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Is Restoration of Hip Center Mandatory for Total Hip Arthroplasty of Protrusio Acetabuli?

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Purpose: While initial fixation using a press-fit of the acetabular cup is critical for the durability of the component, restoration of the hip center is regarded as an attributable factor for implant survival and successful outcome. In protrusio acetabuli (PA), obtaining both restoration of the hip center and the press-fit of the acetabular cup simultaneously might be difficult during total hip arthroplasty (THA). We tested the hypothesis that use of a medialized cup, if press-fitted, will not result in compromise of the implant stability and outcome after cementless THA of PA.

Materials and Methods: A total of 26 cementless THAs of 22 patients with PA were reviewed. During THA, press-fit of the cup was prioritized rather than hip center restoration. A press-fit was obtained in 24 hips. A press-fit could not be obtained in the two remaining hips; therefore, reinforcement acetabular components were used. Restoration of the hip center was achieved in 17 cups; 15 primary cups and two reinforcement components; it was medialized in nine cups. Implant stability and modified Harris hip score (mHHS) between the two groups were compared at a mean follow-up of 5.1 years (range, 2-16 years).

Results: Twenty-six cups; 17 restored cups and nine medialized press-fitted cups, remained stable at the latest follow-up. A similar final mHHS was observed between the restored group and the medialized group (83.6±12.1 vs 83.8±10.4, *P*=0.786).

Conclusion: Implant stability and favorable results were obtained by press-fitted cups, irrespective of hip center restoration. THA in PA patients showed promising clinical and radiological results.

Key Words: Total hip arthroplasty, Protrusio acetabuli, Hip center, Medialization

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INTRODUCTION

Protrusio acetabuli (PA) is an intrapelvic displacement of the acetabulum and femoral head[1,2)]. Development of this deformity can occur as a result of various conditions that compromise the mechanical properties of the acetabulum[3,4)]. Total hip arthroplasty (THA) is technically demanding and its association with a high rate of failure in patients with PA has been reported[5)]. Obtaining stable fixation of the acetabular cup is difficult due to deficient medial wall and thin peripheral edge of the acetabulum. There is a risk of further migration and loosening of the acetabular cup due to the deficient bone stalk[5)].

Various techniques have been proposed for THA of PA[5-10)]. While cemented acetabular components were used in early studies[11,12)], cementless acetabular components have been favored in recent studies[4)]. Studies on cementless acetabular component have emphasized that restoration of the hip center is critical for implant survival and successful outcome after THA[10)]. However, initial fixation using a press-fit of the acetabular component into the host bone is mandatory for the stability and durability of the component. Some degree of medialization is inevitable in order obtain a press-fit of the acetabular component into the protruded acetabulum. According to the classic concept of THA proposed by Charnley[13)], cup medialization provides biomechanical benefits, because the medialization increases the abductor moment arms. In the presence of PA, it might be difficult to obtain the hip center restoration as well as a press-fit of the acetabular component simultaneously during THA. Thus, balance must be achieved between restoration of the cup center and its trade-off of unstable cup fixation. It is not certain which of the two, medialized press-fit versus restoration of the hip center, is more beneficial for implant survival and better functional outcome in THA of patients with PA.

The purpose of this study was to compare cup stability and functional outcome between medialized acetabular cups and anatomically restored cups in cementless THAs of patients with PA.

MATERIALS AND METHODS

The study design and protocol of this retrospective study were approved by the Institutional Review Board (IRB) of Seoul National University Bundang Hospital (No. B-2005/612-102), and the informed consent was waived by the IRB.

A total of 22 patients (26 hips) with PA underwent primary THA from June 2003 to December 2017 at a single tertiary referral hospital. A diagnosis of PA was made when an intrapelvic displacement of the femoral head medial to the ilioischial line (Kohler's line) was observed on an anteroposterior (AP) radiograph of the hip (Fig. 1)[1,6)]. Cementless prostheses were used in all operations.

These patients were followed up for 2 to 16 years (mean, 5.1 years) after the index THA. There were five male patients (7 hips) and 17 female patients (19 hips), with a mean age at the time of THA of 59.9 years (range, 24.5 to 74 years), and a mean body mass index of 22.5 kg/m^2 (range, 16.0 to 29.7 kg/m^2) (Table 1).

The causes of PA were rheumatoid arthritis in 14 hips, post-traumatic arthritis in seven hips, ankylosing spondylitis in four hips, and previous infection in one hip.

The amount of acetabular protrusion was measured on hip AP view. Theoretically, the inner wall of the acetabulum, which appears as a pelvic tear-drop on the AP radiograph, would be the ideal reference structure for measuring the amount of acetabular protrusion. However, the tear-drop was not visible or moved medially in 10 of our patients. Thus, the method reported by Sotelo-Garza and Charnley[14)] was adopted for the measurement. The rim of the original pelvis, a projection of the upper margin of the pubic ramus, was taken as a reference line instead of the tear-drop and the distance between the original pelvic rim and the quadrilateral plate of protruded pelvis was measured (Fig. 1).

The amount of acetabular protrusion ranged from 2.8 to 21.9 mm (mean, 9.3 mm). According to the Sotelo-Garza and Charnley system[14)], the grade of PA was mild (<5 mm) in five hips, moderate (6-15 mm) in 19 hips, and severe (>15 mm) in two hips.

1. Preoperative Planning

AP and trans-lateral hip radiographs, scanography, and computed tomography (CT) scans (Mx8000 IDT; Philips, Eindhoven, The Netherlands) of the pelvis and proximal femur were taken preoperatively. On-screen templating with digital radiographs was used in deciding on the size of the implant[15)]. To guide the cup positioning, abduction and anteversion of the acetabulum were measured on the preoperative CT scan[16)].

2. Surgical Techniques

All operations were performed by three high-volume (>200 hip surgeries/year) surgeons using the Kocher-Langenbeck

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Table 1. Demographics of Patients with Protrusio Acetabuli

	Overall (n=26)	Medialized group (n=9)	Restored group (n=17)	*P*-value
Sex				0.674
Male	7	2	5	
Female	19	7	12	
Age (yr)	59.9±14.8	64.6±12.7	57.4±16.0	0.247
Body mass index (kg/m^2)	22.5±3.3	23.3±2.6	22.0±3.6	0.341
Diagnosis				0.375
Rheumatoid arthritis	14	5	9	
Post-traumatic arthritis	7	4	3	
Ankylosing spondylitis	4	0	4	
Previous infection	1	0	1	
Grade				0.104
Mild (<5 mm)	5	0	5	
Moderate (6-15 mm)	19	8	11	
Severe (>15 mm)	2	1	1	
Cup abduction (°)	41.6±5.6	37.4±5.2	43.8±4.5	0.003
Cup anteversion (°)	24.5±9.3	23.7±8.5	24.9±10.0	0.748
Postoperative LLD (cm)	0.5±0.9	0.2±0.9	0.7±0.9	0.286
Follow-up duration (yr)	5.1±4.3	5.3±3.5	4.6±4.6	0.364
mHHS	83.7±11.1	83.6±12.1	83.8±10.4	0.786

Values are presented as number only or mean±standard deviation.
LLD: leg-length discrepancy, mHHS: modified Harris hip score.

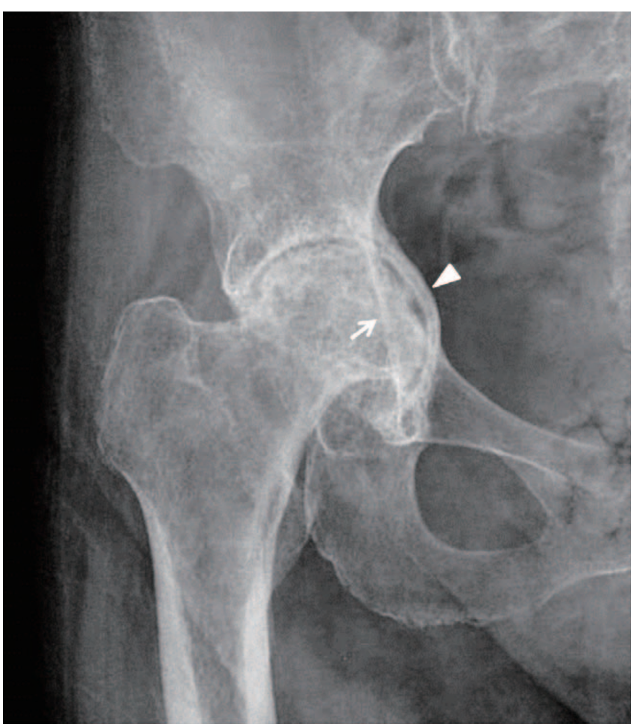

Fig. 1. Amount of acetabular protrusion was measured by the distance between the ilioischial line (arrow) and the protruded quadrilateral plate (arrowhead).

approach[17]. The sciatic nerve was identified and protected during the operation in all patients.

The femoral head was not dislocated when there was a risk of posterior wall fracture of the acetabulum during the dislocation maneuver. Instead, two osteotomies were made; the first osteotomy was made below the femoral head and the second one was made at the base of the femoral neck. Then, excision of a thick block of the femoral neck measuring 1.5 to 2.5 cm was performed, followed by removal of the femoral head from the acetabulum[18].

Press-fit fixation of the acetabular cup was prioritized rather than restoration of the hip center. Acetabular preparation was performed in two stages. Reaming of the peripheral edge of the acetabulum was performed first and the diameter of the reamer was gradually increased until the surface had been reamed enough to obtain a press-fit of the cementless acetabular cup. Although the cup size was planned preoperatively, it was determined intraoperatively because templating was often misleading in the case of PA. Cartilage and fibrous tissues of the medial floor inside the acetabulum were then removed.

A medial acetabular defect was observed after reaming in 18 hips; the defect was filled with autogenous bone graft from the excised femoral head. The bone graft was firmly impacted and was rounded using reverse reaming.

The acetabular cup was positioned using the CT measurements of acetabular abduction and anteversion as the alignment-guide[16]. The target abduction of the cup was 40°-45°[19]. The target anteversion of the cup was 15° until August 2009. After that, the cup was anteverted according to the concept of combined anteversion[16,20]. Cementless implants were used exclusively due to concern regarding cement-related cardiopulmonary complications[21].

A press-fit of the acetabular cup was obtained in 24 hips. A press-fit could not be obtained in the two remaining hips because the acetabular rim defect was >50% or the acetabular rim was too thin. Thus, reinforcement acetabular components with a hook and three iliac flanges were used in these two hips.

PLASMACUP® SC (Aesculap, Tuttlingen, Germany) was used in nine hips, Bencox cup (Corentec, Seoul, Korea) in seven hips, Pinnacle cup (DePuy, Warsaw, IN, USA) in five hips, G7 cup (Zimmer Biomet, Warsaw, IN, USA) in one hip, ABT cup (Zimmer Biomet) in one hip, and Delta TT cup (Lima lto, Udine, Italy) in one hip. SPH reinforcement cups (Lima lto) were used in two hips with defective rim of the acetabulum.

A nonunion found at the transverse acetabular fracture site in one hip with posttraumatic osteoarthritis was fixed with a reconstruction plate.

BiCONTACT® stem (Aesculap) was used in nine femurs, Bencox M stem (Corentec) in eight femurs, Corail stem (DePuy) in four femurs, Taperloc Microplasty (Zimmer Biomet) in two femurs, KAR stem (DePuy) in one femur, Trilock stem (DePuy) in one femur, and Minima stem (Lima lto) in one femur.

Delta ceramic-on-ceramic bearing (BIOLOX delta; CeramTec, Plochingen, Germany) was used in 16 hips, alumina ceramic-on-ceramic bearing (BIOLOX® forte; CeramTec) in six hips, alumina ceramic-on-polyethylene bearing in three hips, and a metal-on-polyethylene bearing in one hip. The diameter of the femoral head was 28 mm in eight hips, 32 mm in 11 hips, and 36 mm in seven hips.

After implantation and reduction of the hip prostheses, the posterior capsule and the short external rotators were tightly repaired to the crest of the greater trochanter[22].

3. Postoperative Care

Patients were encouraged to walk with toe-touch weight bearing with the aid of two crutches for four weeks and then were allowed weight-bearing.

4. Follow-up Evaluations

Follow-up evaluations were performed at 6 weeks, 3, 6, 9, and 12 months, and every year thereafter. AP and trans-lateral hip radiographs were taken and modified Harris hips score (mHHS) were measured at each follow-up. A postoperative scanogram was taken at 6-week follow-up.

5. Classification of Medialized Cup and Restored Cup

The restoration or medialization of the cup center was evaluated on postoperative 6-week AP radiograph. Hips having any portion of the acetabular cup protruding medial to Kohler's line were classified as the medialized group. Hips having the whole portion of the cup located lateral to Kohler's line were classified as the restored group.

Seventeen cups; 15 primary cups and two reinforcement components, were classified as the restored group, and nine cups were classified as the medialized group. In the medialized group, the amount of medialization ranged from 6.8 to 19.6 mm (mean, 11.8 mm) (Table 2).

6. Cup position and Radiological Evaluations

The cup position was measured on postoperative 6-week radiographs. Measurement of cup abduction was performed using the method described by Engh et al.[23], and the method reported by Woo and Morrey[24] was used for measurement of cup anteversion[25].

Postoperative leg length discrepancy, migration of the acetabular cup, stability of the acetabular and femoral components, wear of the bearing surface, and osteolysis were evaluated.

The leg length discrepancy was measured on postoperative 6-week scanogram[26]. The vertical length between the ankle mortise and upper body of the first sacral vertebra was measured. Both sciatic notches were used as the proximal reference when the first sacral vertebra was not visualized in the scanogram.

The 6-week AP and cross-table lateral radiographs were used as the baseline studies for assessment of cup migration, implant stability, bearing wear, and osteolysis.

Evaluation of the stability of the acetabular cup was performed using the method reported by Latimer and Lachiewicz[27], and that of the femoral stem using the method reported by Engh et al.[28]. Measurement of the bearing was performed according to the method reported by Livermore et al.[29]. A diagnosis of osteolysis was made according the criteria established by Engh et al.[30]. Location of the osteolytic lesions

Table 2. Hip Center Restoration, Intraoperative Press-Fit and Postoperative Stability of Cup in 26 Total Hip Arthroplasties of 22 Patients with Protrusio Acetabuli

Patient No.	Sex	Age (yr)	Side	Cause of protrusion	Preoperative protrusion (mm)	Hip center restoration	Intraoperative press-fit of cup	Cup stability	Follow-up duration (yr)
1	F	71	Lt.	Post-traumatic arthritis	11.7	Restored	Obtained	Stable	7.2
2	M	36	Rt.	Ankylosing spondylitis	7.2	Restored	Obtained	Stable	5.1
		25	Lt.	Ankylosing spondylitis	7.4	Restored	Obtained	Stable	16.2
3	M	68	Rt.	Rheumatoid arthritis	8.9	Restored	Obtained	Stable	8.6
4	F	60	Rt.	Rheumatoid arthritis	15.9	Restored	Obtained	Stable	5.4
5	F	69	Lt.	Post-traumatic arthritis	9.9	Restored	Obtained	Stable	8.1
6	F	35	Rt.	Rheumatoid arthritis	3.1	Restored	Obtained	Stable	2.0
		35	Lt.	Rheumatoid arthritis	2.8	Restored	Obtained	Stable	2.0
7	F	73	Lt.	Rheumatoid arthritis	4.7	Restored	Obtained	Stable	3.9
8	M	67	Rt.	Ankylosing spondylitis	6.2	Restored	Obtained	Stable	3.1
9	F	59	Rt.	Post-traumatic arthritis	5.3	Restored	Obtained	Stable	8.3
10	F	49	Rt.	Ankylosing spondylitis	4.3	Restored	Obtained	Stable	2.1
11	F	63	Rt.	Rheumatoid arthritis	8.3	Restored	Obtained	Stable	2.2
12	M	62	Lt.	Previous infection	10.9	Restored	Obtained	Stable	2.5
13	F	62	Lt.	Rheumatoid arthritis	4.8	Restored	Obtained	Stable	3.7
14	F	74	Rt.	Rheumatoid arthritis	9.2	Restored	Not obtained	Stable	4.1
		73	Lt.	Rheumatoid arthritis	11.3	Medialized (9.0 mm)	Not obtained	Stable	4.5
15	M	70	Lt.	Rheumatoid arthritis	13.3	Restored	Obtained	Stable	4.8
		69	Rt.	Rheumatoid arthritis	14.3	Medialized (19.6 mm)	Obtained	Stable	5.3
16	F	66	Rt.	Post-traumatic arthritis	7.6	Medialized (8.6 mm)	Obtained	Stable	2.3
17	F	74	Rt.	Rheumatoid arthritis	9.0	Medialized (6.8 mm)	Obtained	Stable	2.8
18	M	74	Rt.	Post-traumatic arthritis	14.4	Medialized (15.8 mm)	Obtained	Stable	3.6
19	M	34	Rt.	Post-traumatic arthritis	12.5	Medialized (13.0 mm)	Obtained	Stable	8.4
20	F	55	Rt.	Rheumatoid arthritis	21.9	Medialized (11.5 mm)	Obtained	Stable	11.7
21	M	69	Lt.	Rheumatoid arthritis	10.4	Medialized (11.3 mm)	Obtained	Stable	2.3
22	F	66	Lt.	Post-traumatic arthritis	7.7	Medialized (10.1 mm)	Obtained	Stable	5.1

Patient Nos. 2, 6, 14, and 15 underwent bilateral total hip arthroplasties. Patient No. 14 were operated with reinforcement cups.
F: female, M: male, Lt.: left, Rt.: right.

was based on the three zones reported by DeLee and Charnley[31] on the acetabular side, and the seven zones reported by Gruen et al.[32] on the femoral side.

Radiological evaluations were performed by two independent observers who did not participate in THAs.

7. Clinical Evaluation

Clinical evaluations were performed using modified Harris hip score (mHHS)[33].

8. Comparison between the Medialized Group and the Restored Group

The postoperative migration of the acetabular cup, implant stability, radiological change, and mHHS at the final follow-up were compared between the restored group and the medialized group.

9. Statistical Analysis

Student *t*-test or Mann–Whitney U test was performed for comparison of continuous variables, and the chi-square test or Fisher exact test was performed for comparison of dichotomous variables. A *P*-value less than 0.05 was considered significant. Statistical analyses were performed using IBM SPSS Statistics for Windows (ver. 25.0; IBM, Armonk, NY, USA).

RESULTS

The mean abduction and anteversion angles of the acetabular component were 37.4° (range, 29° to 44°) and 23.7° (range, 10° to 38°) in the medialized group and 43.8° (range, 20° to 52°) and 24.9° (range, 5° to 42°) in the restored group, respectively.

Postoperatively, the mean leg length discrepancy was 0.2 cm (range, –1.0 to 2.0 cm) in the medialized group and 0.7 cm (range, –0.5 to 3.2 cm) in the restored group.

The 24 primary cups (eight medialized cups and 16 restored cups) and two reinforcement cups (one medialized cup and one restored cup) had no migration and were regarded as having bone-ingrown stability. All of the 26 stems were well-fixed with bone-ingrowth (Fig. 2, 3).

There was no occurrence of hip dislocation in either group during the follow-up period. No measurable wear of the bearing surface was detected on radiographs. Periprosthetic osteolysis was not observed in any hip.

One patient (patient No. 2) in the restored group sustained a Vancouver type B periprosthetic femoral fracture after a fall. Internal fixation was performed using two plates for treatment of the fracture. Otherwise, there was no hip revision during the follow-up period.

No statistical difference in the mHHSs was observed between the two groups at the latest follow-up (mean, 83.8 points; range, 57-100 points in the restored group vs mean, 83.6 points; range, 65-100 points in the medialized group).

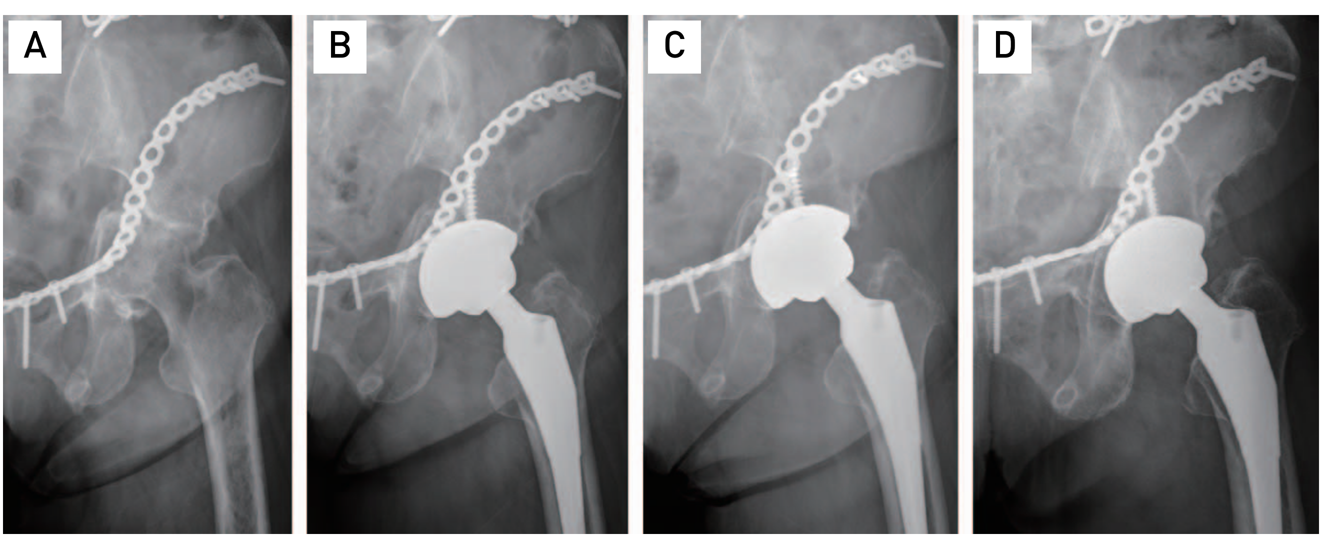

Fig. 2. (A) A 71-year-old female patient had previous pelvic trauma on the left hip. She had multiple pelvic bone fractures with intra-articular extension one year ago and received open reduction and internal fixation using a reconstruction plate. (B) She underwent total hip arthroplasty. The hip center of rotation was restored. Postoperative 6-week radiograph. (C, D) Radiographs at postoperative one year (C) and eight years (D).

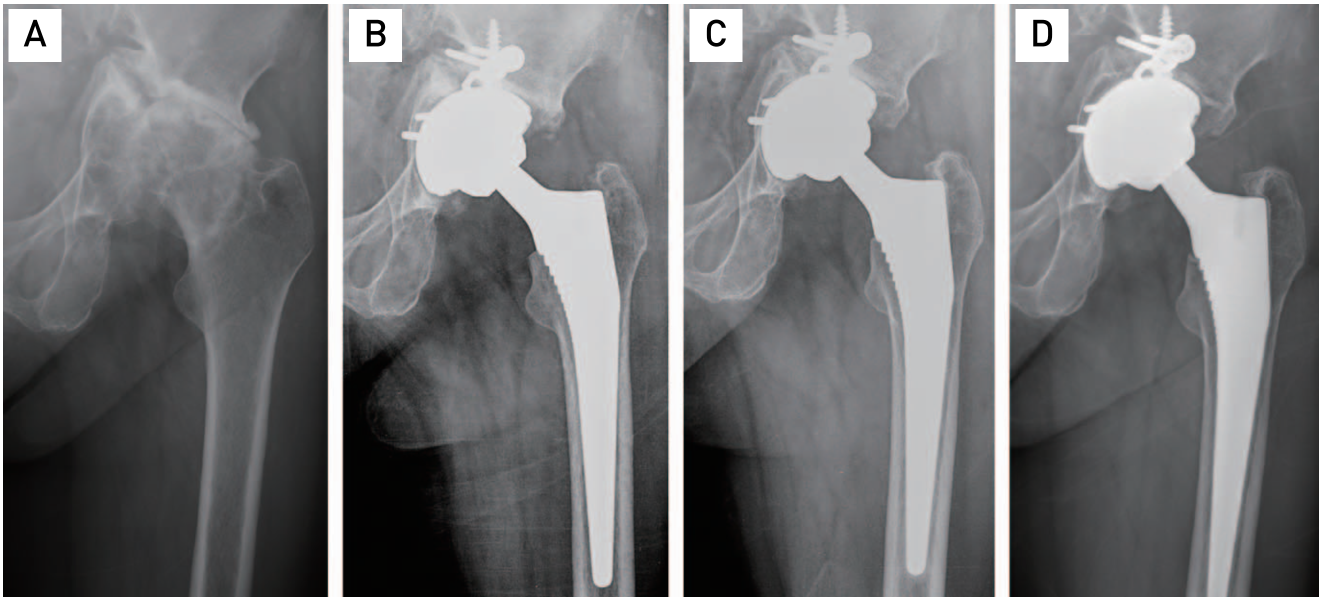

Fig. 3. (A) A 66-year-old female patient had previous pelvic trauma on the left hip. She had a pelvic fracture and hip joint dislocation 16 years ago, which were treated conservatively. (B) She underwent total hip arthroplasty. Nonunion of the acetabular fracture was fixed with a plate and the cup center was medialized. Postoperative 6-week radiograph. (C, D) Radiographs at postoperative one year (C) and six years (D).

DISCUSSION

Although several techniques for cup implantation have been recommended for THA of PA, the best recommendation is still unknown.

Findings of our study demonstrated that press-fitted cementless cups, irrespective of the restoration of the hip center, showed an association with durable implant stability and favorable functional outcome.

An emphasis on restoration of the hip center was found in the literature. In 1980, Ranawat et al.[34] reviewed 35 cemented THAs performed in patients with PA. In their study, restoration of the anatomical center of rotation appeared to be a critical factor for stable fixation of the acetabular component. A radiolucent line was observed in 16 of 17 acetabular components, which was positioned 1 cm superiorly or medially beyond the anatomical position. No radiolucent line was observed in 13 acetabular components, which were positioned within 5 mm of the anatomical center[34]. Since this study was reported, restoration of the hip center in THA of PA has been advocated by other authors[35]. In 1987, Bayley et al.[11] reviewed 93 cemented THAs in patients with PA; 53% of the cases of PA were treated with cement alone, 36% with mesh or an anti-protrusio shell, and 11% with a bone graft. A high percentage of radiolucent lines were observed in all three groups. The highest rate of 50% was observed in the cement alone group, in which the center of rotation was not corrected to within 10 mm of the anatomic position. They concluded that restoration of the anatomic cup position was crucial irrespective of combined use mesh, anti-protrusio shell, or bone graft in cemented THA of PA[11]. Baghdadi et al.[10] evaluated survivorship of 127 THAs for treatment of PA as a function of restoration of the hip center. In their 2- to 25-year follow-up study, an increase in the risk of cup loosening of 24% was observed for each 1 mm medialization of the cup from the native hip center of rotation[10]. An extension study of 65 hips at longer than 10 years after the THA was conducted by the same authors in 2015. At 15 years, the estimated survival rate from revision was 70% for THA, 85.4% for the acetabular component, and 83% for the femoral component. Evidence of non-progressive radiolucency was observed in five unrevised acetabular components[6].

The medial defect should be filled with bone graft for restoration of the native hip center. Sufficient contact between the acetabular component and the host bone is crucial for achievement of a satisfactory result of bone graft[36]. Garbuz et al.[37] compared results between cementless cups with host bone contact >50% and those supported by <50% of the host bone. They reported that the overall success rates were 90% and 76%, and the revision rates were 14% and 45%, respectively. They recommended the use of a reinforcement ring in cases where the host bone support was less than 50%[37].

On the other hand, one study reported that an intraoperative secure fixation of the cup is mandatory to achieving durable stability of the cup in THA for treatment of PA[38]. Even though medialization of the cup has been scrutinized by previous authors, the medialization with a respective increase in the femoral offset is known to have a biomechanical benefit of increasing abductor moment arm[39].

Restoring the hip center and obtaining a press-fit of the cup simultaneously is difficult in THA of hips with PA. In PA, the peripheral rim of the acetabulum is often weak and thin, and obtaining a press-fit of the acetabular cup is difficult. In such situations, surgeons have a dilemma regarding which of the two should have priority; restoration of the hip center with insecure fixation of the cup versus press-fit of the cup with medialization. In our study of PA patients, stable fixation and good clinical results were obtained after cementless THA with use of press-fitted cups, irrespective of the hip center restoration.

This study had limitations. First, it was a retrospective review including a small number of PA patients without a control group. The operations were performed by three surgeons and the enrollment period was very long (15 years) and various implants were used. Second, our study was conducted in East Asia, and the mean body mass index of our patients was 22.5 kg/m^2. Our results might not be generalized to patients with large constitutions in Western countries. Third, clinical outcomes might differ for patients who underwent surgery on both hips compared to those who underwent surgery on only one hip. Fourth, factors enabling restoration of the hip center were not identified in this study. Future conduct of a multi-center study including a larger cohort might be warranted.

CONCLUSION

THA in PA patients showed promising clinical and radiological results in both the medialized acetabular component group and the restored hip center group.

CONFLICT OF INTEREST

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

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