Delayed Fracture of a Zirconium Head After Total Hip Arthroplasty

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Abstract

We present a case of fracture of a zirconium head after a cemented total hip arthroplasty. The fracture occurred 81 months after the index operation without any history of trauma. The patient was thin, not participating in sports, and the zirconium head had 0-mm neck length. Preoperative radiographs demonstrated aseptic loosening of both components and significant polyethylene wear. Fracture pattern was unusual as the major fragment was half of the head. A revision was performed to a cementless arthroplasty.

CASE REPORT

A 50-year-old man (weight, 58 kg; height, 169 cm) with right femoral head osteonecrosis secondary to sickle cell–thalassemia disease underwent cemented total hip arthroplasty (THA). A posterolateral approach was used. The acetabular cup was an all-poly ultra-high molecular weight polyethylene (UHMWPE) with 49-mm external diameter, 28-mm internal diameter, and 20º elevated lip (Reflection; Smith & Nephew, Memphis, Tennessee). The femoral component was a cemented stainless steel Charnley Elite-Plus stem, size 3 with a 9/10-mm trunnion and 40-mm offset (DePuy International Ltd., United Kingdom), and a distal centralizer was used. The cement used was low viscosity CMW3 with gentamycin (DePuy International Ltd.). The head was a white zirconium ceramic 28/0 (Prozyr; Saint Gobain Desmarquest, Evreux, France).

The authors have obtained the patient's informed written consent for print and electronic publication of the case report.

The patient did well until 81 months after the index operation, when suddenly, while rising from a seated position, he noticed a squeak, and pain developed in his right hip. He was able to ambulate. The patient could not recall any history of trauma. He was not engaged in sport activities and he reported having a sedentary lifestyle.

Radiographs showed a fractured femoral head, liner wear, and loosening around the femoral prosthesis at Gruen zones 1, 2, and 7 (Figure 1). There also was some heterotopic calcification between the lesser trochanter and the lower wall of the acetabulum (Brooker grade 3) but without causing any symptoms. Revision of both components was performed 2 weeks later because the blood bank could not find compatible blood (the patient had multiple transfusions in the past). Meanwhile, the patient remained ambulatory despite medical advice to the contrary. During the operation, we found the largest fragment, which was almost half of the head, attached to the taper. Components were removed easily and an uncemented prosthesis was implanted. The head was submitted for analysis without any preceding autoclaving.

Reconstruction of the head revealed that only a few tiny fragments were missing (Figure 2). The fractured ball had 3 major parts (Figure 3). What is of interest is that the biggest fragment was almost exactly half the head. The fracture surface was in a plane parallel to the ball-head axis. This is characteristic of primary ball fracture.[1,2] In the same fragment, the edges formed by the fracture plane and the cone were not sharp but uneven due to edge chipping, which took place after the primary fracture event. Therefore, these fracture surface edges were not available for fractographic analysis.

The remaining fracture surfaces also were flat, but again, the fracture surface edges adjacent to the bore were lost. The second fragment contained the other

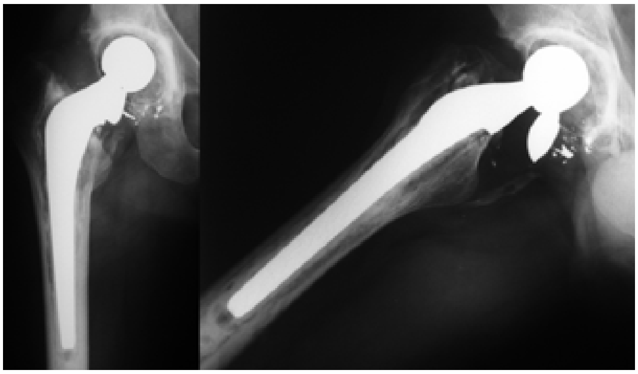

Figure 1. Preoperative radiograph, demonstrating fracture of the head, aseptic loosening of femoral component, and liner wear. Note that the greatest fragment remains attached to the taper.

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Figure 2. Reconstructed head: view from the face surface and the pole. Only a few minor fragments are missing. Note the significant liner wear and the coronal split of the head.

half of the top of the bore, and the third smallest fragment had only a point contact at the upper taper–crown region of the bore. It is known that the point of highest tensile stress in the prosthetic head is at the superior corner of the bore.[3,4] Because of the fracture pattern of the head, we believe that the crack propagated from that point towards the surface of the sphere. The fracture lines of the 3 fragments met on the external surface of the ball at a point 32.75° away from the pole.

The outer surface of the third fragment had a few black markings indicative of metal transfer. The monoclinic phase content on worn (Figure 4) and polished regions was 31% and 10%, respectively, and the monoclinic phase content on the primary fracture surface was 17%. All of these values are well above the acceptable upper limit for monoclinic zirconia in human implants, which is 5%, and we conclude that the residual strength of the ceramic material was rather low.

DISCUSSION

Ceramics have been used as bearing surfaces in THA since 1970.[5] Alumina has excellent mechanical and tribologic properties (high compressive strength and surface hardness, high wettability, superior surface polish, corrosion resistance, and biotolerability)[6] and very low wear rates when coupled with alumina or polyethylene.[7,8] These properties depend mainly on the grain size and the purity of alumina powder used. The major disadvantage of alumina has been increased brittleness due to limited tensile and yield strength.

Zirconium was introduced in 1985 to overcome the issue of alumina head fractures because zirconium has greater resilience and better fracture toughness.[9] Grain size and density influence zirconium stability. Zirconia used in orthopedics are 100% tetragonal grains. Tetragonal to monoclinic transformation can occur under certain thermodynamic conditions and any change in manufacturing process may accelerate this transformation.[10] Such changes ultimately will decrease the overall strength of the material.[11]

Prozyr is the commercial grade of zirconia femoral heads used most often worldwide. Over 500,000 zirconia heads have been implanted since 1985. The estimated fracture rate for these heads between 1985 and 1997 was 0.0085% (28/330,000).[4] In 1998, the manufacturer introduced a significant change regarding thermal processing (sintering) of zirconia heads (the company introduced a tunnel furnace method instead of the batch furnace production method), decreasing the cooling rate threefold. All balls produced were subjected to proof testing during manufacturing to eliminate defective balls.[3] Despite this, in 2000, several zirconia head failures began to occur.

The 2001 manufacturer recall applied to 9 batches of zirconia ceramic femoral heads manufactured since early 1998, and, by February 2004, 343 zirconia head factures from 13 batches were reported to the manufacturer.[4] One hundred fifty-four of these failures were

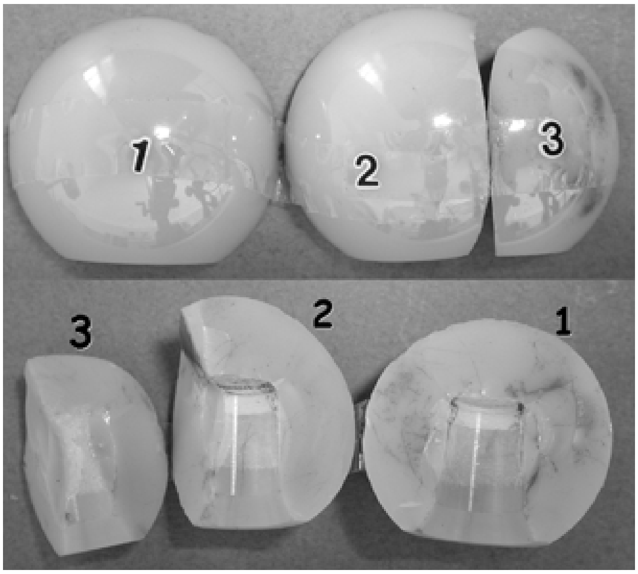

Figure 3. The 3 fragments that originated from the fracture event. The greatest fragment (fragment 1) is half of the head.

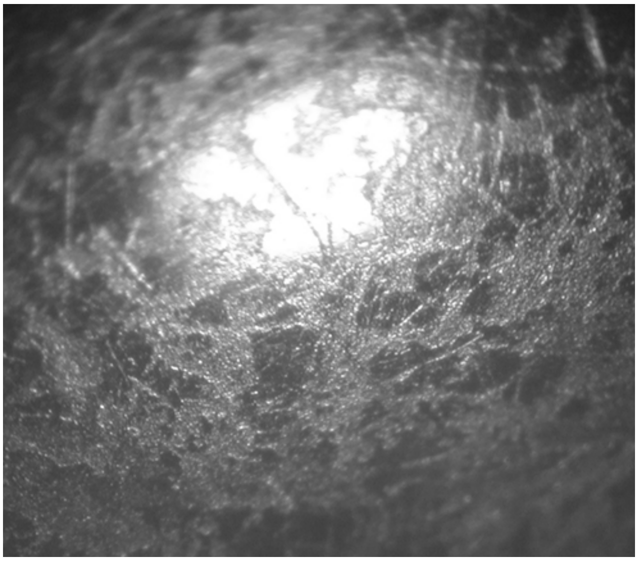

Figure 4. Light microscope photograph of a worn-out region on the outer head surface of fragment 3.

from a single batch and occurred 12 to 32 months after operation. Apart from defects in manufacturing process, other causes of fracture include trauma, implantation of zirconium heads on nonrevised tapers, and use of a stem not recommended by the manufacturer of the head.[6] In a report of 5 fractured zirconia heads, all were 28-mm diameter with a long neck bore (+8 mm). The mean weight of these patients was 91 kg (range, 75 to 131 kg) and the mean time to failure was 25 months (range, 23 to 28 months).[4] It is probable that the increased stresses at the trunnion-bore contact area due to the long neck design of the heads contributed to the failures.

We report this case because there are some interesting features distinct from previous reports. For instance, the fracture occurred 81 months after the index operation (in most reports this interval was less than 3 years); the patient was thin, had a sedentary lifestyle, was not involved in sports, and never had a history of trauma; and the head used was 0 mm in length. Furthermore, an important point is the unusual fracture pattern (3 major fragments only, with the greatest part being half the head). In most reports, the pattern is multifragmentary. Half of the head remained attached to the trunnion until the time of revision, and, until then, the patient was ambulatory despite medical advice.

The femoral stem had cement implant radiolucency at Gruen zones 1, 2, and 7. This probably was caused by polyethylene debris invading the canal. Furthermore, it has been recognized recently that modifications made to Elite-Plus stem geometry (more cylindrical distal part in respect to the original Charnley stem) rendered it rotationally unstable with an unacceptably high failure rate.[12] Finally, the cement used may be another cause of early stem loosening. A cadaveric study has shown that CMW3 was associated with cement-implant interface gaps, which resulted in increased stem migration[13]; these results were in accordance with those from the Norwegian Arthroplasty Register.[14]

Reasons for rapid polyethylene liner wear include the roughened surface of the ball secondary to the monoclinic transformation, the sterilization technique with ethylene oxide (which has been shown to double the penetration rate when compared with gamma-sterilized polyethylene[15]), and the increased anteversion angle, which was calculated to 45°. Significant polyethylene damage also was present in all 5 zirconia femoral head fractures in the report of Masonis and colleagues.[4] A previous report of high rates of aseptic loosening using a zirconia-UHMWPE couple found that the loosening was due to the black heads (surface not oxidized after sintering) used in that series.[16] Other causes of premature failure include resterilization in autoclave, during which, yttrium oxide (the stabilizing oxide of zirconia) is hydrolyzed.

CONCLUSIONS

The overall decrease of the strength of the zirconium ball, as shown by the significant increase of its monoclinic content and the abnormal motion within the cup caused by liner wear, may have been the precipitating factors for this delayed fracture of the zirconium head.

AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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