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Revision Total Hip Arthroplasty after Ceramic Bearing Fractures in Patients Under 60-years Old; Mid-term Results

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Purpose: Although advances in technology have reduced the risk of ceramic implant fractures in total hip arthroplasty, these injuries do occur and their treatment remains challenging. There is a lack of studies reporting on the effectiveness of ceramic components in revision hip arthroplasty after ceramic bearing fracture. The aim of this study is to evaluate clinical and radiologic outcomes of revision surgery with ceramic-on-ceramic components after ceramic bearing fractures in young (i.e., under 60 years old) and active patients.

Materials and Methods: Eight patients who, from May 2004 to November 2011, underwent ceramic-on-ceramic revision surgery following a ceramic component fracture and had more than 6 years follow up were enrolled in this study. All eight patients were male with mean ages at first and revision surgeries of 39 years (range, 31-50 years) and 43.8 years (range, 33-60 years), respectively. There were 6 and 2 cases of ceramic liner and ceramic head fractures, respectively. The average time from the first operation to revision surgery was 54.3 months (range, 9-120 months), and the average follow up period was 9.7 years (range, 6-13.3 years).

Results: At the last follow up, all patients showed improvement in Harris hip score and pain relief and there were no cases of loosening or osteolysis.

Conclusion: Revision total hip arthroplasty using ceramic-on-ceramic components after ceramic component fracture is a feasible and appropriate surgical option in young and active patients.

Key Words: Hip prosthesis, Ceramic fracture, Revision hip surgery

INTRODUCTION

Total hip arthroplasty (THA) has been successfully used for the treatment of end-stage hip disease; however, THA failures have occurred in the long term, most commonly due to aseptic loosening caused by periprosthetic osteolysis[1]. Since the leading cause of loosening has been identified as polyethylene wear debris of acetabular prostheses after THA using metal-on-polyethylene articulations, studies on alternative bearing surfaces are actively being pursued[2].

Aseptic loosening and subsequent periprosthetic osteolysis have emerged as serious problems, particularly in young and active patients who have a longer life expectancy and

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use an excessive range of hip motion[3-5]. More wear-resistant ceramic-on-ceramic (CoC) articulations and alumina-on-alumina articulations with a lower coefficient of friction (0.09) compared with metal-on-polyethylene articulations (0.21) have drawn attention as attractive new alternatives for younger and more active patients based on their ability to avoid or significantly reduce problems associated with wear debris particles from polyethylene components[6,7]. Although the fracture rate of third-generation ceramic components has been reduced to 0.004%, concerns about the safety of CoC bearings remain because fractures of ceramic liners or heads have been reported after THA using CoC articulations[8-10].

For management of ceramic component fractures, complications (e.g., articulation wear and metallosis) have been reported when the fractured ceramic heads are replaced with metal-on-polyethylene bearings. A new stem and ceramic bearing can be implanted after removal of a well-fixed femoral stem, or a ceramic head can be inserted with a metal adapter[11,12]. Although controversy about treatment of ceramic liner fractures remains, revision surgery using CoC bearings is recommended[11,12]. Ceramic bearing fractures are rare and most previous studies have involved older patients[11] with short-term follow-up; only a few mid- and long-term studies on treatment outcomes of revision THA following ceramic bearing fractures in young and active patients have been reported[13].

The aim of this study is to evaluate the clinical and radiologic outcomes of revision THA using third-generation CoC articulation after ceramic bearing fractures in active patients under 60-years old.

MATERIALS AND METHODS

This study involved a total of 8 patients younger than 60 years of age who: i) underwent revision surgery with CoC bearings for management of a third-generation ceramic bearing fracture from May 2004 to November 2011 and ii) had a minimum follow-up of 6 years. The patients were all male. The mean ages at the time of the initial and revision operations were 39 years (range, 31-50 years) and 43.8 years (range, 33-60 years) years old, respectively. All patients were classified as American Society of Anesthesiologists (ASA) grade 1 before revision and the average follow-up period after revision was 9.7 years (range, 6-13.3 years). The most common reason for the initial THA was avascular necrosis of the femoral head (Table 1).

Table 1. Basic Characteristics and Results of the Patients

Patient	Age at revision (yr)	Initial diagnosis	Stem of primary THA	Cup of primary THA	Between prior operation and revision (mo)	Reason for 2nd operation	Complication after revision	Follow-up after last revision (mo)	Pre-HHS score	Last-HHS score
1	33	ONFH	Bicontact SD Stem	Aesculap, PLASMA Cup	21	Liner breakage	None	153	59	92
2	47	ONFH	Smith-Nephew, SL-Plus Stem	Smith-Nephew, EP-FIT PLUS Cup	50	Liner breakage	None	114	82	96
3	46	ONFH	Smith-Nephew, SL-Plus Stem	Smith-Nephew, EP-FIT PLUS Cup	84	Liner breakage	None	84	72	93
4	46	ONFH	Smith-Nephew, SL-Plus Stem	Smith-Nephew, EP-FIT PLUS Cup	9	Liner breakage	None	159	41	92
5	60	ONFH	Secu-Fit	Stryker, Trident Cup	120	Liner breakage	None	72	65	89
6	38	ONFH	Bicontact SD Stem	Aesculap, plasma Cup	45	Ceramic head breakage	None	132	53	86
7	39	ONFH	Smith-Nephew, SL-Plus Stem	Smith-Nephew, EP-FIT Plus Cup	30	Liner breakage	None	136	60	89
8	38	DDH sequelae	DePuy, AML	Depuy, Duraloc Option Cup	75	Ceramic head breakage	None	78	51	93

All patients were male.
THA: total hip arthroplasty, HHS: Harris hip score, ONFH: osteonecrosis femoral head, DDH: developmental dysplasia of hip.

Third-generation ceramic bearings were used in the first surgery for all patients. The liners used were a sandwich liner (n=4) and a full ceramic liner (n=4). The femoral head diameters were 28 mm (n=7) and 32 mm (n=1). The femoral neck lengths were short (n=4), medium (n=2), and long (n=2). There were 2 cases of ceramic head fracture and 6 cases of ceramic liner fracture. The causes for fracture of ceramic components were determined based on patient interview and medical records. Of the 2 patients with ceramic head fractures, fractures occurred after a fall (n=1) and without any trauma (n=1); a short neck was used in the initial surgery in both patients. Of the 6 patients with ceramic liner fracture, fracture appeared to be caused by trauma (n=1), improper position of the ceramic liner (n=1), and impingement associated with frequent stable squatting and sitting cross-legged positions (n=4).

Clinical evaluations involved: i) comparisons of pre- and post-operative Harris hip scores (HHS)[14], ii) assessment of ambulatory ability according to the Koval classification[15] preoperatively and at the last follow-up, and iii) pain assessments. Individuals were classified according to HHS as excellent (greater than 90 points), good (between 81 and 90 points), fair (between 71 and 80 points), or poor (less than 70 points). For radiologic evaluation, femoral osteolysis was assessed by dividing the proximal femur into seven Gruen zones[16]; progressive and continuous periprosthetic lucencies greater than 2 mm thick on postoperative follow-up radiographs were considered as indicating osteolysis. Patients were deemed to have acetabular osteolysis when continuous radiolucency lines greater than 2 mm thick were detected in DeLee and Charnley zones[17]. The presence of other complications was also examined.

Statistical analyses were performed using SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA). Data were analyzed using the Mann-Whitney *U*-test and Wilcoxon signed-rank test. Differences were considered statistically significant at $P<0.05$. This study was performed after gaining Institutional Review Board approval from our institution (2015-04-020).

RESULTS

A thorough synovectomy was performed at the time of revision surgery to prevent possible complications (e.g., third-body wear caused by residual ceramic particles and metallosis). Irrigation was repeated several times to remove any ceramic particles remaining in the adjacent soft tissue and bearing surfaces. One of the two patients with ceramic head fracture underwent revision using the fourth-generation ceramic bearing with metal adapter concerning plastic deformation of the Morse taper junction (Fig. 1); the other patient with head fracture underwent revision of the cup. The 6 patients with ceramic liner fractures underwent revision using the third-generation CoC bearings from the same manufacturer by replacing the original component to the

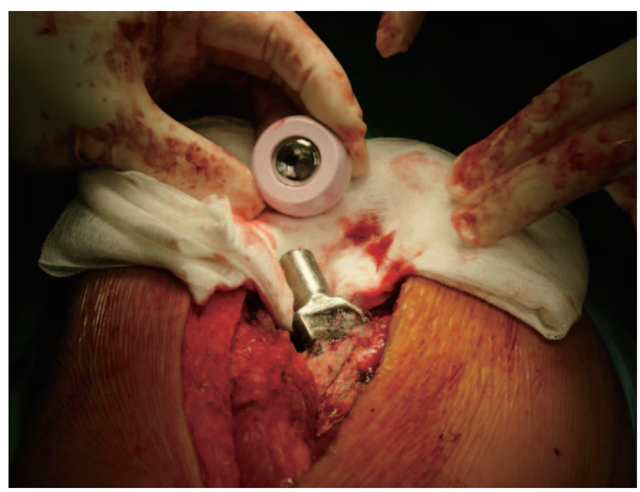

Fig. 1. Metal adaptor was used because of taper damage.

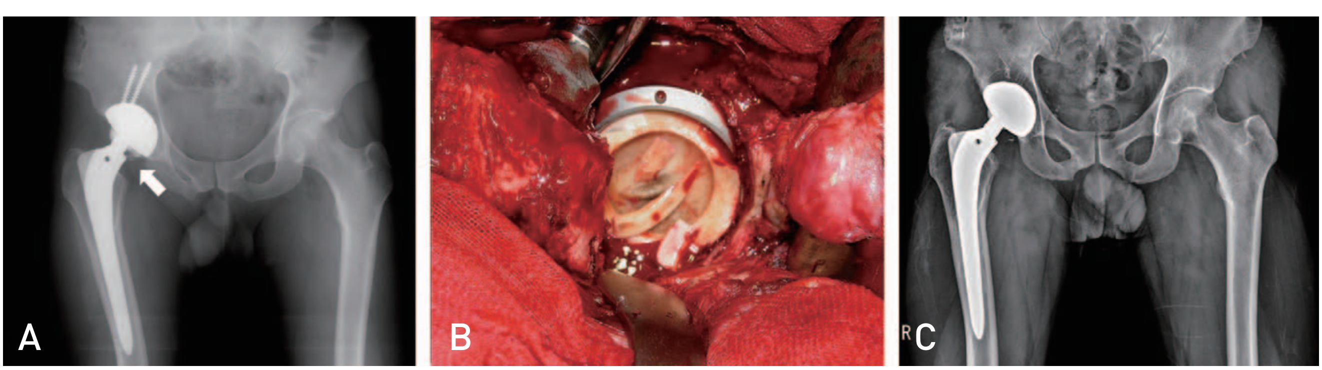

Fig. 2. (A) Anteroposterior radiograph of pelvis (patient 1) shows fractured ceramic particles (arrow). (B) Intraoperative photograph shows fractured ceramic liner. (C) Radiograph taken 9 years after revision surgery shows no osteolysis or implant loosening.

femoral head with a longer neck.

Clinical evaluations revealed that the average HHS improved from 63.2 points (range, 41-82 points) to 91.8 points (range, 86-96 points) (*P*=0.01). Favorable HHS outcomes were achieved in all cases (excellent, 5; good, 3). Although all 8 patients complained of mild pain after revision, pain was relieved with conservative management. Progressive improvement was noted and at the final follow-up visit, no patient complained of pain that influenced their ability to perform daily activities. The waling ability of all patients was evaluated as grade 1 (independent community ambulatory) according to the Koval classification[15], and there were no cases with diminished ambulatory ability at the last follow-up visit.

Radiologic assessment revealed no instances of loosening or osteolysis around the femoral or acetabular component and bony stability was achieved in all patients at the final follow up (Fig. 2). During the follow-up, one patient experienced heterotopic ossification in the absence of overt symptoms.

DISCUSSION

The leading cause of aseptic loosening–a major complication of hip arthtoplasty–has been identified as polyethylene wear debris of acetabular prostheses after THA using metal-on-polyethylene articulations. Because of this, studies on alternative bearing surfaces (e.g., metal-on-metal, CoC, ceramic-on-metal) are being actively pursued[18]. Of these bearing types, a CoC bearing appears to be an attractive alternative for younger and more active patients based on its improved wear resistance and lower coefficient of friction[6,7]. However, concerns about the safety of CoC bearings remain because ceramic liner or ceramic head fractures have been reported after CoC THA[8-10]. Excluding trauma, the major causes of alumina breakage are recognized to be neck-liner impingement and edge loading; these causes may be due to a reduction in head-neck ratio resulting from the use of 28 mm alumina head and circular-shaped neck, and the use of thinner, polyethylene-reinforced alumina liners. The use of a short-neck ceramic head is a known risk factor for ceramic head fracture[19]. Furthermore, a high rate of alumina liner breakage has been reported in patients with larger anteversion angles of the acetabular cup by Ha et al.[20] and in male patients with a heavier weight by Poggie et al[21]. In the present study, the subjects were all male and underwent surgeries with short-neck heads. Additional risk factors were the use of sandwich-type liners (n=4) and lifestyle habits that may be contributing to impingement (n=4).

Standard clinical guidelines for the treatment of third-generation ceramic fractures have not yet been established. In cases of ceramic head fractures, a newly replaced ceramic head can be fractured by stress concentrated on the head even with only mild erosive changes of the taper. Two revision THA treatment approaches have been suggested; the first is to insert a new stem and ceramic head after removing a well-fixed femoral stem and the alternative is to exchange the original components with cobalt-chromium femoral heads on polyethylene-bearing surfaces without stem revision[22].

In revision surgeries, the insertion of a new ceramic head onto a damaged Morse taper may result in weakened tensile strength within the ceramic components by concentrating areas of stress, and thus may initiate fractures in the newly implanted ceramic head. Although this potential challenge can be avoided by stem revision, the removal of a well-fixed femoral stem remains controversial and raises technical challenges (e.g., massive transfusion, prolonged operation time, and risk of complications such as damage to the remaining bone stock). Although rare, serious complications (e.g., metallosis) have been reported when using a metal head during revision THA due to ceramic particles that remain because of incomplete synovectomy[11,23,24]. In a multicenter survivorship study, Allain et al.[11] have reported that third-body wear can be accelerated by ceramic particles that remain in the adjacent soft tissue and bearing surfaces after revisions of ceramic head fracture. Matziolis et al.[24] have recommended that if the stem is not removed, CoC bearings with a metal adapter would be used because complete removal of ceramic debris during revision is impossible in most cases and residual ceramic particles in the metal-on-polyethene bearings can lead to the wear of metal bearings. In this study, taper damage was confirmed in 1 case with ceramic head fracture and a new ceramic head with a metal adapter was used.

The treatment of ceramic liner fractures remains controversial and has been rarely described[4,25,26]. Liner fractures typically have larger fragments than fractured head fragments, so the removal of the fractured fragments is easier; unless the head fracture is associated, revision with new CoC bearings can be performed because the Morse taper is not damaged. Park et al.[27] have suggested that, since ceramic heads are more durable than cobalt-chrome heads, more wear-resistant CoC bearings are favorable for use in revision surgeries of liner fractures with no gross damage to the Morse taper. Moreover, Traina et al.[26] and Hannouche[28] have performed revision surgeries using ceramic heads in patients with ceramic liner fractures. In our study involving young (i.e., less than 60 years old) and active patients, HHS improved, and no complications (e.g., metallosis, osteolysis and prosthetic loosening) occurred at the last follow-up in any revisions using CoC bearing surfaces after CoC bearing fracture.

This study was limited by the relatively small sample size. Additionally, no revisions using fourth-generation ceramic bearings–which are more durable and have improved wear resistance compared to third generation ceramic bearings were included in this study. Also, since most patients received their first surgery in other hospitals, the authors were unable to accurately assess the position of the acetabular and femoral components that could affect ceramic bearing surface fractures. However, the relatively small sample size rather attempts to demonstrate excellent hardness, wear resistance and biocompatibility of CoC bearing surfaces. Studies regarding fractures of fourth-generation ceramic heads have been rarely reported.

This study obtained satisfactory clinical and radiologic outcomes by performing revision THA using CoC components after ceramic bearing fracture with an average follow-up of 9.7 years in active patients under 60 years old. Further studies with larger sample sizes and longer follow-ups are necessary.

CONCLUSION

Considering wear in ceramic bearing surfaces, osteolysis and biocompatibility of ceramic wear particles, revision THA using CoC components after ceramic bearing fracture resulted in satisfactory clinical and radiologic results in young and active patients during an average follow-up of 9.7 years in our study. When performing revision for ceramic bearing fracture, a thorough synovectomy is recommended to prevent third-body wear caused by residual ceramic particles and the use of CoC bearing surface is considered to be a better option than metal-on-polyethylene bearing surfaces. If removal of the well-fixed femoral stem is unnecessary during revision surgery, the use of a ceramic head with a metal adapter might be a good option to avoid the risk of damaged Morse taper.

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CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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