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Mid-term Results of Revision Total Hip Arthroplasty Using Delta Ceramic-on-Ceramic Bearing

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Background: Delta ceramic-on-ceramic (CoC) articulation affords excellent outcomes in primary total hip arthroplasty (THA). However, the safety and reliability of this bearing in revision THA need more evidence. This study aimed to report complications, radiological changes, clinical results, and survivorship of revision THA using Delta CoC articulation at minimum 5-year follow-up.

Methods: We reviewed 118 revision THAs (113 patients: 68 men and 45 women) performed with use of Delta CoC bearing. Their mean age was 58.7 years (range, 30–90 years) and their mean body mass index was 24.6 kg/m^2 (range, 15.2–32.5 kg/m^2). These patients were followed up for 5–12 years (mean, 7.2 years). We evaluated squeak, grinding sensation, ceramic fracture, dislocation, periprosthetic joint infection (PJI), periprosthetic fracture, prosthetic loosening, ceramic wear, osteolysis, modified Harris hip score (mHHS), and survivorship with any reoperation after the revision as the endpoint.

Results: Two patients (1.7%) had grinding sensation, but no patient had ceramic fracture. Reoperations were necessary in 9 hips (7.6%) due to PJIs in 2, stem loosening in 2, cup loosening in 2, recurrent dislocation in 2, and periprosthetic fracture in 1. No hip had measurable wear or osteolysis. The average mHHS improved from 53.3 points before the revision to 82.3 points at the final follow-up. Survivorship was 91.6% (95% confidence interval, 86.3%–96.9%) at 12 years.

Conclusions: The Delta ceramic bearing appeared a reliable option for revision THA, showing encouraging mid-term results with acceptable survivorship and a low complication rate.

Keywords: *Revision hip arthroplasty, Delta ceramic, Complication, Survivorship*

Polyethylene wear and debris-related osteolysis are main causes of failure after total hip arthroplasty (THA). Contemporary ceramic-on-ceramic (CoC) articulations, which have excellent wear properties that can be translated into extended survivorship of THA, were introduced in the 1990s. However, noise and ceramic fracture appeared as serious complications of the CoC bearing.[1-3)]

Delta ceramic (BIOLOX Delta; CeramTec, Plochingen, Germany), a composite of 82% alumina and 17% zirconia, has been introduced to reduce ceramic fracture in 2005. This newest ceramic reduced the fracture rate of ceramic parts, especially head component, and showed excellent results in primary THA.[4,5)] The Delta CoC bearing might be a reliable bearing option in revision THA in young patients with a long life expectancy. However, only two studies have reported the results of revision THA using this bearing.[6,7)] The first study was a retrospective case review of a small cohort[6)] and the second one was a

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registry study, which lacked in follow-up rate and rigorous evaluation.[7]

Therefore, we conducted a retrospective review on a large cohort of consecutive patients, who underwent revision THA with use of the Delta CoC articulation, to determine the rates of squeaking and ceramic fracture, the incidence of periprosthetic joint infection (PJI), radiological changes, clinical results, and survivorship at mid-term follow-up.

METHODS

The design and protocol of this retrospective study were approved by the Institutional Review Board of Seoul National University Bundang Hospital (No. B-2103/670-103), which waived informed consent of patients.

From March 2008 to December 2015, 253 patients (277 hips) underwent revision THA with use of Delta CoC bearing at two tertiary referral hospitals. We excluded 76 patients (87 hips) who underwent revision surgery due to PJI because these patients needed multiple staged procedures and had poor outcome irrespective of the bearing type. Among the 177 non-PJI patients (190 hips), 64 patients (72 hips) who were not followed up for a minimum of 5 years were excluded. Finally, 113 patients (118 hips, 68 men and 45 women) were enrolled in this study (Fig. 1).

The mean age at the time of revision surgery was 58.7 ± 11.7 years (range, 30–90 years), and the mean body mass index was 24.6 ± 3.2 kg/m^2 (range, 15.2–32.5 kg/m^2). The mean follow-up period was 7.2 ± 2.1 years (range, 5–12 years). Prior operations were THA in 95 hips, bipolar hemiarthroplasty in 18 hips, and resurfacing arthroplasty in 5 hips. Reasons for the revision were aseptic implant loosening in 84 hips (cup loosening in 37, stem loosening in 22, and loosening of both components in 25), recurrent dislocation in 14, periprosthetic fracture in 13 (acetabular fracture in 4 and femur fracture in 9), fracture of ceramic liner in 6, and fracture of ceramic head in 1 hip. Prior articulations were metal-on-polyethylene in 51 hips, CoC in 30, ceramic-on-polyethylene in 28, metal-on-metal in 8, and metal-on-ceramic in 1 hip (Table 1). Ninety-three hips had acetabular osteolysis: 57 (61%) AAOS type II cavitary defects, 25 (27%) type III combined defects, 9 (10%) type I segmental defects, and 2 (2%) type IV pelvic discontinuities.[8] Sixty-four hips had femoral bone loss: 35 (55%) AAOS type II segmental defects, 23 (36%) type III combined defects, 5 (8%) type I segmental defects, and 1 (2%) type VI femoral discontinuity.[9]

All the revision operations were performed by three senior surgeons (KHK, YCH, and YKL) under spinal anesthesia in 23 patients, combined spinal and epidural an-

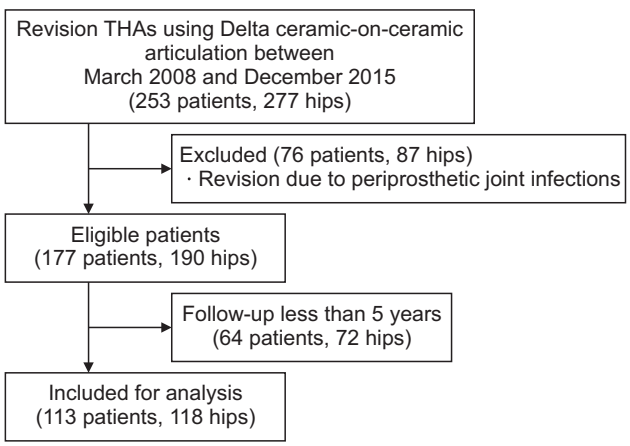

Fig. 1. Flowchart of patient recruitment. THA: total hip arthroplasty.

Table 1. Demographic Data of 113 Patients (118 Hips) Undergoing Revision Total Hip Arthroplasty Using Delta Ceramic-on-Ceramic Articulation

Variable	Value
Age (yr)	58.7 ± 11.7
Sex (male : female)	72 (61) : 46 (39)
Body mass index (kg/m^2)	24.6 ± 3.2
American Society of Anesthesiologists score	1.9 ± 0.7
Koval grade	1.6 ± 1.2
Primary surgery	
Total hip arthroplasty	95 (81)
Bipolar hemiarthroplasty	18 (15)
Resurfacing arthroplasty	5 (4)
Reasons for revision	
Aseptic loosening	
Cup	37 (31)
Stem	22 (19)
Both components	25 (21)
Recurrent dislocation	14 (12)
Periprosthetic fracture	
Acetabulum	4 (3)
Femur	9 (8)
Ceramic liner fracture	6 (5)
Ceramic head fracture	1 (1)

Values are presented as mean ± standard deviation or number (%).

esthesia in 50, and general anesthesia in 45. The posterior approach was used in 116 hips (98%), and the combined anterior and posterior approach in 2 (2%).[10] Both cup and stem were revised in 58 hips, only the cup was revised in 45, and only the stem was revised in 15. In 7 hips, a trochanteric osteotomy was done for the removal of the stem. Cementless components and Delta CoC bearings were used in all revisions (Table 2). The diameter of the ceramic head was 28 mm in 2 hips, 32 mm in 23, and 36 mm in 93.

Patients were instructed to walk with partial weight-bearing using crutches for 6 to 12 weeks after the surgery. The duration of the protected weight-bearing was individualized according to the intraoperative stability of the prosthesis and whether the trochanteric osteotomy was done. The patients were also advised to abstain from squatting or sitting on the floor to avoid ceramic fracture and noise.

Follow-up evaluations were done at postoperative 6 weeks, 3 months, 6 months, and 1 year, and yearly thereafter. Clinical evaluation was performed using the modified Harris hip score (mHHS).[11] At each follow-up, we asked patients whether they had noise on the operated hip using a questionnaire and a face-to-face interview. The noise, if present, was classified into snapping, clicking, popping, grinding sensation, or squeak.[12] Grinding sensation and squeak were considered as ceramic-related noises. Two independent observers (SJW and JHK), who did not participate in the index revision surgery or follow-

Table 2. Implants Used for 112 Revision Hip Arthroplasties

Variable	Manufacturer	Number
Cup		
Pinnacle cup	DePuy, Leeds, UK	36
Mirabo cup	Corentec, Cheonan, South Korea	22
Bencox cup	Corentec, Cheonan, South Korea	19
Exceed ABT cup	Biomet Orthopedics, Warsaw, IN, USA	8
Plasmacup	Aesculap, Tuttlingen, Germany	5
Continuum cup	Zimmer, Warsaw, IN, USA	4
Bencox Hybrid cup	Corentec, Cheonan, South Korea	4
Trilogy cup	Zimmer, Warsaw, IN, USA	3
G7 cup	Biomet Orthopedics, Warsaw, IN, USA	2
Total		103
Stem		
Bencox II stem	Corentec, Cheonan, South Korea	23
Benfix long stem	Corentec, Cheonan, South Korea	10
Arcos stem	Zimmer, Warsaw, IN, USA	10
KAR stem	DePuy, Leeds, UK	8
S-ROM stem	DePuy, Leeds, UK	6
Bicontact long stem	Aesculap, Tuttlingen, Germany	5
Taperloc stem	Biomet Orthopedics, Warsaw, IN, USA	4
Corail stem	DePuy, Leeds, UK	3
M stem	Corentec, Cheonan, South Korea	3
C2 stem	Lima Corporate, Villanova, Italy	1
Total		73

up evaluations, performed radiographic evaluations using the 6-week radiographs as the baseline for comparisons.

Cup abduction and anteversion were measured on postoperative 6-week radiographs.[13,14] To detect ceramic fracture, serial radiographs, hip anteroposterior views, and trans-lateral views were reviewed. If any radio-opaque density was seen around the hip joint, a ceramic fracture was suspected, and computed tomography scan was performed for confirmation. Stem fixation was assessed using the method of Engh et al.[15] and cup fixation using the method of Latimer and Lachiewicz.[16] The wear of ceramic bearing was measured according to the method of Livermore et al.[17] Osteolysis was diagnosed according to the criteria of Engh et al.[18] and was localized according to the 3 zones of DeLee and Charnley[19] on the acetabular side and according to the 7 zones of Gruen et al.[20] on the femoral side.

For statistical analysis, IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA) was used. To compare the variables between the two groups, Student *t*-test was used for the continuous variables while chi-square tests were used for categorical variables. Paired *t*-test was used to compare the preoperative and final mHHS. Kaplan-Meier method was used for the survival analysis. The endpoint was defined as reoperation after the index revision for any reason. The survival time of maintained implants was evaluated with the last follow-up date or the date of death. A p-value < 0.05 was considered significant.

RESULTS

Noise

Two patients (1.7%) reported grinding sensation. One patient, who underwent revision due to ceramic head fracture, experienced the noise at 4 years after the revision. The other patient, who underwent revision due to cup loosening, experienced the noise at 2 years after the revision. In both patients, the noise occurred intermittently while rising from sitting, squatting, or stooping, was not audible to others, and did not limit activities.

Ceramic Fracture

No ceramic head fracture occurred during the follow-up period and no radio-opaque density suggestive of chip fracture of the ceramic liner was seen on serial radiographs.

Clinical and Radiographic Assessment

The mean cup abduction and anteversion were 42.6° ± 5.3° (range, 25.7°–53.0°) and 23.4° ± 6.0° (range, 6.0°–37.0°), respectively. No hip had measurable wear or osteolysis except for 4 hips (2 hips with loose cups and 2 hips with loose stems), and all the cups and stems achieved bone-ingrown stability. The average mHHS improved from 53.3 points (range, 6–97 points) before the revision surgery to 82.3 points (range, 48–98 points) at the final follow-up (p < 0.001).

Other Complications

Dislocation occurred in 3 patients (3 hips). One patient was successfully treated with closed reduction and abduction bracing for 2 months. Two patients, who had recurrent dislocation, were treated with re-revision. In 1 patient, the short-neck head was changed with a long-neck head and in the other patient, the ceramic liner was changed with a 10° elevated polyethylene liner in addition to head exchange from a short-neck to a long-neck. After the revision, there was no recurrent dislocation in both patients.

PJI occurred in 2 patients and was treated with two-staged re-revision arthroplasty. After then, there was no evidence of recurrent infection until the final follow-up. Two patients had stem loosening and the loose stems were changed with longer ones. These two re-revised stems obtained bone-ingrown stability (Fig. 2). Two cups were loose and changed with larger ones. In 1 patient with cavitary defect, bone graft was done. In both patients, the re-revised cups obtained bone-ingrown stability (Fig. 3).

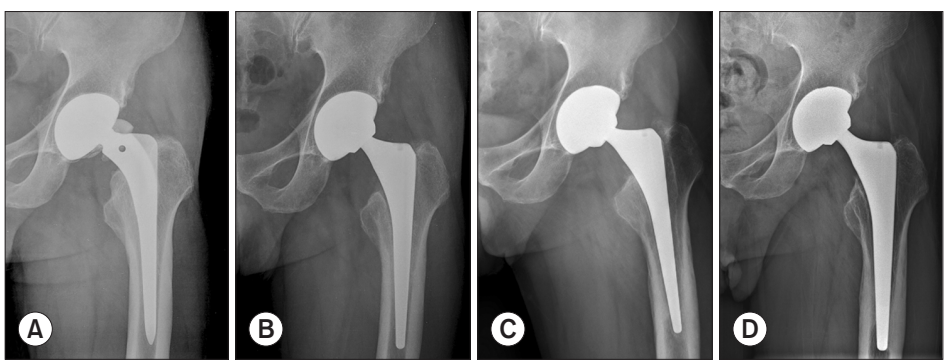

Fig. 2. (A) A 58-year-old male patient had a ceramic fracture at 8 years after ceramic-on-ceramic total hip arthroplasty. (B) Due to severe trunnion damage, the stem was revised and the bearing surface was changed with Delta ceramics. (C) The stem was loose at 5 years after the revision. (D) The loose stem was revised with a larger one and was stable at 5 years after the re-revision.

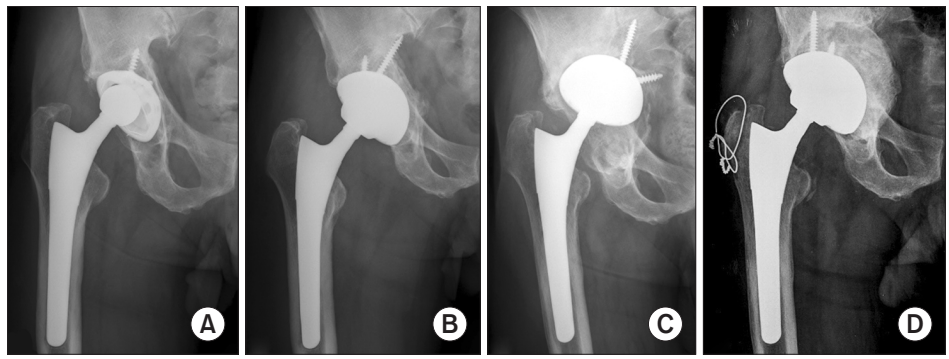

Fig. 3. (A) A 71-year-old male patient underwent revision due to wear of polyethylene liner at 22 years after primary total hip arthroplasty. (B) The cup was changed with a larger one and the bearing surface was changed with Delta ceramic head and liner. (C) On the postoperative 2-year radiograph, the revised cup protruded into the acetabulum. (D) The acetabular defect was filled with allograft bone and the loose cup was changed with a larger one. The cup was stable at 11 years after the re-revision.

One patient sustained Vancouver type B2 periprosthetic femoral fracture (PFF)[21] after a fall. The fracture was successfully treated with open reduction and internal fixation.

Survivorship

Reoperations were done in 9 hips (7.6%): 2 (1.7%) due to PJI, 2 (1.7%) due to stem loosening, 2 (1.7%) due to cup loosening, 2 (1.7%) due to recurrent dislocations, and 1 (0.8%) due to PFF (Table 3). Survivorship with any reoperation after the index revision as the endpoint was 91.6% (95% confidence interval, 86.3%–96.9%) at 12 years (Table 4, Fig. 4).

Table 3. Complications after 118 Revision Hip Arthroplasties Using Delta Ceramic-on-Ceramic Articulation

Complication	Case
Ceramic fracture	0
Cup loosening	2 (1.7)
Stem loosening	2 (1.7)
Dislocation	3 (2.5)
Periprosthetic joint infection	2 (1.7)
Periprosthetic femoral fracture	1 (0.8)
Noise	2 (1.7)

Values are presented as number (%).

DISCUSSION

In this mid-term large cohort study of revision THA using Delta CoC bearing, no ceramic fracture occurred, squeaking rate was 1.7%, the PJI rate was 1.7%, and the 12-year survival rate was 91.6%. The performance of the Delta CoC bearing for revision was reliable and comparable to previous studies.[6,7]

To date, only two studies have reported outcomes after revision THA using the Delta CoC bearing. Chang et al.[7] retrospectively reviewed 52 revisions using the Delta CoC bearing at 4 to 9.9 years postoperatively. In their study, no squeaking or ceramic fracture was reported, PJI was reported in 2 hips (3.8%), and pelvic osteolysis developed in 1 hip. Castagnini et al.[6] reviewed 327 revision THAs using the Delta CoC bearing surfaces to assess the survival rate and to identify reasons for re-revision using a regional registry in Italy. In their study, the mean follow-up period was 4.1 years (range, 0–10.5 years). Although the study included uncensored patients, the survival rate was 90.5%, and the reasons for re-revisions were recurrent dislocations in 2.8%, cup loosening in 1.5%, and septic loosening in 1.6%. The authors identified no ceramic fracture and did not report the rate of squeaking. There were no fractures of either ceramic head or ceramic liner in the current study, as well as in the two previous studies.[6,7] This finding might be related to the improved mechanical strength of the Delta ceramic composites, which translates into reduced brittleness and increased toughness.[22]

Noise is an annoying complication of CoC bearings. It was noted in 1.7% of our patients, while no patient had noise in prior studies of Castagnini et al.[6] and Chang et al.[7] The different study nature (rigorous evaluation with a specific questionnaire on squeaking at each follow-up versus retrospective review) might explain the differences in observed squeaking frequency between our study and the two prior studies. Furthermore, unlike Western people, most Korean patients have a lifestyle of sitting on the floor cross-legged, which might explain the high incidence of

Table 4. Number of Remaining Hips at Each Year after the Revision Surgery

Number at risk	Year											
	0	1	2	3	4	5	6	7	8	9	10	11
Hip	116	114	112	110	110	80	66	50	39	25	12	5

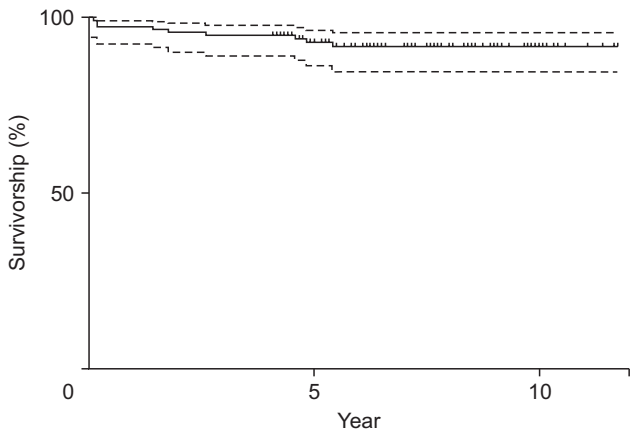

Fig. 4. Survivorship with any reoperation as the endpoint. Tick marks indicate censored data, dotted lines indicate the upper and lower limits of the 95% confidence interval.

squeaking in the current study.[23]

PJI is a devastating complication that can lead to reduced quality of life.[24] It is more frequent after revision THA than after primary THA.[25,26] Use of CoC bearings has been known to decrease the risk of PJI compared to other bearings.[27,28] Thus, one plausible merit of the use of a ceramic bearing in revision THA might be a low PJI rate. The PJI rate was 1.7% in our study, which is comparable to previous studies.[6,7]

This study has several limitations. First, it is a retrospective review and lacks a comparative control. Second, the mean body mass index of our patients was 24.6 kg/m^2. Results might be different in overweight or obese patients. Third, all revisions were done by expert surgeons, who optimally positioned the acetabular cup. Suboptimal positioning of the cup might increase the rates of dislocation, ceramic fracture, and noise. Fourth, we could not identify risk factor(s) for failure after this type of revision arthroplasty because the number of re-revision cases was too small for statistical analysis. Further studies with larger cohorts are warranted. Fifth, various acetabular cups and femoral stems were used in this study, and we could not determine the difference in the results according to the type of implant. The mid-term results of revision THA using the Delta CoC bearing were encouraging with a reliable survivorship. This bearing coupling is recommendable in revision THA for young patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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