Catastrophic Failure of a Modular Revision Total Hip Polyethylene Insert

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Abstract: Early catastrophic failure of a modular polyethylene component is a potential problem after revision total hip arthroplasty. We describe an unusual case of polyethylene failure that occurred within 18 months of implantation in which no obvious technical error or mechanical failure was identified. The acetabular polyethylene insert was prepared with gas plasma sterilization, and the shelf life was 4 months. Radiographic evaluation used generalized Hough transforms to assess the cup articulation. We identified cup penetration of 2.8 mm before revision and catastrophic destruction of the polyethylene liner at the time of revision. Possible factors implicated for failure included a thin polyethylene liner, increased hip separation, femoral head mismatch, and the high activity level of a younger patient. We believe that this case report highlights the need for future investigations of these subtle factors.

Key words: revision hip arthroplasty, polyethylene failure, hip separation, wear, generalized Hough transform.

Module metal-backed acetabular cups are currently the most widely used uncemented acetabular components. This prosthetic option offers significant flexibility in revision arthroplasty by offering surgeons the ability to change femoral head size, liner offset, and liner buildup. However, there are a number of problems associated with these modular devices, such as failure of the insert fixation, exaggerated polyethylene wear, implant dissociation, and destructive wear-induced osteolysis [1-10].

This case report identifies the early catastrophic failure of a revision polyethylene liner used for the routine revision of a failed press-fit acetabular component. Although no obvious technical or mechanical reason for failure was identified, a number of circumstantial factors were explored, including the time of polyethylene packaging until implantation, polyethylene sterilization methods, hip component separation, and abnormal wear that may occur with mixing implants from different manufacturers.

Case Report

A 54-year-old woman who stood 5 ft and 6 in and weighed 154 lb (body mass index = 24 kg/m²) had undergone a right total hip arthroplasty in July 1987 using a porous coated anatomic (PCA) (Howmedica, Rutherford, NJ) prosthesis. The original acetabular component was a nonmodular device with chrome-cobalt porous coating. By
September 1998, the patient had developed symptoms of moderate pain aggravated by walking a distance of 3 blocks. The leg lengths were equal, and the range of motion was satisfactory. The Harris Hip Score at that time was 68. Radiographs revealed a radiographic demarcation about the acetabular component with superior tilting of the implant (Fig. 1).

In January 1999, a revision of the acetabular component was done and a grossly loose implant but an intact acetabular rim and a well-preserved acetabular subchondral plate were found. A 58-mm Solution cup (Depuy, Warsaw, Ind) was press fit with 1-mm underreaming, followed by the placement of 2 dome screws. Bone graft was not required in this case. For this particular device, a Duracon (Depuy) 48-mm standard polyethylene liner is recommended by the manufacturer. This implant had a minimum polyethylene thickness of 6 mm. The liner was a neutral flat surface without elevation or lip. Manufacturing records indicated that the implant had been prepared with gas plasma sterilization, and there was no anomaly or deviation from standard preparation. The time from packaging to use for this specific implant was 4 months. The femoral component was found to be well seated, with minimum wear of the tapered trunion. A new PCA 28-mm femoral ball with a skirted +15-mm neck length of the original manufacturer was then implanted. Postoperative recovery was uneventful, and the patient had resumed normal activities at 3 months with a pain-free hip.

Within 18 months of the revision arthroplasty, the patient developed new symptoms with increasing pain on activity, subluxation, and clicking. The range of motion of the hip was satisfactory without significant pain. Radiographs revealed evidence of catastrophic failure of the polyethylene insert with superior migration of the femoral head into the metal shell. There was no evidence of metal debris in the joint (Fig. 2). In May 2001, a second acetabular component revision was done to the right hip and the acetabular liner was found to be worn through, with fragmentation of both the liner and the metal locking wire used with this device. The liner was in several fragments, and the circumferential locking wire had broken into several smaller pieces with at least one piece free in the joint. No metal staining of the soft tissues could be seen. The acetabular component was exchanged for a new 60-mm Trilogy (Zimmer, Inc, Warsaw, Ind) porous-surfaced revision component that was press fit with one adjunct superior dome screw. The polyethylene liner had extended offset by 7 mm, and the previously placed femoral head was replaced with a new PCA 28-mm femoral head with a skirted 15-mm neck length. The patient had an uneventful recovery and has remained asymptomatic for the past 4 years.

Radiographs were serially evaluated for polyethylene wear using the generalized Hough transform method of Alford et al [11] that allows for the determination of both wear and hip separation. This method uses a 2-dimensional to 3-dimensional registration algorithm and requires the creation of 3-dimensional models of the implants using AutoCAD mechanical drawing software. The models are then overlain to the 2-dimensional radiographs. An error analysis indicated that this method could reliably detect wear or separation of greater than...
0.25 mm. For the present study, wear was measured on a standing anterior-posterior radiograph that presumes that the joint was maximally articulated. Hip separation was measured on a supine frog lateral radiograph. Using the Hough transform calculation, the Solution revision cup polyethylene demonstrated 2.5 mm of wear penetration at 16 months and 2.8 mm of wear by 22 months. Hip separation of the ball from the socket was measured and found to be an average of 7.3 mm (SD = 1.4 mm; Fig. 3).

**Discussion**

Catastrophic failure of acetabular components has been described as wear through or fracture of the polyethylene liner [12,13]. Liner dissociation with failure of the locking mechanism has also been identified but did not appear to be the etiology in this case report [3,6,10]. The modular 58-mm Solution revision cup liner that had failed had a minimum nominal thickness of 6.0 mm and was a neutral surface without lip or elevation. The shell had a thickened wall dimension of 9 mm with peripheral holes for adjunct screw fixation. The manufacturer in this instance had chosen to create an internal cup dimension that allowed use of the Duracon 100 series 48-mm primary acetabular polyethylene insert. The original PCA femoral component was well fixed and left unchanged, whereas the modular femoral head had a skirted neck with the longest possible length.

The early failure within 18 months of a satisfactorily placed acetabular component by an experienced revision surgeon has raised concern, particularly as this design conforms to the industry standard that suggests the need for a minimum of 6 mm of polyethylene thickness throughout the liner dimension. Berry et al [12] had also identified 10 cases of failed acetabular liners from various manufacturers, but all devices had less than 5 mm of nominal thickness of the polyethylene and none had failed before 2.4 years after the original surgery. They identified other causes such as being younger than 40 years, obesity greater than 80 kg, and acetabular inclination greater than 50° as predictive factors [12]. Similarly, Engh et al [13] found wear through of 4 polyethylene liners and noted liner thickness to be 5 mm, but their patients were active men younger than 65 years.

Bartel et al [14,15] drew attention to the importance of polyethylene thickness as a source of increased contact stress if the thickness is lower than 6 mm. Several finite element studies have shown that increased contact stresses result from back-sided nonconformity and matching thinner polyethylene liners with large femoral heads [16-18]. However, Young et al [19] evaluated the same type of liner as presented in this case report with limited shelf life and gas plasma sterilization packaging and could not find evidence for increased nominal wear rates.

Femoral head roughness has been identified as another source of exaggerated polyethylene wear. Although it may seem intuitive that a smoother surface should perform better, Haraguchi et al [20] noted that a ceramic femoral head actually had inferior wear characteristics despite known improvements in surface roughness and surface density. Orishimo et al [21] performed a wear analysis of matched bilateral total hip arthroplasties and found that up to 40% of wear could be attributed to unquantified sources. Both groups of authors suggested that other factors such as sizing tolerances and third body wear could be operative. The failed cup and liner in this case report were replaced with a different cup design from another manufacturer. However, we do not have direct evidence to support the possibility of third body wear or femoral head sizing mismatch in this anecdotal case. Bone graft or bone substitute was not used. A skirted modular femoral head was used, which may have led to early liner impingement. However, destruction of the liner would not permit investigation for that problem.

Femoral head separation clearly was identified in this case report after the initial revision, and the finding is consistent with prior studies [22,23]. Several recent reports have implicated this...
phenomenon as a source of exaggerated wear [24,25]. Manaka et al [24] duplicated the striped wear on alumina ceramic femoral heads similar to those found on human retrieval specimens by using a hip separation model. Moreover, the amount of wear of the alumina-on-alumina hip implants with microseparation ran in the simulator revealed a 35-fold increase in steady-state wear. In fact, the authors concluded that the in vivo situation may be even worse after comparing the greater damage seen in human retrievals with that in laboratory specimens [24].

Recently, improved digital technology for studying 2-dimensional radiographs allows for rapid determination of distances in the articulation such that both penetration wear and hip separation may be calculated [11]. The method is a modification of the generalized Hough transform that was developed to detect geometric shapes that can be expressed parametrically, such as a circle or ellipse. Importantly, this method gives results comparable with prior validated 3-dimensional computer models for determining hip separation. The generalized Hough transform is a transform space that highlights a specific image feature. The algorithm searches through each image for the 2 circles of the implant and marks a center dot for the femoral head and a center dot for the acetabular cup. The distances between the centers can then be used to compute the separation and implant wear by calculating the distance between the femoral head and the edge of the acetabular cup. We found that the cup in this case report had 2.8 mm of cup penetration and an average of 7.3 mm of hip separation. Although the amount of hip separation was substantial in our case report, there is no evidence to conclude that this was the reason for exaggerated wear. In addition, we may report that our second revision device revealed exaggerated wear after 4 years of in situ use. However, we believe that this problem bears future investigation.

In conclusion, catastrophic early failure of this contemporary revision acetabular component causes concern because evolutionary improvements in manufacturing methods and implant design should have all but eliminated this possibility. We believe that factors leading to premature failure could include a thin polyethylene liner, third body debris, femoral head mismatch, hip joint separation, and the high activity level of a young active patient. We believe that this case report highlights the need for future investigations of these subtle factors.

References


