Posterior Tibial Polyethylene Fracture in Cruciate-Retaining Total Knee Arthroplasty

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Introduction

One of the common prostheses for primary total knee arthroplasty (TKA) is a cruciate-retaining (CR) design. The tibial polyethylene inserts commonly used in TKA are made of ultra-high molecular weight polyethylene (UHMWPE). The CR TKA design retains the posterior cruciate ligament (PCL), which is believed to provide increased stability, promote femoral roll back, improve proprioception, and enhance stair-climbing ability.[1,2] Delamination, adhesive wear, and abrasive wear of the polyethylene component are common mechanisms of failure, but fracture of the component at the posterior side in a CR TKA is rare. The cause of this type of failure is often multifactorial. This case report presents a case of posteromedial polyethylene fracture in a CR TKA.

Case Report

A 56-year-old female (height: 5 feet 7 inches, weight: 185 lbs., BMI 29 kg/m^2) presented with left knee pain for which she had undergone a total knee replacement three and one-half years prior with a diagnosis of primary osteoarthritis. Since the surgery, her knee never felt stable, particularly when walking up and down stairs. She also complained of pain and swelling to the knee, which had been worsening in severity. She previously had undergone physical therapy without any significant relief of the symptoms. She denied any fever or chills, night sweats, or recent weight loss. The patient's past medical history was unremarkable for any trauma to the knee after surgery.

On physical examination, the patient's left knee was mildly tender to palpation medially and laterally. It had range of motion of 0 to 120 degrees of flexion with neutral alignment. The joint opened up 1 mm with valgus stress medially and 2 mm with varus stress laterally in extension. In flexion, the anterior drawer test showed gross laxity with anterior tibia translation. The posterior drawer test also showed significant laxity. Neurovascular function was intact. Her Knee Society score was "poor" (score: 54) according to the Knee Society clinical rating system[3] and her functional outcome score was "fair" (score: 60).

Three radiographs of the left knee were taken (anteroposterior, lateral, and sunrise). The results showed a CR knee without any sign of prostheses loosening. Anterior translation of the tibia was noticed (Figure 1). Laboratory blood tests were negative for infection. Therefore, she was diagnosed with flexion instability status post left TKA, and the plan was for the patient to undergo revision knee arthroplasty. The medical record of the patient's initial surgery obtained from an outside hospital showed a size 2 Stryker Triathlon CR femoral component (Stryker, Mahwah, NJ), and a size 2 Triathlon tibial baseplate with a 9 mm thickness of X3 CR tibial polyethylene insert.

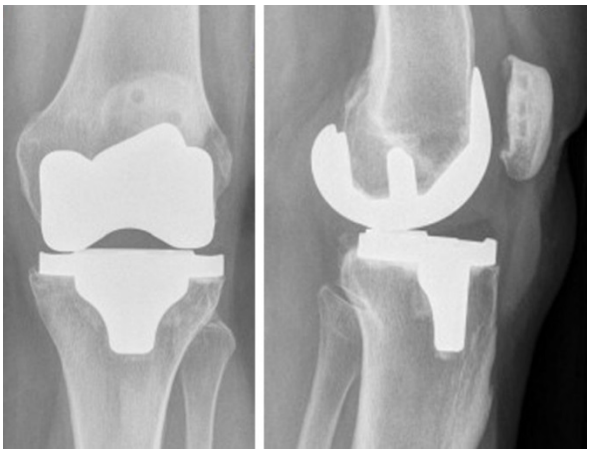

Figure 1. Anteroposterior and lateral radiographs of left knee show evidence of instability with anterior subluxation of tibia.

During the surgery, after the medial parapatellar arthrotomy and synovectomy were performed, a loose fragment of polyethylene was noted in the lateral gutter. This measured 5 mm X 15 mm (Figure 2). Subsequently, the polyethylene insert was removed. A fracture was seen at the posteromedial aspect of the polyethylene insert with severe wear posterolaterally (Figure 2). The femoral component was revised to a size 3 Stryker Triathlon total stabilizing femoral component with 12 mm x 50 mm cemented stem and 5 mm posterior augments both medially and laterally (Figure 3). A 9 mm thickness polyethylene tibial insert also was used to restore the joint line. The tibial component was retained. Intraoperative exam showed excellent range of motion and stability in both flexion and extension.

At the six-week follow-up, the patient reported excellent satisfaction with the TKA revision. Her pain was minimal, and she was able to ambulate unlimited distances without any assistive device. Physical examination of the left knew showed the range of motion of 0 to 130 degrees of flexion with neutral alignment.

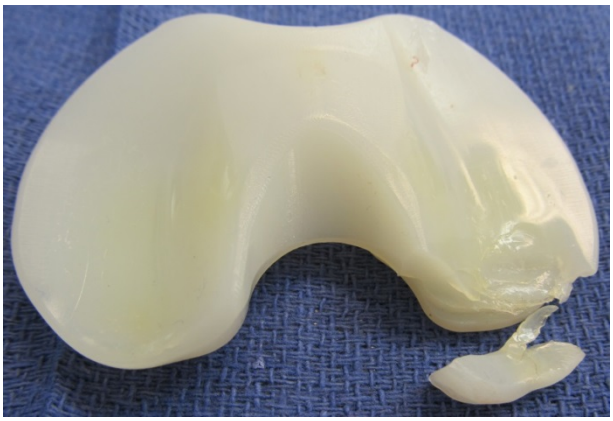

Figure 2. Polyethylene insert with significant posterior wear and posteromedial fracture.

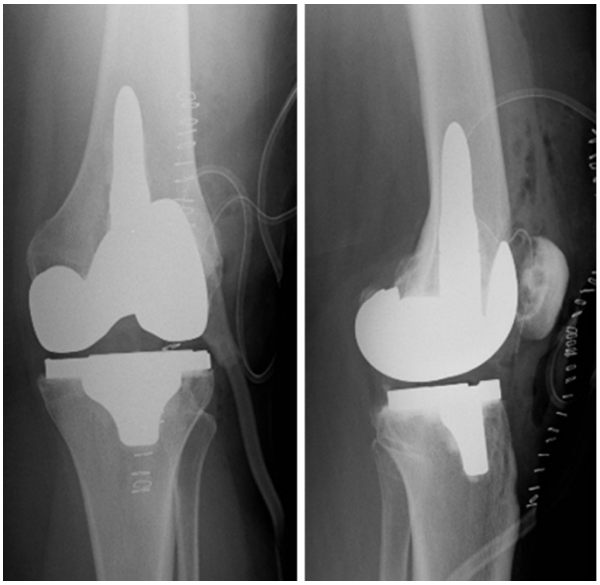

Figure 3. Immediate post-op anteroposterior and lateral radiographs following the revision of the left TKA.

In extension, the joint space opened up 1 mm medially and 1 mm laterally with valgus and varus stresses. Flexion and mid flexion demonstrated stable anterior and posterior drawer tests with firm endpoints. Her Knee Society score improved significantly to "excellent" according to the Knee Society clinical rating system[3] (score: 95) and functional outcome score also improved to "excellent" (score: 90). Her six-week post-operative radiographs are shown in Figure 4.

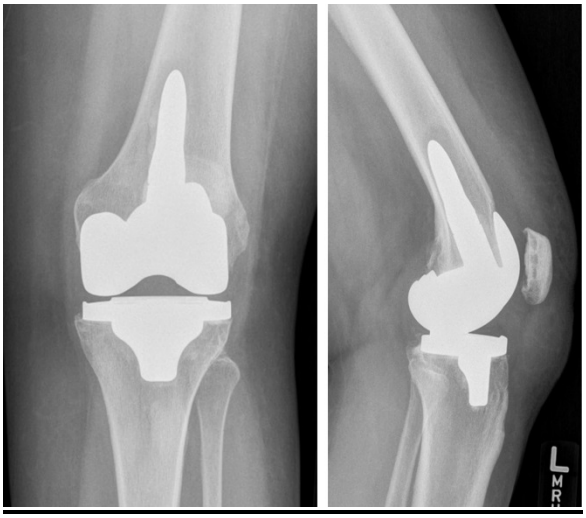

Figure 4. Six-week post-operative anteroposterior and lateral radiographs.

Discussion

In this case, the primary causes of accelerated posterior wear and fracture of the polyethylene tibial insert was suspected to be the improper balance of the soft tissues. To have an excellent outcome with CR TKA, the surgeon must appreciate the importance of proper PCL tensioning. A loose or lax PCL may defeat the purpose of the design as the knee may have instability with anterior and posterior displacement when the PCL is too loose.[4] Along with a flat design and little inbuilt constrain of CR polyethylene insert, anteroposterior instability can allow the femoral component to slide and rotate excessively on the tibia surface. This may increase the shear force and accelerate the polyethylene wear, leading to down sloping of the polyethylene surface. It further accentuates the tibiofemoral subluxation, surface degradation, and subsequent component failure. Alternatively, excessive tensioning of the PCL may lead to excessive femoral rollback. This may lead to increased translation of the articulation posteriorly, thus producing high stress and even increased wear on the posterior polyethylene insert.

Swany and Scott[5] presented three cases of catastrophic posterior wear of tibial polyethylene in CR TKA. In their discussion, the authors contributed the effect of excessive tensioning of PCL as the primary cause of the failures. This could be related to a variety of technical problems such as malrotating or placing a tibial tray too far anteriorly and under resecting the posterior femoral condyles, causing flexion gap tightness. In knees with severe valgus or varus deformities, the medial or lateral release to maintain a balanced gap may require placing a thicker polyethylene insert, thus causing tightness of PCL.

Apart from the technical problems described above, the catastrophic failure observed in this case might come from the inherent properties of the polyethylene. The X3 tibial polyethylene used in this case is a highly cross-linked UHMWPE. The gamma irradiation process, which was used to induce cross-linking, causes restriction of chain mobility in the amorphous region of the polymer and results in limited plasticity within the polyethylene. Decreased in plasticity improves wear resistance. Mechanical properties such as toughness, ductility and resistance to crack propagation, however, are reduced as the consequence.[6] The highly cross-linked UHMWPE is more brittle in fatigue compared to conventional UHMWPE.[7,8] The reduced fatigue strength of highly cross-linked UHMWPE could lead to mechanical failure in conditions that are associated with cyclic local tensile and sheer stresses as seen in total knee arthroplasty.

Another possible cause of the fracture of the polyethylene tibial insert could be influenced by the extent of oxidative embrittlement of the polyethylene resulting from gamma sterilization and subsequent shelf aging. Shelf aging of post-irradiated polyethylene decreases the principal strains of the polyethylene insert by 5% to 10%.[9] Aged polyethylene inserts also showed delamination after fewer than five million cycles.[10] Such decreases in abrasive wear

resistance due to oxidation when subjected to high contact stresses, particularly from an unstable TKA, can exceed the yield stress of the UHMWPE, leading to permanent deformation and subsequent catastrophic failure of the implant. The majority of polyethylene has a standard shelf-life of five years. Therefore, it is advisable to observe expiration dates strictly to reduce the risk of implant failure.

There are many factors to be considered regarding fracture of tibial polyethylene in total knee arthroplasty. Catastrophic failure due to extreme wear and heavy oxidation are quite uncommon with today's improved manufacturing and processing techniques. Nevertheless, such wear and fracture can occur when the knee has flexion instability as highlighted in our case. Accurate bony cuts, restoration of the mechanical axis of weight bearing, and accurate soft tissue balancing, therefore, remain the most important basic fundamentals for the achievement of a successful TKA.

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