Case Reports

Fractures of Threaded Cups

Rare Complications of a Well-established Implant

Arnd T. Hoburg MD, Manav Mehta,
Stephan Tohtz MD, Carsten Perka PhD, MD

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Abstract The use of cementless threaded cups in THA is a well-established treatment. Fractures of the cups are rare complications recorded in individual cases with material defects being discussed as the primary cause. We analyzed three cases of fractured cups. Although all three cups were well fixed to existing bone, we observed deficient osseous backing dorsocranially and abrasion particles. There were no signs of femoroacetabular impingement or infection. The cups showed corrosion debris. Scanning electron microscopic investigations showed characteristics of fretting and fretting-related corrosion. We concluded the fractures occurred because of fretting combined with inadequate bony support leading to fatigue of the material and subsequent fracture.

Introduction

Using cementless threaded cups has been well established as an alternate in THA resulting in satisfactory long-term results [3, 10, 12]. The main reason for revisions is aseptic loosening, which often is accompanied by periprosthetic osteolysis generally induced by wear. Compared with press-fit cups, most threaded cups have considerably thinner walls increasing the probability of implant fracture. However, those are rare complications that have been recorded only in individual cases so far [1]. One report suggests material defects may be the primary cause [8]. However, neither mechanical nor technical examinations document material failures. Over 2 years, we evaluated three patients with broken cup implants and conducted clinical, laboratory, and radiographic examinations to determine their failure mechanism.

Case Reports

Patient 1

A 43-year-old man (182 cm, 80 kg) was treated for primary arthritis of the hip with right THA using a cementless threaded cup (52-mm Bicon® titanium threaded cup, metal/metal combination; Plus Endoprothetik, Rotkreuz, Switzerland). Postoperative radiographs showed a lateralized cup position without osseous cranial and dorsocranial backing (Fig. 1A). After implantation, the patient was free of complaints for 5 years and successively started reporting recurrent pain and motion restriction. After a cycling accident, which involved a fall on the opposite hip, radiographs revealed a fracture of the cup component (Fig. 1B). The patient was treated with a 52-mm press-fit

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A. T. Hoburg (✉), S. Tohtz, C. Perka
Department of Orthopaedics, Trauma and Reconstructive
Surgery, Humboldt University of Berlin, Schumannstraße 20/21,
Charité, 10117 Berlin, Germany
e-mail: arnd.hoburg@charite.de

M. Mehta
Department of Medical Biometry, Julius Wolff Institute, Charité
University Hospital, Humboldt University of Berlin, Berlin,
Germany

Fig. 1A–B (A) A radiograph shows the hip of Patient 1 after primary implantation of the hip prosthesis. Lateralization of the cup can be observed. (B) Fracture of the cup is indicated by an arrow.

TMT cup (Zimmer Inc, Warsaw, IN) with cancellous grafting of the bone defects.

Patient 2

A 38-year-old woman (165 cm, 70 kg) was treated with a press-fit cup and a cementless stem because of congenital hip dysplasia. After 3 years, aseptic cup loosening was diagnosed, and the patient underwent surgery at the same hospital where the original operation had been performed. The stem was well fixed. However, the surgeons believed they could not revise the acetabulum. Therefore, they inserted a Palacos® spacer (Heraeus Medical GmbH, Wehrheim, Germany) as a temporary solution and transferred the patient to our hospital for definitive treatment

(Fig. 2A). Intraoperatively, we noted complete lack of a dorsocranial wall and an enlarged defect created by implantation of the Palacos® spacer. We treated the patient with a cementless threaded cup (Alloclassic®, polyethylene dysplasia inlay, metal-polyethylene combination; Zimmer Inc) and reconstructed the bone defect with a femoral head allograft (Fig. 2B). For several years, the patient was free of complaints and most actively engaged in playing tennis and her career in business administration. After 3.5 years, she began having pain on exertion in the left hip. Although the threaded cup appeared well fixed, it had fractured (Fig. 2C). At revision, the cup was replaced with an elliptic 44-mm TMT cup (Zimmer Inc).

Patient 3

A 30-year-old man (178 cm, 91 kg) was treated with THA of the left hip (Bicon® threaded cup, size 55, metal-metal combination; Plus Endoprothetik) for arthritis secondary to Legg-Calvé-Perthes disease (Fig. 3A). Intraoperatively, a cup three sizes larger than planned was implanted. After 4 years without any complaints, the patient reported progressive pain and distinct grinding sounds in his joint. Radiographs revealed an apparently well-integrated, yet fractured threaded cup (Fig. 3B). The cup was replaced with a Size 60 hemispheric TMT cup (Zimmer Inc), and we grafted the cavitory defect with cancellous autograft.

Results

On further inspection, all cases showed similarities. Intraoperatively, we observed a swollen synovial lining, and a considerable amount of abrasion particles in the area of the

Fig. 2A–C (A) The Palacos® spacer implanted after aseptic cup loosening in Patient 2 is shown. (B) A postoperative radiograph shows the hip after revision and allogeneic femoral head transplantation. (C) The fractured cup and fractured screw can be seen.

Fig. 3A–B (A) A postoperative radiograph of the hip of Patient 3 after primary implantation of the hip prosthesis is shown. (B) A radiograph shows the fractured cup.

periprosthetic tissue was detected in all three patients. Histologic examination of the tissue revealed a periprosthetic membrane of abrasion-induced type (Type I, meaning histologically the membrane consists of macrophages containing abrasion particles, without signs of infection) [11], wear particles, and histiocytic inflammation. All cups were firmly integrated to the existing but deficient bone, complicating the replacement surgery because the screw mechanism no longer could be used for removal. For Patients 1 and 3, there was no osseous backing dorsocranially, and in Patient 2, the dorsocranial backing from the autograft was deemed inadequate. All other defects merely involved cavity formation. Neither histologic nor microbiologic examinations suggested underlying infection.

On visual inspection of the retrieved cups (Fig. 4), we observed corrosion debris at the metal-metal cup interface. Scanning electron microscopic investigations of the cups showed polished scars along the fracture surface, which are characteristic of fretting and fretting-related corrosion phenomenon (Fig. 5). Furthermore, evidence of corrosion pits close to the fretting scars confirmed fretting and fluid ingress in the cup interface had led to material leaching (Fig. 6). The consequence of material leaching from the implant surface also is supported by evidence of corrosion debris around the implant tissue. The probable location of the crack initiation site between the fragments was near the rim of the shells. We observed no other sites of material failure. The orientation of the crack supported by fretting scars in this location suggests the failure was the result of shear along the thin walls of the cup.

Fig. 4 This retrieved cup from Patient 3 fractured in three parts. The extent of the fracture is in accordance with the magnitude of intraoperatively observed loss of bone stock in the dorsocranial area of the acetabulum.

Discussion

Previous case reports on fractured acetabular cups mainly suggest material defects as the basic cause [8]. Our laboratory examinations, however, were able to exclude overt manufacturing defects as the cause of the cup

Fig. 5A–B Electron microscopic views of the failure surface are presented. (A) The outside free surface of the shell is toward the right of the image; the base of a thread can be seen in the lower right corner. The slightly polished finish (indicated by black arrows) is likely the result of abrasion between the opposing surfaces during steady fatigue crack growth. Abrasion lines also can be seen on the surface (white arrows). The box indicates the location of (B). (B) The image shows the transition from fatigue crack propagation (smooth surface) to fracture (rough surface). Fretting scars are indicated by arrows and the white line indicates the intersection between fatigue crack (right) and fracture (left).

fracture. The technical examinations revealed the typical changes associated with fatigue fractures in all three cases. Because of the fracture morphology and material surface characteristics, we concluded the failure mechanism occurred in two distinct and simultaneous phases. The fretting scars are evidence of a fatigue phase, which occurred as a result of micromotion during cyclic loading of the implant. Followed by a transition into the fast crack propagation phase at approximately 25% of the overall crack length, failure of these titanium shells therefore may have been the result of poor mechanical support, which correlates with the intraoperative observation of lack of bone graft in the dorsocranial area of the acetabulum.

Fig. 6 An overview of the failure surface near the rim of the shell is shown. Some dark spots near the implant surfaces (arrows) are suggestive of pitting corrosion. The failure surface exhibits multiple fracture planes.

As reported previously, corrosion inevitably will follow fretting if the surface oxide is damaged in an aqueous environment [5, 7]. Fractures of other metal implants because of a combination of corrosion and cyclic loading have been described [4]. Therefore, *in vivo* corrosion of metal implants may lead to deleterious outcomes. Low structural stiffness and implant design in the presence of poor mechanical stability resulting from bone defects likely resulted in corrosion susceptibility of the cups. Previous *in vitro* fretting corrosion studies have concluded stiffness and design parameters of metal implants affect corrosion rates leading to implant failure [4, 6].

Intraoperatively, all three patients showed absent (Patients 1 and 3) or inadequate (Patient 2) backing in the dorsocranial area of the acetabulum. It was only in this area that fractures of the threaded cups were found. This region constitutes the main direction of the transmission of force into the pelvis [9, 15]. Owing to the inadequate backing mentioned previously, the maximum stress of the implants regarding their dynamic strength was exceeded as a result of compressive and tensile stress, which subsequently might result in fracture of the prosthesis. We excluded other potential causes, such as femoroacetabular impingement, extensive osteolysis, or infections. If a sufficient amount of bone subsists dorsocranially, maximum ingrowth of the bone on the base of the cup and in the area surrounding the thread can be observed [2]. The use of bone grafts cannot always withstand the large forces (Patient 2) because the limited biologic potency of the graft cannot allow the graft to incorporate before it mechanically fails [13].

The location of the defect is most remarkable. Defects in the anterosuperior area, which are typical of dysplasia, can

be treated with a threaded cup without difficulty. To our knowledge, there have been no cup fractures when threaded cups were used in the treatment of patients with congenital hip dysplasia. Furthermore, because this treatment option is suitable for revisions [14], the more uncommon dorsocranial defects cannot be treated in the same way.

Threaded cups have been recommended as an implant for segmental defects and revision situations [14]. Based on our observations, however, location of the defects appears to be of decisive importance. Therefore, we believe press-fit cups with their thicker walls are preferable in cases with osseous dorsocranial defects to ensure stability. Bone defects in the dorsocranial area can lead to overstrengthening of the cup, which might in turn cause fracture of the implant. In cases with this specific defect situation, we prefer press-fit cups over threaded cups.

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