Late Liner Disassociation of a Pinnacle System Acetabular Component

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abstract

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This article describes a case of late locking mechanism failure and disassociation of a Pinnacle acetabular cup (DePuy, Warsaw, Indiana) and Marathon polyethylene liner (DePuy) 53 months after routine primary total hip arthroplasty in an active patient. Following an uncomplicated initial postoperative recovery, the patient felt a pop while kneeling for gardening activities. The patient had no prodromal symptoms but reported pain with range of motion and weight bearing following the episode. Radiographs appeared to show a fractured liner with intact acetabular and femoral components. Intraoperatively, the liner was disassociated and dislocated inferior to the acetabulum, and 3 consecutive antirotational tines were sheared off the liner at their bases. The acetabular cup and femoral stem were well fixed. Extensive metallosis existed from the femoral head and acetabular shell articulating in the absence of a liner. The patient underwent revision of the acetabular cup, polyethylene liner, and femoral head due to the concern for osteolysis given the extensive metallosis. Revision of the acetabular cup and liner were performed with no further complications. No conclusions could be made as to the exact mechanism of failure following laboratory analysis of the retrieved polyethylene liner. Several possible mechanisms of failure are possible. Although cases of acute disassociation of this system have been reported, this is the first article to our knowledge to report failure at such a late postoperative time.
Modular acetabular components for total hip arthroplasty (THA) are popular due to their ease of exchange in the event of failure or infection and their ability to intraoperatively optimize the combination of acetabular and femoral component coupling for length, offset, and stability. Backside wear occurred with the early modular acetabular designs, which was initially decreased by fashioning polyethylene liners to be more congruent with the metal acetabular shell. In addition, highly cross-linked ultrahigh-molecular-weight polyethylene has been used over the past decade because of its improved wear characteristics.\textsuperscript{1-4} Due to this improved wear profile, evidence exists of decreased fatigue strength and resistance to crack propagation.\textsuperscript{1-4}

Frank polyethylene liner fracture and locking mechanism fracture have been reported.\textsuperscript{5-7} Fracture and locking mechanism failure can lead to disassociation of the liner from the shell and spinout. Several theories exist regarding the mechanism of failure, including migration of a loose acetabular shell or screw, impingement, malpositioned components, and incomplete seating of the liner intraoperatively.\textsuperscript{5}

One of the most widely reported designs correlated with liner disassociation is the Harris-Galante acetabular cup (Zimmer, Warsaw, Indiana),\textsuperscript{8,9} which had potential for locking mechanism failure at the polyethylene and metal locking tines. The Duraloc system (DePuy, Warsaw, Indiana) had high pushout and lever-out strength in several studies.\textsuperscript{10,11} However, a recent case report analyzed 5 Duraloc locking ring failures.\textsuperscript{7}

The Pinnacle acetabular cup (DePuy) was introduced in 2002, with the ability to use metal, polyethylene, or ceramic liners. Although laboratory studies showed lower push-out and lever-out resistance compared with the Duraloc cup, clinical results have not shown greater incidence of disassociation at early follow-up.\textsuperscript{11-13} Mesko\textsuperscript{5} reported early liner disassociation of a Pinnacle cup and Marathon polyethylene liner (DePuy) at 23 months postoperatively.

The current article describes the late disassociation of a primary THA using the Pinnacle acetabular cup and Marathon polyethylene liner revised 54 months postoperatively.

**Case Report**

A 70-year-old woman with a body mass index of 33.9 kg/m\textsuperscript{2} presented with an 18-month history of worsening left hip pain. She had advanced left hip osteoarthritis and underwent an uncomplicated left THA in June 2006 using a small-incision modified direct lateral approach. Implants included the Pinnacle Sector II 52-mm acetabular cup with a Marathon cross-linked ultrahigh-molecular-weight 32-mm neutral polyethylene liner, a Summit #2 high-offset femoral component, and a 32-mm, +9 cobalt chrome femoral head (Figures 1, 2).

Postoperatively, she was maintained on partial weight bearing for 2 weeks and anterior hip precautions with no active abduction for 6 weeks, which are part of the standard physical therapy protocol following THA using a direct lateral approach at our institution. Her hospital course was uncomplicated, and she was discharged on postoperative day 3. At 4-month follow-up, she reported no pain. She had regained excellent flexion and abduction strength and reported returning to all activities of daily living, which included frequent gardening in a squatting and kneeling position. She was seen annually thereafter and reported no complications.

In November 2010, approximately 53 months postoperatively, the patient was gardening, arose from a kneeling position, and heard a pop in her left hip. She was able to ambulate and had minimal pain initially, but reported an onset of a grinding and squeaking noise in the hip, which was not present prior to this episode. She sought immediate treatment at a local urgent care clinic and was seen in follow-up several days later at an orthopedic clinic, at which point she reported increasing pain. Despite this, she was able to ambulate with no limp, had full hip range of motion (ROM) with a palpable grinding, and was neurovascularly intact. Radiographs revealed femoral head malalignment in the cup consistent with a fractured polyethylene liner (Figure 3).

The patient underwent polyethylene liner and femoral head revision with pos-
sible revision of all components approximately 2 weeks after the onset of symptoms. She was made nonweight bearing until revision, and she reported partial compliance. Intraoperatively, the previous abductor and capsular repair was intact. On entering the hip joint, extensive metallosis and inflammatory-appearing synovial fluid existed, with no purulence or necrosis. The polyethylene liner was intact, although it was dislocated inferior to the acetabular cup. Wear was visible on the femoral head and acetabular component, presumably from metal-on-metal wear in the absence of the polyethylene liner.

After dislocating the femur anteriorly and removing the liner, 2 of the tines from the locking mechanism on the polyethylene liner were retrieved from the hip capsule. On closer inspection, the liner was found to have deformed slightly into an ovoid shape, and 3 of the 6 tines had sheared off at the base (Figure 4). No visible sign of impingement existed on the femoral neck trunnion, acetabular component, or liner rim. Due to the deformed liner shape, an attempt to replace the liner for trial of ROM to recreate pathology in situ was not feasible. Thorough debridement was achieved, and the acetabular cup was revised due to concern for the amount of wear on the bearing surface of the acetabular cup due to its direct contact with the metal femoral head, the significant metallosis seen in the surrounding tissues, and the possibility of acetabular osteolysis. New components placed included the Pinnacle acetabular cup with an 18-mm cancellous screw, a 36-mm inner diameter Marathon polyethylene liner, and a 36-mm, +12 cobalt chrome femoral head (Figure 5).

The patient was doing well clinically and radiographically 12 months postoperatively. The patient granted permission to review and describe de-identified information in this article.

**Discussion**

The shells and liners of cementless acetabular components used for THA have evolved. Backside wear was reported with early modular designs and was initially decreased by fashioning the polyethylene liners to be more congruent with the metal acetabular shell. In addition, highly cross-linked ultrahigh-molecular-weight polyethylene has been used over the past decade for its improved wear characteristics.\(^{1,4}\) Due to this improved wear profile, decreased fatigue strength and resistance to crack propagation occurred, which contributes to the incidence of polyethylene fracture with impingement or edge loading when used with first- and second-generation designs.\(^{1,7}\) Gamma-irradiation of polyethylene in inert media, increased liners thickness and conformity, elimination of sharp corners and unsupported edges in locking mechanisms, and impingement awareness have decreased the incidence of polyethylene rim fractures and disassociation in THA.\(^{10,14-17}\) Third-generation acetabular components use these design principles to allow the use of highly cross-linked polyethylene and reap the benefits of lower wear rates with less incidence of polyethylene fracture and disassociation.\(^{10,15}\)

The Pinnacle acetabular cup is a third-generation, titanium alloy, fully hemispheric cup. The polyethylene locking mechanism consists of a Morse taper ending in a small raised ring, which fits in a groove in the acetabular cup, and 6 tines protruding from the polyethylene, which act as antirotational devices. These tines fit in recesses in the outer edge of the acetabular cup and are flush with the rim of the cup when the liner is fully seated. This system can accommodate metal, ceramic, and conventional gamma vacuum foil or cross-linked (Marathon or Altryx [DePuy]) polyethylene liners. Polyethylene liners are mostly used.\(^{5,13}\) Marathon polyethylene is moderately cross-linked by using 50 kGy of irradiation in gas plasma and is remelted at 155° for 24 hours. This intermediate dose of irradiation allows for moderate cross-linking to reduce wear, with a moderate decrease in fatigue strength.\(^ {18}\) Remelting eliminates free radicals formed during sterilization and cross-linking but also decreases fatigue strength.

Given the relatively short period of use of the Pinnacle cup, few outcome reports have been published. In 2004, Engh et al\(^ {13}\) reviewed 596 press-fit Pinnacle cups. Although mean follow-up was 0.5 years (range, 0-2.6 years), 2 revisions were performed. Neither was associated with a mechanical locking mechanism failure or polyethylene fracture. Another multicenter study of 1183 Pinnacle cups in 2007 reported no cases of disassociation at mid-term follow-up.\(^ {19}\) Two case reports of fracture and disassociation of the Pinnacle and Marathon combination were reported.\(^ {5,5}\) In the first case, the patient had a 28-mm, 10° buildup extended lip liner with 4-mm offset 23 months after implantation of a Pinnacle multi-hole cup. A polyethylene rim fracture in the extended lip existed at revision surgery. No liner dislocation was reported. Intraoperatively,
a similar trial liner with 10° buildup was placed, and extension and external rotation impingement existed, which was implicated as the mode of failure. A neutral liner was placed, leaving the acetabular and femoral components in place after they were well fixed and appropriately positioned. In the second case, in which a Pinnacle Sector II cup and 32-mm neutral polyethylene liner were implanted, the patient was also 23 months postoperative. The liner was dislocated from the cup intraoperatively, and 3 of the antirotational tines on the liner were sheared off at the base when retrieved. The cup, screws, and femoral components were appropriately aligned, well fixed, and left in place, and a 36-mm metal liner was implanted. No specific means of locking mechanism failure were reported. The findings in this case are similar to the intraoperative findings in our patient, in which 3 consecutive tines were sheared off and the liner disassociated and dislocated on entering the joint.

The 54-month duration of implantation prior to disassociation in our patient is unique, and many possibilities for failure have been proposed. Simple incomplete seating of the liner during the index procedure was unlikely to cause failure at such a late time. Our patient reported frequent gardening involving squatting and kneeling positions, which increase the risk of anterior and superior impingement, causing inferior subluxation of the femoral head on the fully hemispheric Pinnacle cup. Predisassociation radiographs showed 50° to 55° of abduction and 20° to 25° of cup anteversion, which accommodates these activities well rather than leading to impingement. In our case, examination of the retrieved polyethylene by the manufacturer’s biomechanics laboratory revealed that the locking mechanism failed and became unlocked in the region of the antirotational locking tines that were sheared off. Based on wear patterns and gross inspection of the retrieved components, evidence existed of femoral head subluxation at the rim of the liner in the broken tines but not of impingement between the femoral neck and the cup.

No firm conclusions could be made as to the means of locking mechanism failure and liner disassociation. Based on the deformation of the liner, wear patterns, and duration of the patient’s symptoms, the locking mechanism failed, allowing motion of the liner in the cup. This motion caused abnormal stresses on the derotational tines, which eventually caused them to shear off. When the tines sheared off, the liner had no further stability in the cup and disassociated at extreme hip flexion during gardening. The patient reported no discomfort during the initial phase of locking mechanism failure and became symptomatic when the liner disassociation occurred acutely. The manufacturer reported that this shearing off of tines and spinout has been anecdotaly reported in several other cases and in the literature once. The mechanism causing the tines to shear off and the liner spinout was not reproducible in their lab.

The locking mechanism of the Pinnacle system relies on a small ring buildup on the liner that engages a groove in the cup. In addition, the antirotational tines fit in grooves on the edge of the cup to provide rotational stability. Several modes of disassociation are possible, 1 of which is ring failure. If the ring disengages or is not engaged completely at the index procedure, continued forces during weight bearing could cause point loading on an incongruous cup–liner construct, leading to a lever-out force on the liner. The liner could then begin to asymmetrically rotate and piston in the cup, causing abnormal stresses on the tines and breakage. Impingement, whether from malpositioned components or repetitive activities involving extremes of hip ROM, could also cause a lever-out force on the liner at the impingement site on its rim or as a contrecoup force from femoral head subluxation opposite the impingement. Another potential mode of failure is rotational torque. Whether external rotational force during activities would cause locking mechanism failure or vice versa is unknown. If the polyethylene is incompletely seated intraoperatively, the liner is at risk for failure. The manufacturer currently recommends meticulous inspection of each derotational tine for complete seating in its groove. Although visualization and palpation of the tines is the currently accepted method, potential exists for a more objective validation method of ensuring complete locking mechanism engagement.

Despite early mechanical testing of the locking mechanism for the Pinnacle system used with polyethylene liners showing less pullout strength than for other comparable devices, the Pinnacle system used with Marathon cross-linked polyethylene has shown favorable short- and midterm outcome data. Less motion and improved congruity between the modular components and the increased use of highly cross-linked polyethylene compared with the Duraloc system showed Pinnacle to have modestly lower wear rates (0.03 vs 0.04, respectively) but significantly lower retroacetabular osteolysis (0% vs 19%, respectively) in 1 recent report. Although cross-linked polyethylene has decreased resistance to crack propagation and the remelting process affects the tensile strength, the exact dose of irradiation and temperature for remelting that balances the advantage of low wear rates and disadvantage of fracture potential is not known. Surgeon-controlled factors, including attention to component fixation, positioning and sizing, avoiding impingement, careful seating of the liner in the cup, and assuring no debris is interposed between the modular components, are paramount.

**Conclusion**
In this otherwise straightforward case, an active patient sustained a locking mechanism failure nearly 5 years postoperatively. The mechanism for failure is not fully understood. We report this case as a
potential cause for concern, especially due to previously published reports of similar failures.

**REFERENCES**


