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Case Report

Fractures of Cementless Thin-Walled Cups

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Abstract: Cementless threaded cups are commonly used in total hip arthroplasty. A method to match the elasticity of the cup to that of natural bone is reducing the wall thickness of the implant. Despite good results with this philosophy of implantation, we recently observed 3 cases of implant fractures after the implantation of such thin-walled cups called "Bicon." We performed a thorough analysis of 1 of these cases including a histological examination and a technical failure analysis (including scanning electron microscopy) to establish the chronology and cause of the failure. Multiple fractures of the thin-walled metal-back cup were determined to be caused by fatigue. We have concluded that due to the specific material and design parameters of this cup, under adverse circumstances such as the lack of primary or secondary osteointegration, there is a risk of failure due to fatigue. **Key words:** total hip arthroplasty, threaded cups, implant failure.
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Threaded cups have been proven to be suitable for cementless hip arthroplasty as well as spherical press-fit cups [1,2]. Ever since Morscher [3,4] examined the problems of elasticity of hip joint implants, efforts have been made to match the elasticity module to that of natural bone. One way to achieve this is to reduce the thickness of the implant wall. The Bicon cup system (Plus Endoprothetik AG, Rotkreuz, Switzerland) represents the concept of thin-walled cups (Zweymüller) and has shown good results [1,2,5]. With this implant, there is the opportunity to use various different bearings, such as polyethylene on metal, metal on metal, or ceramic on ceramic. However, despite good clinical results, we recently observed 3 cases of Bicon cup implant fractures [2]. All 3 had hip joint arthroplasty between 4 and 7 years before the fractures. At the time of surgery, each showed good bone stock, and the arthroplasty was followed by normal osteointegration. Thereafter, none experienced any clinical or functional problems for a period of several years. Two of the patients had polyethylene on ceramic; the third had metal-on-metal bearings. The onset of pain was initiated by a minimal trauma in only 1 case. Each showed radiolucent areas in DeLee/Charnley zones I and II. To establish the chronology and cause of the failure, we performed a thorough analysis of 1 of the abovementioned cases.

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Case Study

In March 1995, a 51-year-old woman having dysplastic coxarthrosis, type 2 according to Hartofilikadis et al [6,7], with severely reduced range of

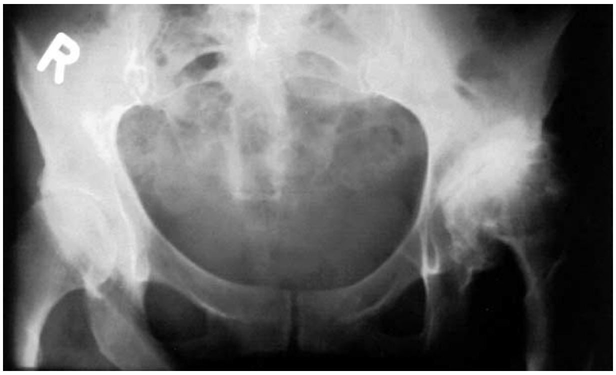

Fig. 1. Preoperative radiograph with dysplastic coxarthrosis type 2 according to Crowe on the left side.

motion and a leg length discrepancy of 2 cm, underwent primary total hip arthroplasty. She weighed 70 kg and had a body mass index of 26 m^2/kg (Fig. 1).

A Bicon cup (Plus Endoprothetik AG) with the following measurements was implanted: size 5 (outer diameter 56, inner diameter 53, wall thickness 1.5 mm), a Sikomet metal-on-metal bearing (sandwich liner with polyethylene between the cup and the metallic bearing part) (Sikov Medizintechnik GmbH, Vienna, Austria), and an "SL" straight tapered stem (Fig. 2).

The cup was positioned in the "true acetabular region" according to Stans et al [8] and in the

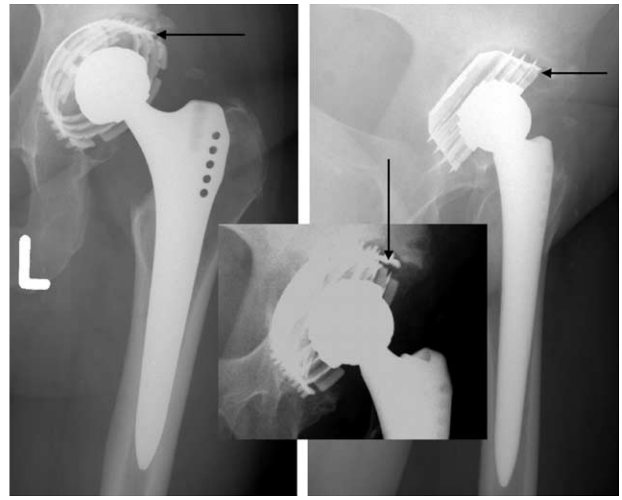

Fig. 3. X-ray 6 years postoperative with a fine fracture line in the craniolateral part of the cup, best seen in the axial view and radiolucent lines in the bone-implant interface in zones I and II.

Lewinnek safe zone [9] with an inclination angle of 47° and a radiological anteversion angle of 24°.

In January 2001, after 6 years without any symptoms, the patient sustained a minor trauma by falling on ice. The patient had increasing pain and was examined in our hospital in May 2001. Radiographs revealed distinct radiolucent lines around the acetabulum in DeLee/Charnley zones I and II (corresponding to type II of Effenberger

Fig. 2. Total hip arthroplasty 3 days postoperative.

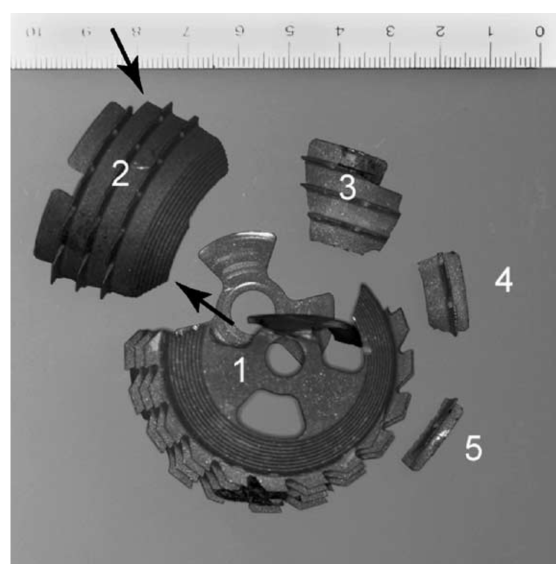

Fig. 4. Macroscopic overview of the cup fractured into 5 fragments. Fragments 1, 2, and 3 due to fatigue, fragments 4 and 5 generated during revision surgery.

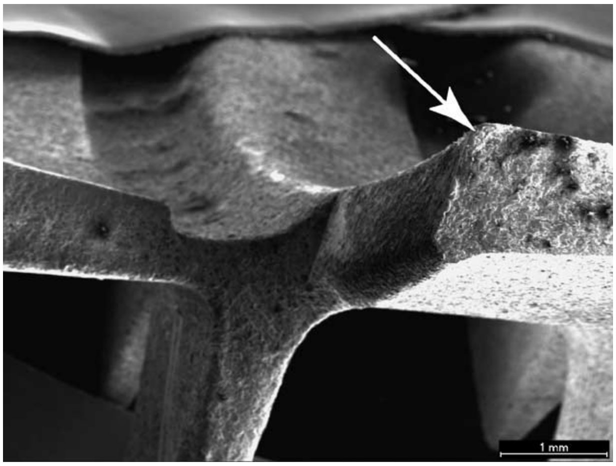

Fig. 5. SEM image (magnification ×25) of fragment 2. The arrow marks the origin of a crack at 1 of the notches for the insertion instrument (region of the upper arrow in Fig. 4).

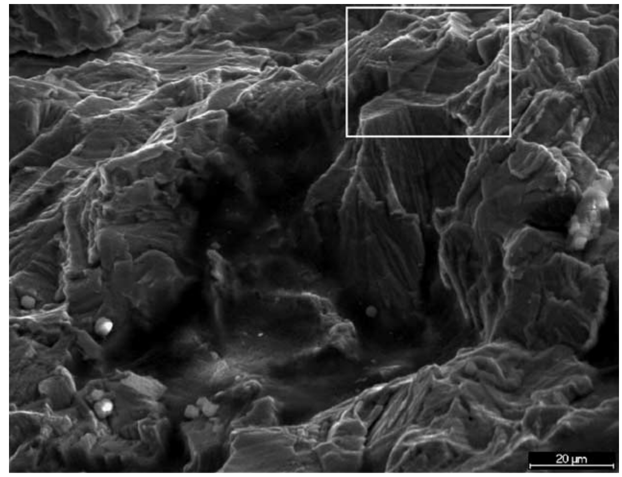

Fig. 7. SEM image (magnification ×800) of the fracture surface at the polar region of fragment 2 (lower arrow in Fig. 4).

et al [10]) which had not been visible in previous years. An exact tangential radiograph of the acetabulum revealed a fine hardly noticeable fracture line in the implant (Fig. 3). In June 2001, revision surgery was performed, and it was discovered that the cup had fractured into 3 fragments. There were no signs of impingement at the stem's neck or at the corresponding rim of the metal insert. The insert was intact and not dislocated.

Results

Histological analysis revealed metallosis with 2 types of intracellular inclusions as a reaction to wear debris. A determination whether the wear particles were made of titanium or chrome-cobalt could not be made.

Failure analysis of the cup revealed multiple fractures with a hemicircular crack in the polar area and several radial cracks starting at the grooves for the insertion device (Fig. 4). The cup was broken into 5 fragments; however, 2 of these fragments had been created during the revision operation by the extraction of the implant.

No material defects, such as inhomogeneities, occlusions, shrink holes, and so on, were discernible using macroscopic examination and scanning electron microscopy (SEM). In addition, there was

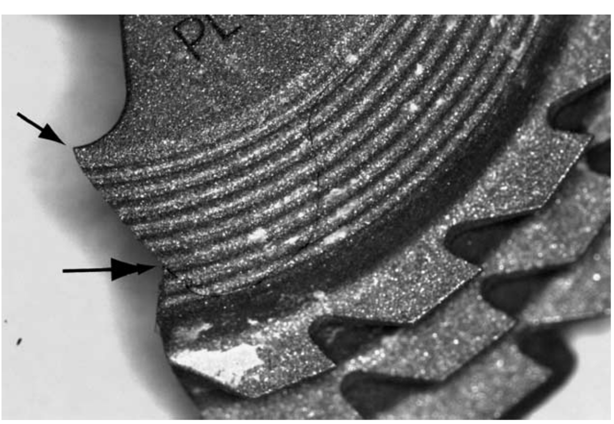

Fig. 6. Macroscopic view of the polar region of fragment 1. Crack origin marked with arrow; later, the crack branched out into 2 flaws (double arrows).

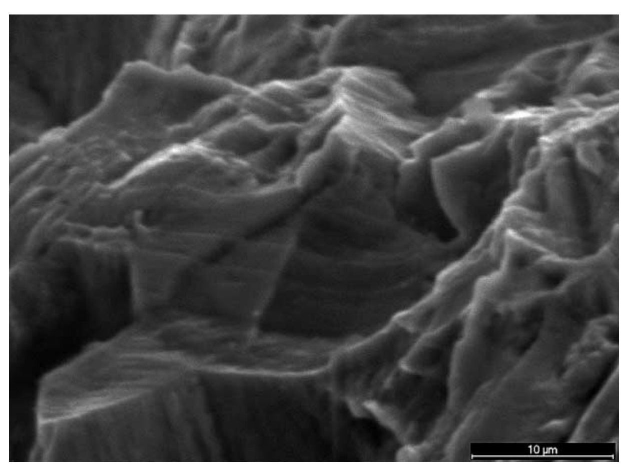

Fig. 8. SEM detail of Fig. 6 (magnification ×3000) showing fracture surface with striations (marked rectangle in Fig. 6).

no proof of flawed manufacturing or improper implantation. Using SEM, the origin of cracks and the type of fracture (fatigue vs forced rupture) could be analyzed. On fragment 2 (Fig. 4), there were 2 regions where cracks had developed independently of each other (see arrows in Fig. 4). One crack started at 1 of the notches for the insertion instrument (Fig. 5). The other crack began near the polar region from 1 of the 3 holes and later branched out into 2 flaws (Fig. 6).

The fact that there were multiple origins for the cracks proves that the implant was generally overloaded. All cracks developed sequentially. A forced rupture due to the patient's traumatic fall could be excluded as the cause by the presence of so-called striations. Fig. 7 displays the fracture surface of fragment 2 at the polar region. At high magnification, the striations, which are typical of fatigue failure, are recognizable (Fig. 8).

Discussion

Failure analysis of the cup revealed that the multiple fractures were due to fatigue. Therefore, although this patient had fallen onto the hip, the failure of the implant was not the result of this trauma. The primary cause for failure was general overloading of the implant. Multiple cracks developed from regions of high mechanical loading and stress concentrations, for example, the notches for the insertion instrument and holes in the polar region. The coarsely blasted outer surface of this thin-walled implant made of pure titanium was a further factor that led to failure because of the notching sensitivity of this material. SEM investigation proved that the cracks increased slowly by cyclic loading of the patient. The location of the crack origins corresponded on one hand with the hoop and bending stress within the cup and, on the other hand, with the design of the shell with its equatorial grooves and polar perforations.

Based on these results and our experience, we have concluded that under adverse circumstances such as the lack of primary or secondary osteointegration, which is due to specific material and design parameters of a thin-walled cup as in the abovementioned case study, there is a risk that cups cannot accommodate long-term mechanical loading.

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