He had undergone surgery for right fibular fracture at the age of 67 years, but there was no ankle motion restriction or ankle pain. Although he underwent conservative treatment, mobile-bearing PS TKA was carried out in February 2011 using Vanguard Rotating Platform High Flex implant (Biomet, Warsaw, IN; hereafter referred to as



Figure 1. Preoperative radiographs. (a) Anteroposterior, (b) lateral, (c) Merchant, and (d) full-length.

Vanguard RP), using conventional gap technique because his knee pain further worsened and hydrarthrosis became more marked. The selected implant size was 67.5 mm for the femur and 79 mm for tibia, and a 14-mm thick tibial polyethylene insert was used. The implant was anchored to the bone using cement fixation technique; the patella was not replaced. Postoperative radiographic alignment showed an FTA of 174° and tibial posterior declining angle of 1° , with the Mikulicz line passing through 19% of the lateral compartment (Fig. 2). Both the postoperative clinical course and radiographic course were favorable, but a mild flexion contracture was observed with ROM of -15° and 130° in extension and flexion, respectively. He started normal rehabilitation a day after the operation, and at 6 months after surgery, he started strength

training rehabilitation 3–4 days per week and playing drums for 2 hours once a week as postoperative ADL, but he did not play high-intensity sporting activities accompanied with contact play. He visited our department again on May 2013 because of a sudden pain on the right knee and a strong sense of instability without any definitive trigger such as trauma. Strong instability was observed in anterior and posterior drawer test, and fracture and dislocation of the tibial polyethylene insert were observed in radiographic imaging at his revisit (Fig. 3). After the replacement surgery of the tibial polyethylene insert in June 2013, fracture was observed at the cone base of tibial polyethylene insert (Fig. 4). As the extension gap was slightly tight, the fractured insert was replaced again with a 12-mm thick tibial polyethylene insert. The fracture surface of the



Figure 2. Postoperative radiographs. Only axial view was photographed after an operation for one week. (a) Anteroposterior, (b) lateral, (c) Merchant, and (d) full-length.

removed tibial polyethylene insert was observed and scanned using a photomicrograph (VHX-2000; Keyence, Osaka, Japan) after surgery. It was then coated with Pt-Pd for vapor deposition and observed using scanning electron microscopy (S-3700N; Hitachi-High Technologies, Tokyo, Japan; hereinafter referred to as SEM). The patient's postoperative course was favorable, and he resumed his regular activities. However, a mild flexion contracture remained, with ROM of -10° and 130° in extension and flexion,

respectively. A 3-dimensional kinematic analysis of the behavior of the tibial polyethylene insert after revision surgery was performed using 2D-3D registration technique [5,6] in May 2014.

Figure 5a shows the fracture surface of the tibial polyethylene insert cone. A raised striation pattern was found on the upper part of the red circle, but it was blurred. Based on the figure, fatigue breaking was assumed to have originated and progressed from the posterior (lower part of Fig. 5a) toward the anterior of the cone

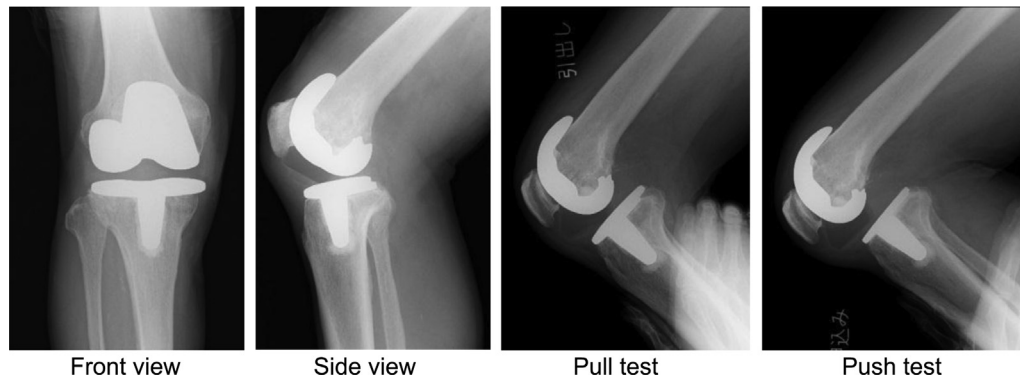


Figure 3. Radiographs of the dislocated tibial insert.

(upper part of Fig. 5a). However, the protrusion on the fracture surface of the tibial polyethylene insert (Fig. 5b, blue ellipse) did not correspond with the shape of the cone fracture surface.

Figure 6 shows the SEM images of the fracture surface. Locations A-E roughly correspond with locations A-E in Figure 5 (photomicrographic image).

Figure 7 shows the magnified image of the cone fracture surface in visual field A. A difference in level was found at the part in the magnified image ($\times 50$), and a striation pattern was observed in Figure 7c ($\times 2000$), indicating progression of the fatigue breaking from the lower to the upper part.

Magnified SEM images of visual field B are shown in Figure 8. A dimple image was observed, which indicates the final breaking point. Magnified SEM images of visual field C are shown in Figure 9. A raised striation crossing from the upper to the lower part of the image is observed. Visual field D (Fig. 10) is an image of the tibial polyethylene insert cone surface as shown in Figure 6. Although slightly blurred, a striation crossing from the upper to the lower

part of the image can be observed. Location E is potentially the final breaking point because a dimple image was observed in visual field E (Fig. 11), which indicates that fatigue breaking progressed from the upper to the lower part of the image. The initiating point of the fatigue fracture is suggested in Figure 6b (yellow square), and the starting point was crushed.

Striation is a striped pattern [7] on the fatigue fracture surface that is caused by the gradual progression of a crack that develops because of repeated changes in load. Based on the previously mentioned results, the fracture resulted from repeated bending stress toward the direction of the red curved arrow (Fig. 12), causing fatigue fracture at location 1, which progressed toward the direction of red curved arrow directions (from the lower to upper part in the image) and led to fatigue breaking in location 2. Then, fatigue breaking progressed from the lower to upper part of the image, and ductile fracture occurred at the point encircled in blue, resulting in fracture. The axis direction of the initiating point was the border of the linear and curvature parts of the cone.

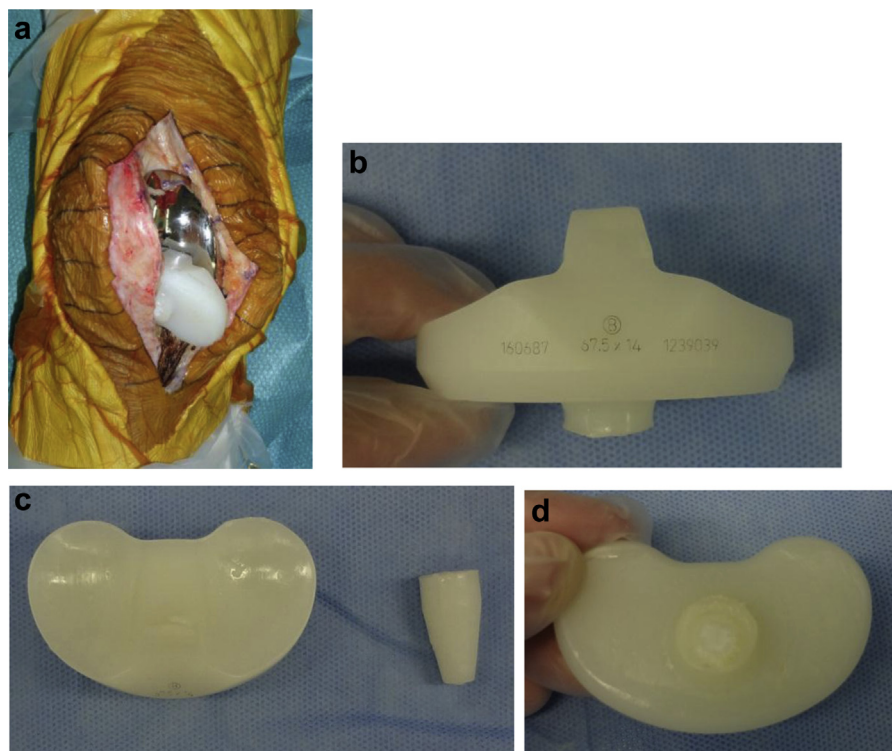


Figure 4. Intraoperative photographs. (a) The tibial insert was easily dislocated due to the fracture at the cone base of the tibial insert. (b) Front of the tibial insert. (c) Top of the fractured cone and tibial insert. (d) Bottom of the tibial insert.

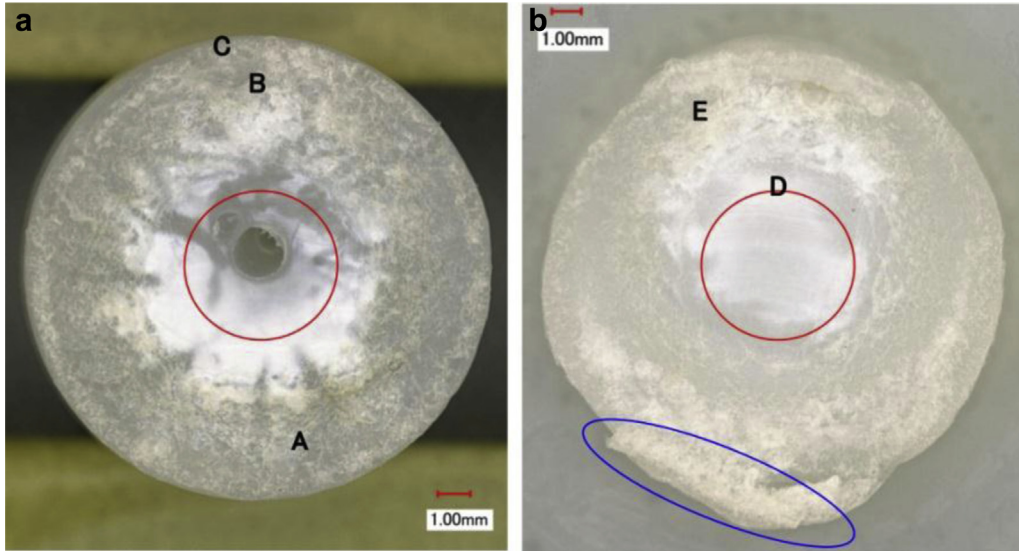


Figure 5. Photomicrographed fracture surface of the tibial insert. (a) Photomicrographed fracture surface on the cone side. A raised striation marking is observed in the upper area encircled in red. The center opening is a hole drilled for removal at the time of the replacement surgery. (b) Fracture surface on the insert side. A protrusion is observed in the blue ellipse area; however, it did not correspond with the contour of the fracture surface in (a). Alphabets A through E in the photomicrograph express arbitrary positions on the fracture surface.

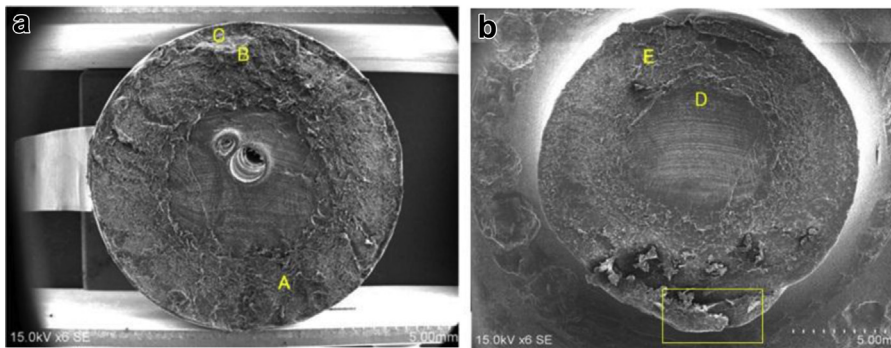


Figure 6. Overall SEM images. (a) Fracture surface on the cone side. (b) Fracture surface on the insert side. Locations A through E roughly correspond with those on the photomicrographic images in Fig. 5.

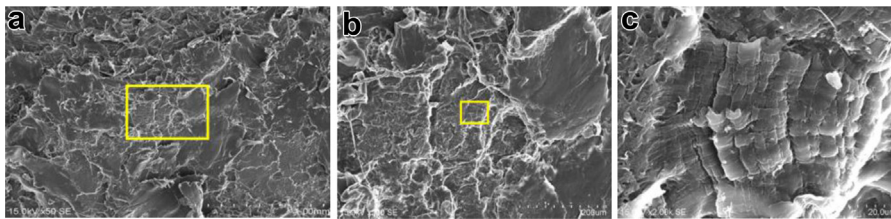


Figure 7. Visual field A. (a) Visual field A in Fig. 6a ($\times 50$ magnification). (b) The area enclosed by the yellow square in (a) ($\times 200$ magnification). (c) The area enclosed by the yellow square in (b) ($\times 2000$ magnification).

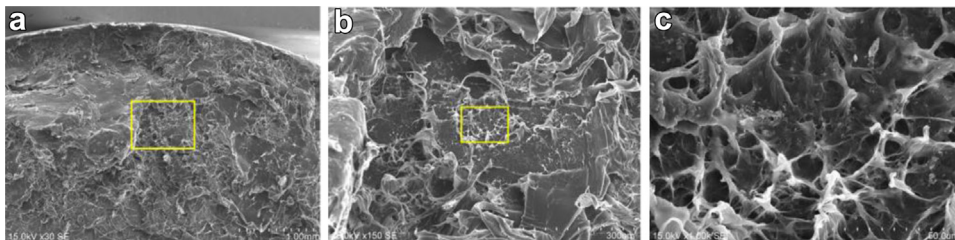


Figure 8. Visual field B. (a) Visual field B in Fig. 6a ($\times 30$ magnification). (b) The area enclosed by the yellow square in (a) ($\times 150$ magnification). (c) The area enclosed by the yellow square in (b) ($\times 1000$ magnification).

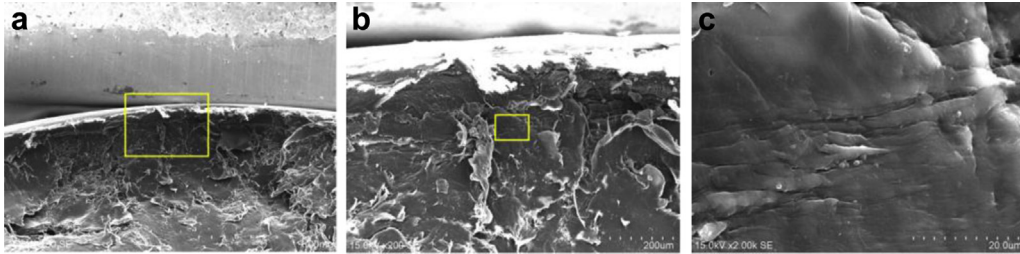


Figure 9. Visual field C. (a) Visual field C in Fig. 6a ($\times 50$ magnification). (b) The area enclosed by the yellow square in (a) ($\times 200$ magnification). (c) The area enclosed by the yellow square in (b) ($\times 2000$ magnification).

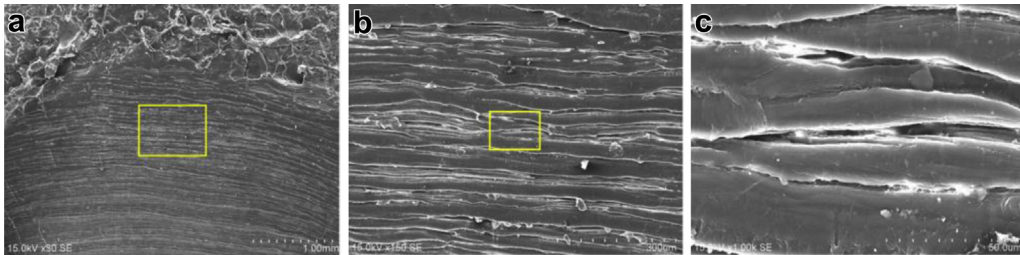


Figure 10. Visual field D. (a) Visual field D in Fig. 6a ($\times 30$ magnification). (b) The area enclosed by the yellow square in (a) ($\times 150$ magnification). (c) The area enclosed by the yellow square in (b) ($\times 1000$ magnification).

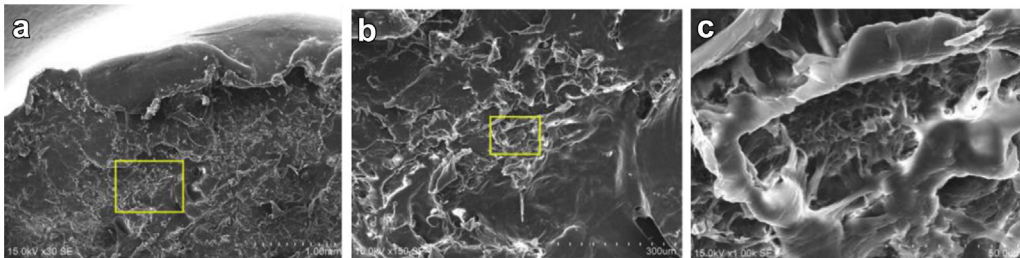


Figure 11. Visual field E. (a) Visual field E in Fig. 6a ($\times 30$ magnification). (b) The area enclosed by the yellow square in (a) ($\times 150$ magnification). (c) The area enclosed by the yellow square in (b) ($\times 1000$ magnification).

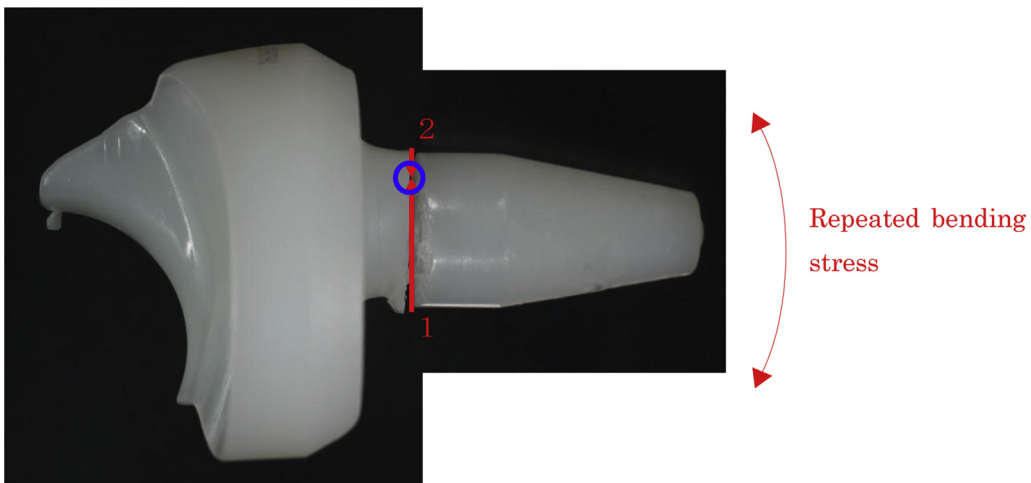


Figure 12. Side view of the fractured tibial insert.

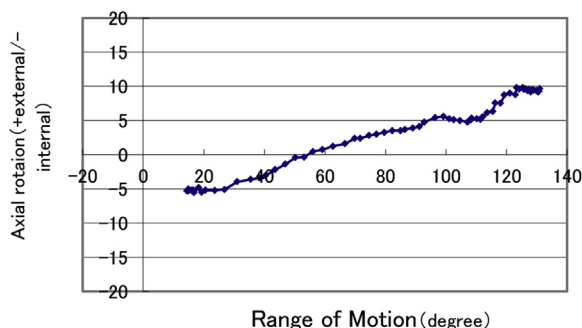


Figure 13. Axial rotation angle of the femoral component to tibial component at each flexion angle.

The axial rotation angle of the femoral component to the tibial component at each flexion angle showed a gradual lateral rotation, along with deeper knee flexion starting at medial rotation of 5° in knee joint extension of 10° and lateral rotation of 10° at knee joint extension of 130° (Fig. 13). Considering the characteristics of Vanguard RP, that is, the high conformity of the tibial insert with the femoral component, the rotation mechanism of the tibial polyethylene insert may have been maintained.

Discussion

The rotation of tibial insert in mobile-bearing PS TKA reduces contact stress between implants, which leads to less abrasion and fracture of the polyethylene insert. Therefore, favorable outcomes in patients who underwent mobile-bearing PS TKA have been reported [1,2]. Meanwhile, it is well known that the post of the tibial polyethylene insert can be fractured [8] because of the impingement that occurs repeatedly between the post and the metal femoral cam of tibial insert in PS knee prosthesis, in which knee joint stability and roll-back mechanism are maintained by post-cam mechanism [3], and nontraumatic fracture has also been reported [9]. However, nontraumatic fracture of the cone, which serves as a rotation axis, has not been reported in mobile-bearing PS TKA. In our case, a favorable lower-limb alignment in standing position, with an FTA of 174° and the Mikulicz line passing through 19% of the lateral compartment, was obtained after mobile-bearing PS TKA, and a mild genu valgum was observed. Fracture has occurred at the cone base in patients with favorable postoperative lower-limb alignment without participating in high-intensity sport, such as in our case. This indicates that heavy mechanical stress is loaded on the cone base in mobile-bearing PS TKA even during normal ADL. This may be because the tibial polyethylene insert in a mobile-bearing PS TKA is secured to the tibial component by a mobile-type bearing in contrast to a fixed type in which a tibial polyethylene insert is strongly fixed to the tibial component. A longitudinal stress is predicted to be concentrated on the tibial cone, especially in knee flexion, because the shape contributes to

the high-rotation conformity of a tibial polyethylene insert to the femoral component [10] and post-cam mechanism. This prediction is compatible with the result of the SEM analysis of the fracture surface, which revealed that a longitudinal stress was responsible for the fracture of the cone base. Kinetic analysis indicated the occurrence of a strong stress even under a condition without a definitive malrotation between the tibial component and the femoral component. The axis direction of the fracture starting point was located on the border of the linear part and the curvature part of the cone, which may suggest that consideration of cone shape is required when designing the tibial polyethylene insert for mobile-bearing PS TKA in the future. Finally, a limitation of this report is the lack of detailed data on soft-tissue balance, owing to the use of conventional gap technique; thus, it is difficult for us to prove completely that the procedure does not have any problem, and the point where mild extension restriction remained after the operation might have caused the implant damage. In addition, kinetic analysis was not carried out between the tibial polyethylene insert and the femur and tibia because a tibial polyethylene insert with a marker for 2D-3D registration technique was not used.

Summary

We reported a case of a patient with nontraumatic tibial polyethylene insert cone fracture after mobile-bearing PS TKA. SEM of the fracture surface showed repeated longitudinal bending stress as the cause of fracture.

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