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HIP ARTHROPLASTY

Acetabular revision arthroplasty using press-fitted jumbo cups: an average 10-year follow-up study

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Abstract

Introduction Acetabular revision arthroplasty using jumbo cups for moderate-to-severe acetabular defects has varied outcomes. We evaluated the clinical and radiological outcomes of acetabular revision arthroplasty using a press-fitted jumbo cup and sought to identify factors that influence outcomes during intermediate follow-up.

Materials and methods Eighty patients (47 men, 33 women; 80 hips) who underwent acetabular revision arthroplasty using press-fitted jumbo cups were included. The mean follow-up period was 10.4 years. Harris hip score (HHS), presence of groin pain, radiographic results, and Kaplan–Meier survival curves were evaluated. Implant design and surgery-related and patient-related factors were assessed to identify influential factors for cup loosening. Migration and wear analyses were performed using Einzel-Bild-Röntgen-Analyse software.

Results The mean preoperative HHS of 53 had improved to 77 at the final follow-up ($p = 0.005$). Nine patients experienced groin pain. Acetabular cup loosening was observed in seven cups (8.7%), and one jumbo cup was replaced with a reinforcement cage. The survival rate of the acetabular cup was 91% at 16 years according to the Kaplan–Meier analysis. Osteolysis was identified around the cup in six cases (7.5%). Acetabular cup loosening occurred more frequently in patients with conventional polyethylene liners than in those with highly cross-linked polyethylene liners ($p = 0.045$). The mean total migration was 1.52 mm, and the mean total wear was 0.98 mm. There was a positive correlation between total migration and total wear ($p = 0.023$; Spearman's rho = 0.388). The mean wear rate of the patients with the cup inclination angle < 50° was significantly lower than those with the cup inclination angle > 50° ($p = 0.001$). There were four cases of complications (three dislocations and one infection) that did not require revision surgery.

Conclusion Press-fitted jumbo cups for acetabular revision arthroplasty exhibited encouraging results during follow-up for an average of 10 years. Use of highly cross-linked polyethylene liners and proper placement of the acetabular component with an inclination angle < 50° may contribute to better clinical outcomes after acetabular revision arthroplasty with jumbo cups.

Keywords Acetabular revision · Jumbo cup · Migration · Wear

Introduction

Acetabular bone defects remain a great challenge in acetabular revision arthroplasty. Use of an uncemented porous cup for acetabular revision arthroplasty has exhibited good long-term results for small cavitary defects [1–3]. However, if there is a large acetabular defect with more than 1 cm of bone loss in which standard cups placed in the anatomical position have difficulty achieving initial stability, then treatment options for acetabular revision include standard porous cups with a structural bone allograft [4, 5], bilobed cups [6–8], reinforcement cages [9, 10], acetabular impaction grafting [11, 12], porous metal augmentation [13–15], and jumbo cups [16–20].

Large, uncemented, hemispherical acetabular components (i.e., jumbo cups) are acetabular cups with minimum outside diameters of 66 mm for men and 62 mm for women [21]. The increased porous surface area of a jumbo cup maximizes contact with the host bone and increases the likelihood of biologic attachment. Bone deficiencies are mostly filled

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by the jumbo cup, thus reducing the need for bone grafting. Therefore, implantation of a jumbo cup is technically straightforward for acetabular revision arthroplasty.

Varied outcomes of jumbo cups with intermediate to long-term follow-up have included 80% to 95% survival rates at 10–20 years [16–20]. In general, outcomes are worse for patients with large acetabular defects (Paprosky types IIc, IIIa, and IIIb) [19]. However, long-term studies that reported more than 15 years of follow-up were mostly performed with earlier-generation implant designs and inhomogeneous reaming methods [19, 20]. Studies of second-generation cementless hemispherical cups that have been recently used for acetabular revision arthroplasty are lacking. Therefore, it is important to document the outcomes of these implants placed using homogenous reaming methods.

Einzel-Bild-Röntgen-Analyse (EBRA) software has been used to measure the migration of acetabular components and wear of polyethylene liners in retrospective studies [22–24]. EBRA is a highly accurate method with 1-mm confidence limits for longitudinal migration and 0.8-mm confidence limits for transverse migration [22]. Recently, studies have reported that EBRA software could be used as an accurate diagnostic tool for detecting aseptic loosening of cementless acetabular components used for revision arthroplasty [25, 26]. Regarding wear, the EBRA measurement had great accuracy comparable with that of a roentgen stereophotogrammetrical analysis (RSA) [24]. In the present study, EBRA software was used for migration and wear analyses.

The purpose of this study was to evaluate the average 10-year outcomes of acetabular revision arthroplasty using press-fitted jumbo cups. In addition, we aimed to identify influencing factors associated with acetabular cup loosening. Multiple surgery-related and patient-related factors were considered.

Materials and methods

Patients who underwent acetabular revision arthroplasty using jumbo cups were evaluated for inclusion in this study. Between January 2000 and January 2013, we performed 85 revision surgeries unrelated to infection using jumbo cups for 85 patients. Of the five patients who were not assessed, three died after a mean follow-up period of 6 years (range 5–8 years) and two were lost to follow-up. Finally, 80 patients (80 hips) were included in the present study. Ethical approval was obtained from the Institutional Review Board of the university hospital prior to conducting this study, and informed consent was obtained from all patients. Demographic data are summarized in Table 1. Acetabular bone defects were classified according to the classification system described by Paprosky et al. [27] (Table 2).

Table 1 Patient demographics

No. of hips	80
Male/female (hips)	47/33
Age (range) (year)	57.7 (30–78)
Body mass index (range) (kg/m^2)	24.3 (19.2–28.3)
Follow-up period (range), year	10.4 (5–16.1)
Implant type	
Titanium mesh fibre mesh cups	44
Grit-blasted cups	36
Polyethylene liner	
Highly cross-linked polyethylene liner	41
Conventional polyethylene liner	39
Cup position	
Mean inclination (range) (°)	42.6 (36–51)
Mean anteversion (range) (°)	17.6 (14–25)

Table 2 Summary of aceatbular defects using the Paprosky classification and bone graft

Paprosky defect classification	No. of hips	Bone graft		
		Morcellized allobone graft ($n=47$)	Structural allobone graft ($n=4$)	No graft ($n=29$)
Type 2A	16 (20%)	2 (2.5%)	0	14 (17.5%)
Type 2B	17 (21.3%)	9 (11.3%)	0	8 (10%)
Type 2C	22 (27.5%)	15 (18.8%)	0	7 (8.7%)
Type 3A	19 (23.8%)	18 (22.5%)	1 (1.3%)	0
Type 3B	6 (7.5%)	3 (3.8%)	3 (3.8%)	0

Revision was performed by a single senior surgeon using a posterolateral approach. Two types of second-generation hemispherical cups were used: Trilogy cups (Zimmer, Warsaw, IN) for 44 hips and standard Wagner cups (Protek, now Zimmer, Winterthur, Switzerland) for 36 hips. The Trilogy cup is a modular hemispherical metal-backed cup consisting of a polyethylene liner and a metal shell. The metal shell is a cluster-holed shell with a titanium–aluminium–vanadium alloy core coated with porous commercially pure (CP) titanium. The standard Wagner cup is made from CP titanium with a wall thickness of 3 mm. The titanium shell is a multi-holed shell with a grit-blasted surface (Fig. 1). Highly cross-linked polyethylene liners were used in 41 hips, and conventional ultra-high-molecular-weight polyethylene liners were used in 39 hips. The highly cross-linked polyethylene liner (Longevity; Zimmer) was made of calcium-stearate-free GUR 1050 resin machined from compression-moulded sheet polyethylene after a process consisting of e-beam irradiation of

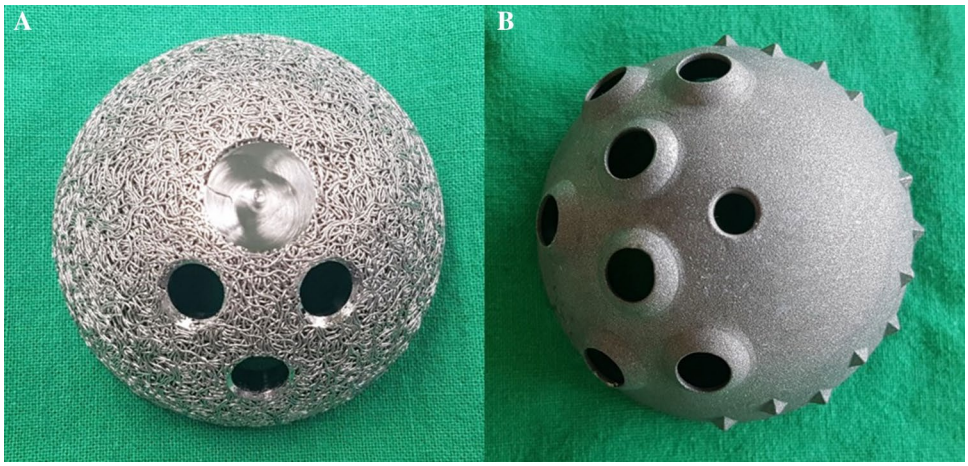

Fig. 1 Images of **a** the Trilogy cup and **b** the standard Wagner cup, showing different types of surface; the Trilogy cup has a titanium fibre-mesh surface, and the standard Wagner cup has a grit-blasted surface

10 Mrad for cross-linking. The conventional ultra-high-molecular-weight polyethylene liner (Sulene; Zimmer) was made of calcium-stearate-free GUR 1020 resin machined from compression-moulded sheet polyethylene.

Press-fit insertion (1- to 2-mm under-reaming) was performed in all cases. To determine the intrinsic stability of the acetabular component, the surgeon intraoperatively assessed whether the cup positioner was maintained without any support after secure placement of the acetabular cup with a cup positioner. Intrinsic stability of the acetabular components was confirmed in all the patients. A mean of 2.1 (range 1–3) screws were fixed in all patients. For severe superomedial or superolateral bone loss, structural bone allograft was used in four hips to provide structural support for the acetabular components and morselized bone allograft was used in 47 hips to fill cavitary bone defects (Table 2).

The clinical and radiographic results were evaluated retrospectively by reviewing medical records and radiographs. Routine follow-up was performed on postoperative day 1, week 2, month 3, month 6, and annually thereafter. The Harris hip score (HHS) [28] was calculated, and the presence of groin pain was evaluated. Two authors who did not participate in the surgery independently reviewed the clinical and radiographic assessments. All anteroposterior radiographs of the hip obtained at follow-up visits were evaluated for radiolucent lines and periprosthetic osteolysis according to the three acetabular zones defined by DeLee and Charnley [29]. According to the criteria identified by Zicat et al. osteolysis was defined as localized bone resorption or endosteal erosion more than 2 mm wide [30]. Acetabular cup loosening was radiologically defined as cup migration of 3 mm, more than 5° of change in cup inclination, or a thick radiolucent line of larger than 1 mm in all three zones. We additionally sought to find related factors, including gender, age, height, weight, body mass index (BMI) and acetabular defect grade among patient factors and the cup inclination angles, cup anteversion angles, head-cup diameter ratio, bone graft, the number of screws, implant types, and the polyethylene liners among implant and surgical factors.

Migration of the acetabular components and wear of the polyethylene liners were measured on hip anteroposterior radiographs using EBRA software. The time points for migration analyses were those routinely used for clinical follow-up. Radiographs were converted to graphic files using the hospital picture archiving and communication system (PACS) (Agfa IMPAX; AGFA-Gevert N.V., Mortesl, Belgium) and the ultra-high-quality setting; they were analysed with EBRA (Universität Innsbruck, Innsbruck, Austria). Total migration of the acetabular components and total wear of the polyethylene liner were evaluated. The Pythagorean theory was applied to calculate the total migration [23, 31].

Statistical analyses

Implant survival and the 95% confidence interval (CI) were calculated using the Kaplan–Meier method and SPSS 16.0 statistical software (SPSS, Chicago, Illinois, USA). The end point was defined as radiographic evidence of acetabular cup loosening. A separate survival analysis for the worst-case scenario was performed, which included the five patients (five knees) lost during follow-up or who died and which assumed all prosthesis failed in the year of their withdrawal [32]. The independent sample Student's *t* test was used to compare age, body mass index, follow-up period, position of the acetabular component, migration of the acetabular component and total wear. Differences in gender, acetabular bone defects, bone grafts, implant types and polyethylene liners were compared using the chi-square test. The correlation between total wear and total migration was analysed with Spearman's rank coefficient (rho); $p < 0.05$ was considered statistically significant.

Results

Clinical and radiographic results

The mean HHS improved from 53 points preoperatively to 77 points at the last follow-up examination (range 49–92; $p = 0.005$). Nine hips (nine patients) were associated with groin pain. Of these, two hips (two patients) showed no radiographic abnormality, and their symptoms subsided after conservative treatment. Seven hips (seven patients) with groin pain showed acetabular cup loosening with focal osteolysis on a plain radiograph. These patients underwent computed tomography (CT) scans to identify if the antero-superior wall was prominent or if anterior acetabular cup overhang is present. Two patients showed anterior acetabular cup overhang of 5 mm and 7 mm, and CT-guided local anaesthetic (LA) injections were performed to identify iliopsoas impingement. The groin pain persisted despite LA injection test, hence making psoas impingement unlikely. One patient with groin pain for 4 years postoperatively showed progressive superomedial migration of the acetabular component with resorption of grafted bone. That patient finally underwent revision surgery using a reinforcement cage at 7 years postoperatively (Fig. 2). Groin pain resolved after revision surgery. A patient who reported groin pain that started 5 years postoperatively had osteolysis detected around the cup; this was proven to be progressive and resulted in cup loosening. However, he could not undergo revision surgery due to life-threatening heart failure. Another two patients with groin pain for 7 years and 8 years postoperatively had cup loosening with progressive osteolysis; however, they refused to undergo revision surgery because of poor economic status. The remaining three patients who reported groin pain that started 6 years, 8 years, and 9 years postoperatively had cup loosening with focal osteolysis. However, they did not agree to undergo further surgical procedures for their hips because they tolerated the pain with conservative treatment.

Age, gender, height, weight, BMI and acetabular defect grade were not associated with acetabular cup loosening (Table 3). Among the implant factors, only the polyethylene liner was associated with acetabular cup loosening. Acetabular cup loosening occurred more frequently in patients with conventional polyethylene liners than in those with highly cross-linked polyethylene liners ($p = 0.045$). Acetabular cup loosening occurred in 3 of 44 hips (6.8%) with titanium fiber mesh cups and in 4 of 36 hips (11.1%) with grit-blasted cups, showing no significant difference ($p = 0.695$). We found no differences in the cup inclination angles, cup anteversion angles, head-to-cup diameter ratios, the number of screws and bone grafts between patients with acetabular cup loosening and those without.

Distributions of radiolucent lines and osteolytic lesions around the jumbo cups are described in Table 4. Eight patients had a radiolucent line at the interface between the acetabular components and the bone. In these patients, cup migration, screw breakage,and changes in cup position were not observed.

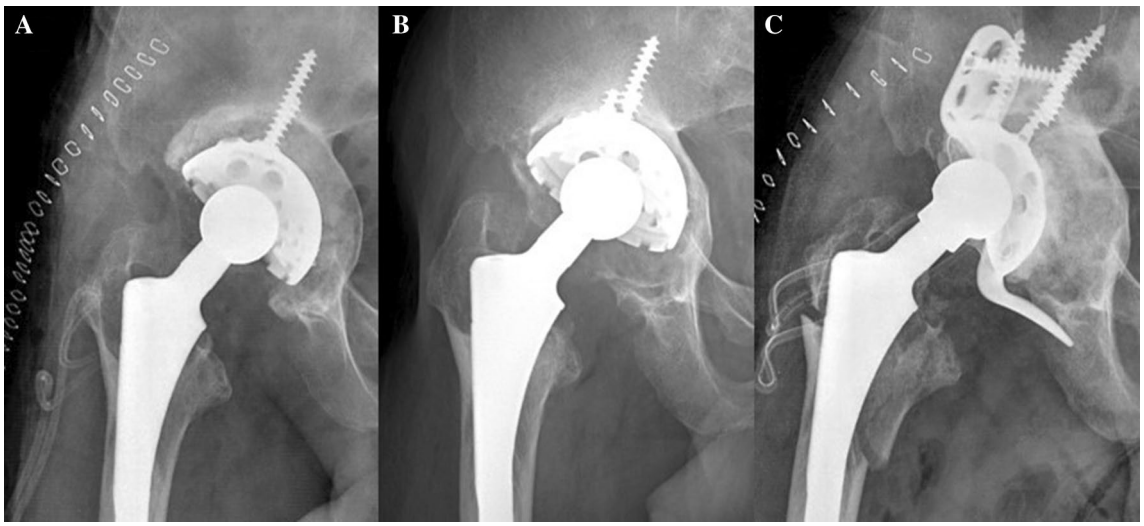

Fig. 2 **a** Postoperative day 1 anteroposterior radiographs of the right hip of a man aged 46 years who underwent acetabular revision arthroplasty using a jumbo cup; **b** The superomedial migration of acetabular component with resorption of grafted bone was shown on postoperative 4 years; and **c** The patient underwent revision surgery using a reinforcement cage with sufficient structural and morselized bone allograft at 7 years postoperatively

Table 3 Comparison between the patients with and without acetabular loosening

Parameter	Patients without acetabular cup loosening	Patients with acetabular cup loosening	*p* values
No. of hips	73	7	
Gender			0.215
Male	42	5	
Female	31	2	
Age (year)[a]	58.1	53.5	0.360
Body mass index (kg/m^2)[a]	24.1	26.4	0.452
Height (cm)[a]	163.5	161.1	0.942
Weight (kg)[a]	58.5	56.2	0.953
Cup inclination angle (°)[a]	42.5	43.6	0.245
Cup anteversion angle (°)[a]	17.7	16.6	0.357
Head-cup diameter ratio[a]	0.445	0.452	0.844
Bone graft			0.876
Morselized allobone graft	44	3	
Structural allobone graft	3	1	
No graft	27	2	
Acetabular defect grade according to the Paprosky classification			0.142
Type 2A	16	0	
Type 2B	16	1	
Type 2C	19	3	
Type 3A	17	2	
Type 3B	5	1	
The number of screws	1.52	1.28	0.396
Implant type			0.695
Titanium fibre mesh cup	41	3	
Grit-blasted cup	32	4	
Polyethylene liner			0.047
Highly cross-linked polyethylene liner	40	1	
Conventional polyethylene liner	33	6	

[a]Values are expressed as means

Table 4 Distribution of radiolucent lines and osteolytic lesions of the cup at 10 years postoperatively

	Radiolucent lines (%)	Osteolytic lesions (%)
Delee and Charnley zone (cup)		
I	3 (3.7)	2 (2.5)
II	4 (5)	3 (3.7)
III	1 (1.3)	1 (1.3)

Migration and wear analys

Migration and wear analysed using EBRA were performed for 71 of 80 acetabular cups. The mean total migration was 1.52 mm (0.8–8.4 mm), and the mean total wear was 0.98 mm (0.01–2.9 mm). The mean direction of migration was proximolateral. The mean migration in the lateral direction was 0.2 mm (− 4.9 to 7.8 mm), and the mean migration in the proximal direction was 1.34 mm (− 4.5 to 6.2 mm). The mean total migration and the mean total wear were significantly greater in the group with cup loosening ($p = 0.002$) than in the group without ($p = 0.024$). For the seven cups with loosening, the mean total migration was 4.6 mm (3.2–8.4 mm), and the mean total wear was 2.2 mm (0.22–2.9 mm). The migration and wear curves of these hips are presented in Fig. 3.

There was no significant difference in total migration of the two different implant types ($p = 0.12$). The differences between the patients with highly cross-linked polyethylene liners and those with conventional polyethylene liners were significant for total wear ($p < 0.001$) but not significant for total migration ($p = 0.14$). The mean wear rate was 0.022 mm per year for patients with highly cross-linked polyethylene liners and 0.171 mm per year for patients with conventional

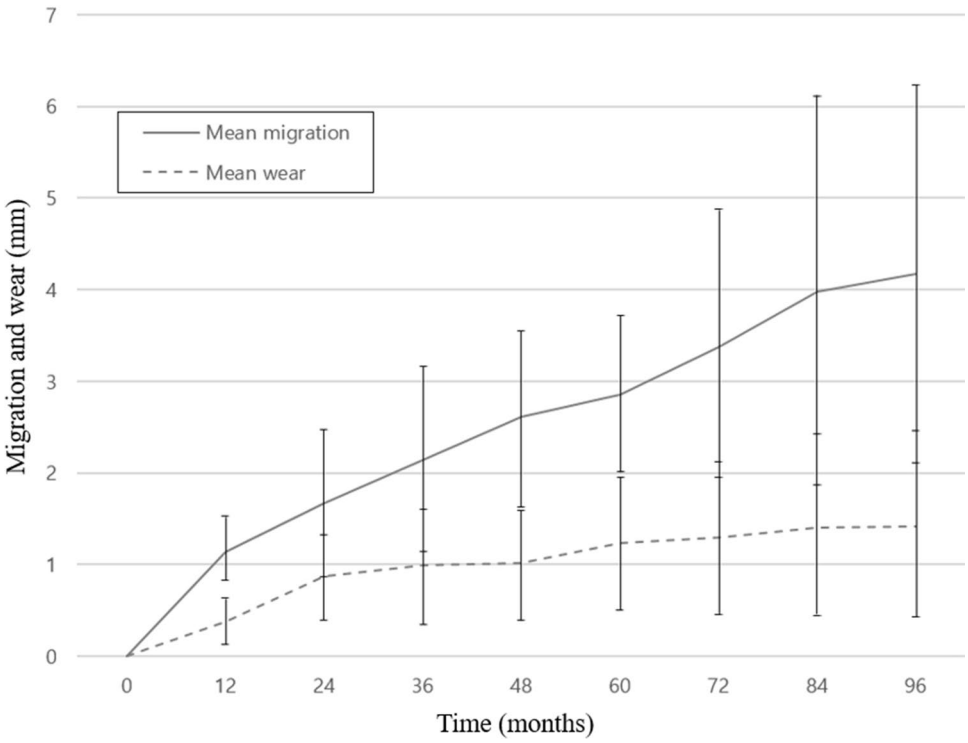

Fig. 3 Mean migration and mean wear for the seven cups with loosening. Mean values plus and minus standard deviation were expressed. Mean migration and wear tended to progress rapidly until 2 years after surgery and wear rate tended to decline gradually after 2 years postoperatively

polyethylene liners. There was a significant positive correlation between total migration and total wear ($p = 0.023$; Spearman's rho = 0.388).

In THAs with the cup inclination angle greater than 50° (10 hips), the mean wear rate was 0.221 mm per year compared with 0.077 mm per year in those with the cup inclination angle less than 50° (61 hips), showing a significant difference ($p = 0.001$). There was no significant difference in total migration between the patients with cup inclination angle greater than 50° and those with the cup inclincation angle less than 50° ($p = 0.125$).

Survival rates

After a mean follow-up period of 10 years (range, 5–16.1 years), the survival rate of acetabular components free from radiographic evidence of acetabular cup loosening was 91% (95% CI, 87.6–94.4%) (Fig. 4). Assuming all five hips in the five patients who died or were lost during follow-up failed owing to acetabular cup loosening, the worst-case scenario analysis revealed a 16-year implant survivorship of 85% (95% CI, 81–89%) using radiographic evidence of acetabular cup loosening as the end point (Fig. 4).

A polyethylene liner was a significant predictor of implant survivorship free from radiographic evidence of definite loosening of the metal acetabular component ($p = 0.045$). The survival rate was 97.4% (95% CI, 94.9–99.9%) for the group with highly cross-linked polyethylene liners and 83.8% (95% CI, 77.7–89.9%) for those with conventional polyethylene liners (Fig. 4).

Complications

Dislocation occurred in three hips that were treated with closed reduction. One superficial infection developed but was treated conservatively. Other complications included delirium (two patients), ileus (one patient), and transient sciatic nerve palsy (one patient). After 3 months, transient sciatic nerve palsy gradually recovered with conservative treatment.

Discussion

The purpose of the present study was to evaluate the mean 10-year follow-up results of patients who underwent revision arthroplasty using press-fitted jumbo cups. At 16 years, 91% of patients were free from radiographic evidence of definite acetabular cup loosening. The mean total migration was 1.52 mm at the end of the 10-year follow-up period, and this was comparable with the means of other cementless acetabular components of primary total hip arthroplasty [31, 33]. Press-fitted jumbo cups using second-generation cementless hemispherical cups exhibited encouraging results of acetabular revision arthroplasty at the average 10-year follow-up. An important finding of the present study was that the polyethylene liner significantly influenced the results of

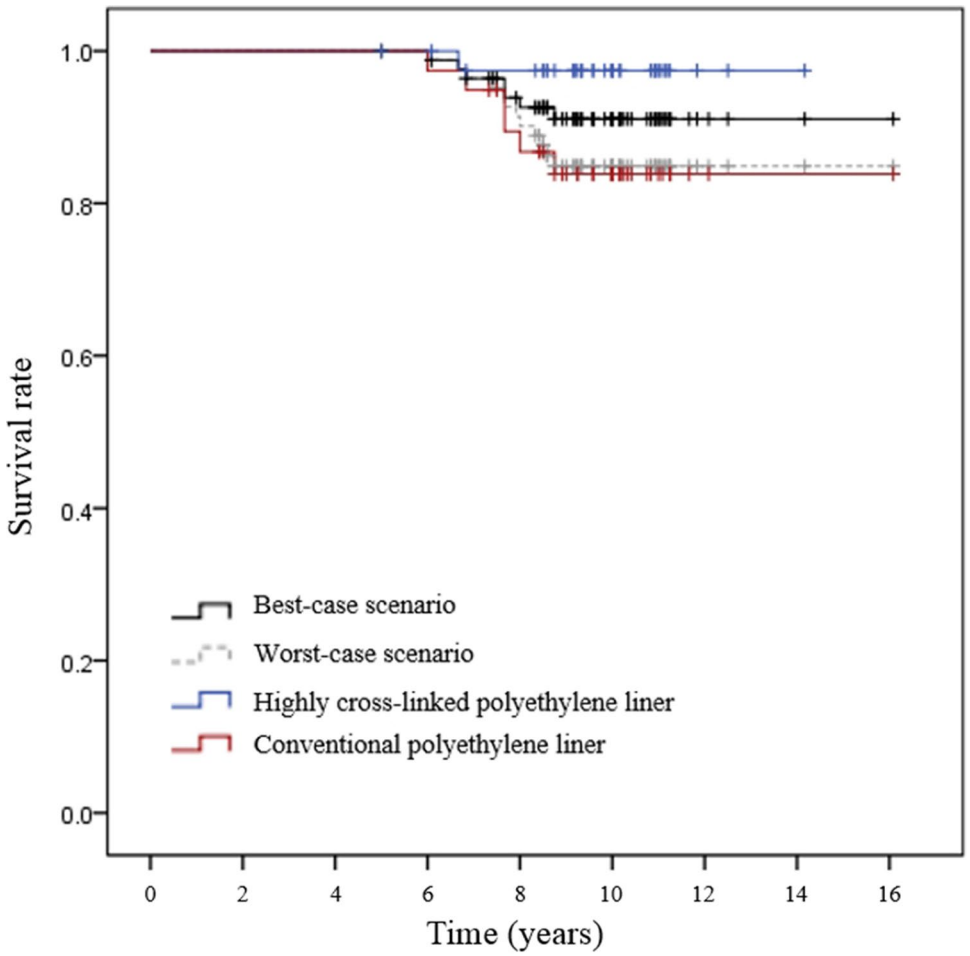

Fig. 4 Kaplan–Meier survival curves with end points of radiographic evidence of definite acetabular cup loosening are shown in the best-case scenario (solid black line) and the worst-case scenario (dashed grey line). Kaplan–Meier survival curves of the groups with highly cross-linked polyethylene liners (solid blue line) and conventional polyethylene liners (solid red line) are presented. The log rank test demonstrated a difference in survivorship between the two groups ($p = 0.045$)

acetabular revision arthroplasty using jumbo cups in terms of implant survival rates and the incidence of acetabular cup loosening. When highly cross-linked polyethylene liners were used, the survival rates were 97.4% and better compared to those reported by other intermediate-term studies of acetabular cup revision using jumbo cups (Table 5). Additionally, wear analysis revealed that acetabular cups with an inclination angle less than 50° showed significantly lower wear rates of polyethylene liners than those with an inclination angle more than 50°. The use of highly cross-linked polyethylene liners and proper placement of the acetabular component with an inclination angle less than 50° are considered necessary for reducing wear particle-induced aseptic loosening and obtaining better long-term results after acetabular revision arthroplasty using jumbo cups.

The present study had several limitations. Because of the retrospective design of the present study, the relatively small number of patients made it difficult to statistically interpret outcomes. Moreover, this study was a mid-term follow-up study; therefore, it was not possible to extrapolate the results to the long-term longevity of jumbo cups for acetabular component revision. The accuracy of the EBRA method is not the gold standard for migration and wear analyses. RSA provides the highest accuracy, but it can only be used prospectively. However, the EBRA method is thought to be the most sensitive retrospective radiologic measurement method. By checking whether the cup positioner was maintained without any support intraoperatively, we confirmed that the wedge fit of the jumbo cups achieved intrinsic cup stability. However, this manual method is subjective and can often be inaccurate. Fehring et al. [34] reported that press-fitted cups without screw fixation, which were confirmed as stable by the manual method, had high degrees of variability in the resisting load and may be at risk for acetabular cup loosening. All cases in the present study underwent additional screw fixation to minimize cup micromotion that can be overlooked by the manual method. Nevertheless, the development of more objective measures to intraoperatively assess cup stability is warranted.

A small cavitary defect during acetabular cup revision can be successfully treated with porous cups [5]. However, when there is an acetabular defect larger than 1 cm, the surgical challenge is achieving initial stability, particularly if it is a combined with peripheral and cavitary defects [18]. In

Table 5 Summary of the literature evaluating outcomes of cup revision arthroplasty using jumbo cups

Author	Methods of bone grafting	Methods of reaming	Implant design	Number of hips	Length of follow-up (years)	Mean age at surgery (years)	Clinical outcomes	Classification of acetabular bone deficiencies	Survival rate (%)
Patel et al. [16]	Eight hips with bulk bone allograft 27 hips with morselised bone allograft	Press-fit insertion: 15 hips Line-to-line reaming: 28 hips	Cementless Ring-Loc acetabular series and Duraloc acetabular cup system with conventional polyethylene liner	43	10 (6–14)	63 (25–86)	Harris hip score: 81 ± 18	Paprosky type 2A: 49% 2B: 14% 2C: 23% 3A: 14%	92 at 14 years
Wedemeyer et al. [17]	15 hips with morselized bone allograft	Press-fit insertion: nine hips Not recorded: eight hips	Cementless Duraloc 100 and 1200 acetabular cup with conventional polyethylene liner	17	6.8 (2.8–12.4)	60 (44–78)	Harris hip score: 83	Paprosky type 2A: 29% 2B: 18% 2C: 24% 3A: 29%	88 at 12.4 years
Gustke et al. [18]	38 hips with bulk bone allograft 100 hips with morselised bone allograft or autograft	Press-fit insertion: all	Cementless APR, InterOp, Converge cup Polyethylene liner: not recorded	196	10 (2–19)	62.5 (27–85)	Harris hip score: 72	Paprosky type 1: 7% 2A: 26% 2B: 33% 2C: 9% 3A: 17% 3B: 8%	96 at 16 years
von Roth et al. [19]	54 hips with particulate bone graft Nine hips with bulk allograft	Not available	Cementless Harris-Galante cup with conventional polyethylene liner	89	20 (14–27)	59 (30–83)	Harris hip score: 71 (30–95)	Paprosky type 1: 7% 2A: 12% 2B: 29% 2C: 19% 3A: 28% 3B: 5%	83% at 20 years
Lachiewicz et al. [20]	107 hips with morselised bone allograft or autograft	Press-fit insertion: 72 hips Line-to-line reaming: 34 hips Not recorded: two hips	Cementless Harris-Galante cup I or II: 55 hips Trilogy cup: 31 hips Trabecular metal tantalum cup: 22 hips	108	8.1 (2–20)	63 (33–88)	Not available	Paprosky type 1: 1% 2A: 20% 2B: 21% 2C: 5% 3A: 37% 3B: 16%	80 at 15 years

Table 5 (continued)

Author	Methods of bone grafting	Methods of reaming	Implant design	Number of hips	Length of follow-up (years)	Mean age at surgery (years)	Clinical outcomes	Classification of acetabular bone deficiencies	Survival rate (%)
Present study	47 hips with morselised bone allograft Four hips with structural bone allograft	Press-fit insertion: all	Trilogy cup: 44 hips Standard Wagner cup: 36 hips Highly cross-linked polyethylene liners: 41 hips Conventional ultra-high molecular weight polyethylene liners: 39 hips	80	10.4 (5–16.1)	57.7 (30–78)	Harris hip score: 77 (49–92)	Paprosky type 2A: 20% 2B: 21.3% 2C: 27.5% 3A: 23.8% 3B: 7.5%	91% at 16 years

APR anatomical porous replacement

these cases, jumbo cups can be a useful surgical option. By reaming more than the peripheral rim defect, a large hemisphere can be formed to maximize contact with the host bone and reduce the need for bone grafting. Gustke et al. [18] reported that acetabular component survivorship was 96% at 16 years for the 196 hips that underwent cup revision arthroplasty using jumbo cups. However, Lachewicz and Soileau [20] followed-up 129 patients over a mean of 8 years and reported a 79.8% survival rate for the acetabular component. Recently, von Roth et al. [19] reported that the acetabular component survivor rate was 83% for 89 hips at 20 years. Although various outcomes after the use of jumbo cups have been reported, various reaming methods may complicate the assessment of these outcomes. In this study, patients who underwent cup revision arthroplasty for acetabular defects were evaluated only when intrinsic stability was achieved by press-fitted jumbo cups.

Reaming of the acetabulum could be performed with two methods: the line-to-line fashion or the press-fit technique, which under-reams 1 to 2 mm less than the cup diameter. The press-fit technique is commonly used to minimize micromotion and provides improved stability of the acetabular components in cementless primary total hip arthroplasty [35–37]. When using jumbo cups for cup revision arthroplasty, the press-fit method has been recommended [18] for achieving stable three-point fixation with the trial component, with excellent results found after 16 years of follow-up. Lachiewicz and Soileau [20] used a combination of these two reaming methods for the revision procedures involving jumbo cups and reported relatively poor results: 80% survival rate at 15 years. This may have been due to the higher distribution of large acetabular defects according to Paprosky classification (58% types IIc, IIIa, and IIIb) compared to other studies. In this study, 58.7% of the acetabular defects were large; this rate was similar to that in the study by Lachiewicz [20]. The reason for the relatively high survival rate despite the high distribution of large acetabular defects in this study can be partly explained by the differences in the reaming method. In the biomechanical study, the rim of the acetabular component fitted with line-to-line reaming was less stable compared to the press-fitted acetabular components [38], thus supporting our results.

There are many causes of groin pain after total hip replacement. The most frequent intrinsic causes include acetabular cup loosening, infection, iliopsoas impingement and tendonitis, synovitis, periacetabular osteolysis and occult pelvic fracture. Of these, problems stemming from soft tissue impingements such as iliopsoas tendonitis can be caused by the use of a jumbo cup [39, 40]. Nwankwo et al. [41] reported in a computer simulation study that protrusion of the anterior edge of the acetabular cup through the anterior wall can occur when anterior column bone is lost by progressive reaming for an oversized cup. In the present

study, anterior acetabular cup overhang of 5 mm and 7 mm was found in two patients. However, CT-guided anaesthetic injection in iliopsoas tendon did not suggest iliopsoas impingement. Cyteval et al. [42] reported that all patients with iliopsoas impingement had an acetabular cup overhang of more than 12 mm and the overhang was always less than 8 mm in the control groups, which was in accordance with our results. Consequently, we concluded that the groin pain of seven patients in the present study was caused by acetabular cup loosening.

Two different implant designs with different surface finishes were used in this study: grit-blasted cups and titanium fibre-mesh cups (Fig. 1). Grit-blasted cups are surface-roughened implants without pores to allow for bone ingrowth. Overgaard et al. noted that porous-coated implants had significantly higher energy absorption during push-out testing than did grit-blasted implants, which was explained by the interdigitated bone-implant interface [43, 44]. However, in the biomechanical study conducted by D'lima et al. [45], the mechanical tests showed no significant differences in the interface shear strength of grit-blasted surface implants and titanium fibre-mesh porous implants. In the present study, we could not find any significant differences in the incidence of acetabular cup loosening for these two different implant designs. In future research, a larger sample size and long-term follow-up period would be necessary to verify the differences in the radiographic results according to implant types.

In the present study, the wear analysis showed that the mean wear rate of the patients with the cup inclination angle less than 50° was lower than those with the cup inclination angle greater than 50°. Little et al. [46] reported that the linear and the volumetric wear rates of conventional polyethylene liner were lower in the group in which the cup inclination was less than 45° than the group in which the cup inclination was greater than 45°. Moreover, Patil et al. [47] evaluated the effect of acetabular abduction on polyethylene wear using finite element analysis and hip wear simulator anaylsis. The authors noted that contact stresses and polyethylene wear increased in THAs with a cup inclination angle greater than 45°, theoretically supporting our results. Therefore, proper placement of the acetabular component with the cup inclination angle less than 50° should allow for reduced polyethylene wear in revision hip arthroplasty using jumbo cups.

Lachiewicz and Watters [48] recommended using acetabular components with enhanced porous coating and highly cross-linked polyethylene liners for acetabular revision arthroplasty. Jafari et al. [49] reported that porous tantalum cups yielded better fixation in revision hip arthroplasty for major bone deficiency than conventional titanium acetabular cups. In the present study, polyethylene liners were a significant influencing factor in the implant survival rate. Acetabular cup loosening occurred more frequently when conventional polyethylene liners were used. Additionally, EBRA analysis showed significantly higher total wear in the group with cup loosening than in the group without cup loosening, and it showed a positive correlation between total migration and total wear. These findings indicated that polyethylene wear is potentially related to acetabular cup loosening. It is still unknown whether polyethylene wear is the cause of or a consequence of acetabular cup loosening. In loose acetabular components, micromovements may lead to an eccentric load on the cup, resulting in increased wear [50]. Additionally, polyethylene debris may be produced in the damaged bone–prosthesis interface, thus causing more injury to the local tissues around the acetabular components [51]. A randomized, controlled trial by Devane et al. [52] noted that highly cross-linked polyethylene liners had significantly reduced wear (mean, 0.03 mm/year) compared with conventional polyethylene liners (mean, 0.27 mm/year) in primary total hip arthroplasty. In the present study, highly cross-linked polyethylene liners had significantly lower wear rate (mean, 0.022 mm/year) compared with conventional polyethylene liners (mean, 0.171 mm/year). Therefore, the authors suggest that more polyethylene particles were released from wear of conventional polyethylene liners induced progressive bone resorption more frequently and resulted in acetabular cup loosening.

In conclusion, press-fitted jumbo cups can confer primary intrinsic stability during acetabular revision arthroplasty and exhibit encouraging rates of acetabular cup loosening and survivorship during an average follow-up period of 10 years. We found that using highly cross-linked polyethylene liners resulted in significantly higher implant survival rates compared with those using conventional polyethylene liners. Moreover, the acetabular cup with an inclination angle less than 50° was associated with a lower polyethylene wear rate than that with an inclination angle more than 50°. Based on our observations, press-fitted jumbo cups, which are properly placed with highly cross-linked polyethylene liners, can provide initial stability of the revised acetabular component with decreased wear particle-induced aseptic loosening, which is essential for successful long-term results.

Compliance with ethical standards

Conflict of interest Jun-Ki Moon, Jaejoon Ryu, Yeesuk Kim, Jae-Hyuk Yang, Kyu-Tae Hwang, and Young-Ho Kim declare that they have no conflict of interest.

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