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Case report

Do Not Postpone Revision of Worn Conventional Liners in Ceramic-on-Polyethylene Total Hip Arthroplasty: A New Dramatic Failure

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ABSTRACT

Catastrophic failure of ceramic-on-polyethylene total hip arthroplasty is still occasionally described. We report on a new case of complete atraumatic penetration of an intact ceramic head through the titanium cup in a cementless total hip arthroplasty due to dramatic polyethylene and metal wear. We reviewed the literature for similar cases and analyzed potential risk factors. Most importantly, revision of radiologically worn liners should not be postponed, especially in young and active patients with conventional liners, because the time to dramatic failure could be shorter than expected.

Introduction

Catastrophic failure of ceramic-on-polyethylene total hip arthroplasty (THA) in the setting of massive material wear is still occasionally described as case reports [1-13]. Despite continuous evolution in the manufacturing of arthroplasty materials, this mode of failure has not yet been eliminated, as all bearing surfaces will wear [14]. There was no superiority between different bearing surfaces in young and active patients until long-term follow-up [15,16]. However, focusing on ceramic-on-polyethylene bearing THA, ceramic heads were associated with reduced wear of conventional polyethylene liners among young and active patients compared with metal heads on long-term follow-up [17]. Further comparison between conventional and highly cross-linked polyethylene liners has demonstrated a lower risk of osteolysis of the latter, as well as protrusion of small-diameter metal heads showing promising clinical results [18-20]. Patients with polyethylene wear might present with mild symptoms or even be asymptomatic. Furthermore, the wear process might show a rapid progression over a short time. As a result, a direct articulation between the femoral head and the acetabular component occurs, leading to massive erosion, extensive soft-tissue reaction, subluxation, or dislocation-like conditions. Here, we report on a new case of such dramatic failures, leaving the ceramic head unfractured. While reviewing the literature, 12 similar cases in 11 reports have been extracted [1-11]. A detailed analysis of all cases, including our case, has been undertaken in this report. Written informed consent was given for publication of this de-identified case report by the involved patient.

Case report

Our female patient had presented at our outpatient clinic for the first time because of advanced knee osteoarthritis on the left side in April 2019. She was 68 years old, and total knee arthroplasty was indicated and scheduled. Her surgical history revealed an ipsilateral cementless THA (SL titanium cup 52 mm, conventional liner, forte ceramic head 28 mm, Spotorno stem; Protek Co., Freiburg, Germany) from 1998 (at the age of 47 years), which had been followed by a THA on the right side 1 year later.

On admission day, an eccentric position of the femoral head was observed on the preoperative standing view of the whole left leg (Fig. 1a). This finding was discussed with the patient, and revision surgery was recommended. At that time, she had no complaints

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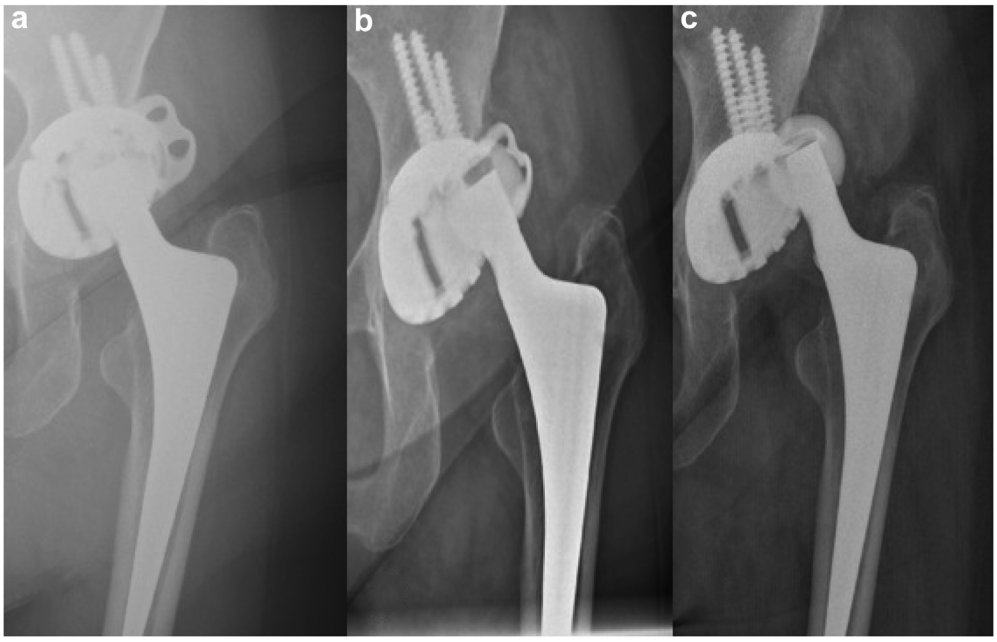

Figure 1. Radiographs from April 2019 (a), November 2020 (b), and January 2021 (c) showing the progression of the massive polyethylene and metal wear leading to penetration of the ceramic head through the superolateral part of the cementless titanium cup. The bubble sign of sever metallosis can be seen in Figure 1c.

about the left hip. Owing to the disabling pain in the knee, she decided to be first operated on the left knee. A non-complicated revision on the left hip was recommended at discharge to be performed as soon as possible. Still, the patient did not appear for 18 months because of personal reasons and later because of restrictions in performing elective surgery during the pandemic of COVID-19.

The patient presented again in November 2020, now 69 years old and with a body mass index of 27 kg/m^2, complaining of mild pain, limping, and squeaking in her left hip for a few months. Radiographs showed worsening of the wear with subluxation of the femoral head and evidence of destructive metallosis showing a time interval of 18 months between only liner wear and complete penetration of the metal cup. On admission day (January 2021), there was more deterioration as the head was superolaterally dislocated (Fig. 1b and c).

The preoperative hip aspiration to exclude periprosthetic joint infection (PJI) revealed no culture growth but elevated alpha-defensin (+1,1 quotient). The total white blood cell count was 772 cells/μl; however, with a high polymorphonuclear percentage (76,5%). The serum C-reactive protein and leukocyte levels were within normal ranges.

We revised the left hip using the posterolateral approach in the lateral decubitus position. During surgery, a large black metallic effusion under pressure was encountered, indicating a massive metallosis. Extensive soft-tissue debridement had to be performed

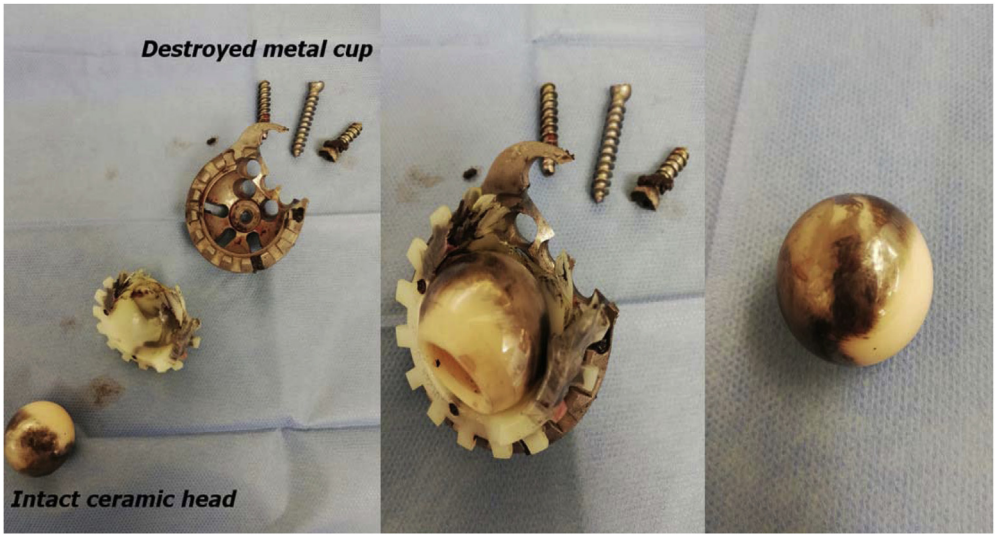

Figure 2. The explanted prosthesis components showing the extensive wear of both the conventional liner and the cementless titanium cup. The penetrated ceramic head shows only black-metallic discoloration without fracture.

because of the gross wear depositions, including an extensive cystic granuloma for both polyethylene and metal wear. The superolateral parts of both the loose cup and the liner were completely worn off. The ceramic head was only black-metallic discolored in the corresponding part but not broken and without significant cracking (Fig. 2). After removing the worn implants, reconstruction of the acetabulum was performed using a cementless revision tantalum shell. A dual mobility cup (Avantage system; Zimmer Biomet Co., Warsaw, IN) was cemented inside it to reduce the risk of dislocation (Fig. 3). The stem was not loose, and the taper showed only grade 2 mild damage, according to Goldberg et al. [21]. Unfortunately, no photos were taken of either the joint before explantation and initial debridement or stem taper. The stem was not revised, and a metal head was used (Avantage system; Zimmer Biomet Co., Warsaw, IN). Postoperatively, intravenous cefazolin every 8 hours was administered for 5 days as antibiotic prophylaxis. Partial weight-bearing (30 kg) was initiated for 3 weeks, followed by a gradual increase in loading (10 kg/week) up to full weight-bearing.

The histological result was congruent with the intraoperative findings showing metal and polyethylene particle deposits with accumulates of macrophages and without signs of infection. Microbiologically, all taken periprosthetic tissue samples were culture negative.

Discussion

Previous reports have suggested potential risk factors for accelerated polyethylene wear, such as high demand of young and active patients, conventional liners, liner thickness, wear at the metal-polyethylene interface, foreign body debris, cup positioning with increased inclination angle, cup design, and multiple joint replacements [1,2,7-11].

Our patient had several risk factors as she was active and relatively young. Analyzing her THA, the cup inclination angle was 55° increasing the load at the cranial part of the cup. Inclination angles above 55° increase the load per unit area in that part with potentially increased risk of wear [3,7,8,10,22]. Having multiple holes in the craniolateral portion of her cup could be involved in the rapid progression of the metal wear. A thin, conventional liner (implanted 23 years ago) was also used. The liner thickness in our case could not be accurately identified (between 3 mm and 5 mm). However, crosslinking seems more effective than the thickness, as crosslinking with decreased liner thickness from 3 mm to 6 mm was not associated with relevant wear differences [23]. In addition, she had multiple joint replacements, which could have a negative impact on her weight-bearing and gait pattern.

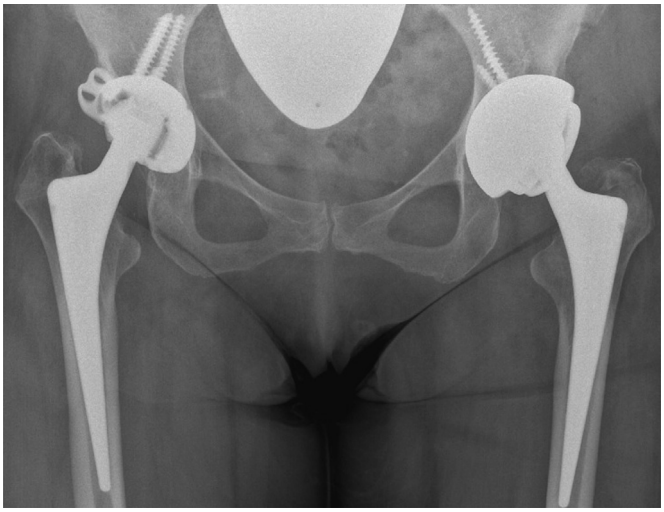

Figure 3. Postoperative radiograph showing the reconstruction of the left acetabulum with a revision tantalum shell. A dual mobility cup was cemented inside it. Eccentric head position can be noted on the right side with the same failed components on the left side; therefore, a future revision was scheduled.

Despite that the risk of wear could be higher in metal-on-polyethylene bearing [17], the number of recorded penetration of ceramic heads through the metal cup is comparable with the reported cases of penetrated metal heads, suggesting that femoral head materials did not exhibit a significant risk factor for such failures [24-29].

Polyethylene manufacturing seems to have a more critical role than the head material because thin and conventional liners were common findings among the cases regardless of the articulating head, and they might have mainly contributed to such catastrophic failures [1-11]. Recent literature has demonstrated favorable long-term THA results using highly cross-linked polyethylene liners with different ceramic and metal heads in general populations, as well as in young patients showing low wear rates [15-20].

Sterilization of ultra-high-molecular-weight polyethylene by gamma or electron beam irradiation (25-40 kGy) induces the formation of free radicals followed by oxidative reactions and molecular weight degradation. As a result, wear and delamination can occur [19,30]. Cross-linked implants were introduced for clinical application at the end of the 1990s. For first-generation cross-linking, saturation could be achieved by a value of 100 kGy of ionizing radiation, followed by thermal remelting to stabilize the free radicals leading to a decrease in the deformation susceptibility of ultra-high-molecular-weight polyethylene. In second-generation crosslinking, vitamin E is used [30].

In all 12 cases, including the current case, cementless THAs using titanium cups were implanted. All of them have reported massive wear of polyethylene liners and metal cups, resulting in penetration of intact ceramic femoral heads [1-11]. We reviewed each case, also considering the discussion by the authors in an attempt to identify common causes of such dramatic failure. Several factors have been considered, including patient- and implant-related data (Table 1). Demographically, the mean age of the affected patients at the time of presentation with reported failures was 57 years (range, 35-85). However, the mean age at primary implantation was 42 years (range, 24-72). Nearly two-thirds were female. It has been reported that the vast majority of the patients were highly demanding active patients. Except for 3 cases, wear and consequently penetration of the ceramic head occurred in the craniolateral portion of the titanium cup with complete erosion of the cup's craniolateral rim in most cases, which highlights the importance of proper positioning of the acetabular component. In those 3 cases, the heads had penetrated centrally. Head sizes were 28 mm and 32 mm without a significant difference in frequency. Different cup sizes were reported, but it is worth mentioning that a specific cup (OptiFix; Smith & Nephew Co., Memphis, TN) from one manufacturer was used in 5 cases. While the average time from primary implantation to failure was 11.6 years (range, 3-22), the time from manifestation to failure was about only 7 months (range, 1-24) according to available data [1-11].

Despite the direct contact between the ceramic head and the metal cup under weight-bearing for a long time, the ceramic head did not fracture in all cases. In addition to the 12 cases, 2 further case reports have described atraumatic penetrations of the intact ceramic heads through metal cups, however, after liner dissociation or liner fracture [12,13]. This highlights the rigidity of ceramic heads against fracture. Alumina mixed heads have shown a lower wear rate than pure alumina heads [31]. The mixed alumina ceramic

Table 1
Retrieved cases from the literature with penetration of an intact ceramic femoral head through a metal cup due to massive wear of ceramic-on-polyethylene total hip arthroplasty.

Author year	Gender	Age (revision/implantation)	Body mass index	Complaint	Time to failure (y)	Year of implantation	Location of penetration	Cup/diameter	Liner thickness	Head	Stem revised	Manufacturer	Possible risk factor by author
Simon/1998 [1]	F	35/29		Groin pain for 18 mo	6	<1992	Lateral	OptiFox 46 mm	3 mm	28 alumina	No	Smith & Nephew Richards, Memphis, TN (cup). Depuy, Warsaw, IN (head)	Thin liner, wear at metal-polythylene interface, young and active patient
Simon/1998 [1]	M	65/58		Squeaking	7	1989	Lateral	OptiFox 54 mm	3 mm	32 alumina	No	Smith & Nephew Richards, Memphis, TN	Thin liner, wear at metal-polythylene interface, high demand of young and active patient
Tsarouhas/2008 [2]	F	72/69		Pain for 4 mo, squeaking	3	<2005	Lateral	Press-fit 46 mm		28 alumina		Plus Orthopedics, Switzerland	
Needham/2008 [3]	F	49/33		Instability and discomfort for 3 wk	16	<1992	Lateral	OptiFix 56 mm	3.7 mm	32 alumina Biolox forte	Yes	Smith & Nephew Richards, Memphis, TN (cup). Plochingen, Germany (Biolox forte head)	Thin liner, wear at metal-polythylene interface, high demand of young and active patient, foreign body debris, incresed cup inclination angle
Sathappan/2009 [4]	F	85/72	23	Pain for 3 mo, inability to bear	13	<1996	Lateral	56 mm			No	Depuy, Leeds, United Kingdom	
Knox/2009 [5]	F	51/42		Increasing pain over about 2 y	9	<2000	Lateral	Furlong cup	10 mm	28 mm	No	JRI, London, UK	
Malizos/2009 [6]	M	38/24			14	<1995	Lateral	OptiFix 54 mm	3 mm	32 mm alumina Biolox	No	Smith & Nephew Richards, Memphis, Tennessee	
Mariconda/2010 [7]	F	50/39	27	Increasing pain for 6 mo	11	1995	Lateral	Expansion cup 50 mm	Conventional	32 mm alumina	No	Center pulse, Sulzer/ Winterthur, Switzerland	Increased cup inclination angle, expansion cup design
Yoon/2012 [8]	M	53/37		Increasing pain	16	1991	Lateral	Optifix	9 mm, conventional	32 mm alumina	No	Smith & Nephew Richards, Memphis, Tennessee	Inclination angle, bilateral affection
Manzano/2014 [9]	M	57/47		Increasing pain over months	10	1994-1995	Central	54 mm	Conventional	28 mm	No	Wright Technologies, Arlington, TN	Conventional liner
Joyce/2017 [10]	M	50/47		Pain for >1 mo	3	2009	Central				No		

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Table 1 (*continued*)

Author year	Gender	Age (revision/implantation)	Body mass index	Complaint	Time to failure (y)	Year of implantation	Location of penetration	Cup/diameter	Liner thickness	Head	Stem revised	Manufacturer	Possible risk factor by author
Malahias/ 2019 [11]	F	74/53	20	Pain, limping	21	1996	Central	REFLECTION 48 mm	Conventional	28 mm	Yes	Smith & Nephew, Andover, MA	Cup positioning, patient activity Young and active patient, Conventional liner
Current case	F	69/47	27	Limp, squeaking, mild pain for few months	22	1998	Lateral	SL cup	Conventional	28 mm	No	Protek/Zimmer	Young and active patient, conventional linear, increased cup inclination, cup design with multiple holes, multiple joint replacement

consists of Biolox delta (CeramTec, Plochingen, Germany) 82% alumina, 17% zirconium oxide, 0.3% chromium oxide, and 0.6% strontium oxide [32].

Preoperative joint aspiration before revision THA is mandatory despite a given indication for a soon surgery, as coincidental PJI is reported to be detected up to 18% [33]. However, PJI workup in case of adverse local tissue reaction could be challenging [34,35]. In our case, the polymorphonuclear percentage of synovial white blood cell count and alpha-defensin were elevated, resulting in 5 points in the newly proposed scoring system for diagnosing PJI and consequently a highly suspected PJI [35]. But arthroplasty surgeons should be aware of this fact and not be confused. All the available clinical, radiological, microbiological, and cytological results must be as a whole interpreted. Intraoperative samples should be sent for both microbiological and histological investigations to confirm the diagnoses and exclude infection.

We emphasize that patients with significant radiological signs of polyethylene wear, especially conventional liners, have to undergo the recommended revision as soon as possible, as the progression of the wear might be faster than thought. Recommendations during surgical consultation must be clear for patients with old thin and conventional polyethylene liners. Even in asymptomatic patients or those with mild symptoms, catastrophic failure might occur, requiring more complex revision procedures. Despite the proper-functioning gluteus medius, we revised our patient using a dual mobility cup to minimize the risk of dislocation, particularly after the needed debridement during surgery.

Summary

- Patients with femoral head penetration of the acetabular component might still present in future with challenging PJI workup. Therefore, management of such cases is recommended to be undertaken in specialized centers.
- Time to failure from the beginning of manifestations is relatively short. Therefore, when wear is radiologically seen, surgery should not be postponed to enable an uncomplicated, simple revision.
- In young and active patients, conventional liners should be avoided. Alumina and mixed alumina ceramic heads on highly cross-linked liners could be the best bearing.
- Attempts should be made to position the acetabular component optimally, not only to decrease the risk of dislocation but also to decrease possible wear.
- Despite the absence of symptoms, regular radiological follow-up is advocated, especially for young and active patients and those with multiple arthroplasties.

Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: The authors declare that they have no conflict of interest regarding this article. Outside the article, one or more of the authors (M. Citak and T. Gehrke) of this article have disclosed the following disclosures: Waldemar Link (T. Gehrke and M. Citak), Ceramtec, Heraeus, and Zimmer (T. Gehrke).

Informed patient consent

The author(s) confirm that informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they

have given approval for this information to be published in this case report (series).

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