Kim et al. BMC Musculoskeletal Disorders (2025) 26:308
https://doi.org/10.1186/s12891-025-08553-8

BMC Musculoskeletal Disorders

RESEARCH

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Dual mobility cups reduce dislocation in isolated cup revision

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Abstract

Background Dual-mobility cup (DMC) is gaining increasing attention in total hip arthroplasty (THA) revision due to its numerous advantages. However, the prognosis after isolated cup revision with DMC remains unclear. This study aimed to compare complications, focusing on dislocation, and analyze clinical outcomes in patients who underwent isolated cup revision after THA.

Methods This retrospective cohort study included 119 patients who underwent isolated cup revision after THA and were followed up for ≥ 2 years from January 2009 to February 2020. Patient demographics, including age, sex, surgical approach, reasons for previous joint replacement surgery, and postoperative complications, were investigated. The patients were divided into DMC and conventional cup (CC) groups, and operative data and postoperative complications were compared between the two groups. Clinical outcomes were compared using the Harris hip score.

Results Forty-nine patients received DMC, and 70 received CC; the two groups had no difference in preoperative evaluation. Although the implants used significantly differed, there was no difference in the cup position. Six patients in the CC group had dislocations, but none had them in the DMC group ($p = 0.042$). Aseptic loosening was the most frequent postoperative complication but showed no significant difference between the two groups.

Conclusions DMC in revision THA can prevent dislocation compared to CC. In particular, DMC is considered a good treatment option in isolated cup revision wherein the surgeon can control the limited options.

Keywords Dual mobility cups, Total hip arthroplasty, Dislocation, Isolated cup revision, Complications

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Introduction

Total hip arthroplasty (THA) is an efficient and reliable surgical procedure with excellent long-term outcomes in patients with degenerative hip pathologies [1]. However, postoperative dislocation is a challenging complication affecting patient outcomes [2], particularly in revision THA, which is associated with higher complication rates than primary THA due to technical difficulties [3, 4]. Furthermore, the dislocation rate in revision THA (5–25%) is higher than that in primary THA (0.2–9%) [5]. The common causes of revision THA are aseptic loosening, recurrent instability, infection, and periprosthetic fracture [6]. The second most common complication of revision THA is dislocation, which is more common in partial revision procedures, such as cups or stems and modular component exchanges, than in total component revisions [7].

The femoral offset is defined as the vertical distance between the center of the femoral head and the axis of the femur, whereas the acetabular offset is defined as the distance between the center of the femoral head and the inner wall of the quadrilateral plate, also known as the true floor of the acetabulum [8, 9]. Most implant studies have focused on the femoral offset, which can be restored through prosthetic stems and head-neck combinations. Although there are few studies on acetabular offset [9], the concept cannot be limited to femoral offset; more attention should be paid to restoring native hip biomechanics by adjusting the acetabular offset al.one during isolated cup revisions [10].

Bousquet invented the dual-mobility cup (DMC) in the 1970s [11]. Early DMCs have disadvantages, including intraprosthetic dislocation (IPD) [12] and wear-induced aseptic loosening of polyethylene (PE), but these disadvantages have been largely eliminated in subsequent generations [13, 14]. Advantages, including increased implant stability and decreased dislocation rates due to an increase in jump distance [15] and increased range of motion [16], have become more prominent, and DMCs have become widespread, particularly in revision THA, where the dislocation risk is higher than in primary THA.

Although there are studies comparing DMC and conventional cup (CC) for revision THA, to the best of our knowledge, reports on the complications of DMCs and CCs in isolated cup revisions are rare. Therefore, this study aimed to analyze the relationship between various factors, including dislocation in patients who underwent cup revision after revision THA due to complications. We hypothesized that the DMC group would have a lower dislocation rate but no difference in the frequency of other complications compared to the CC group was observed in cases of isolated cup revision.

Materials and methods

Patient selection

This study was conducted in accordance with the principles of the Declaration of Helsinki and strengthening the reporting of observational studies in epidemiology (STROBE) guidelines for cohort studies, and Pusan National University Yangsan Hospital institutional review board (No. 05-2023-040) approval was obtained. This study enrolled 253 patients who underwent THA revision between January 2009 and February 2020. The inclusion criteria were patients who underwent THA or bipolar hemiarthroplasty (BH) at our hospital, underwent isolated cup revision, or completed ≥ 2 years of follow-up. The exclusion criteria were patients who: (A) underwent total component revision, (B) underwent only stem revision, (C) and underwent modular component exchange. Eighty-seven patients underwent total component revision, 12 underwent stem revision only, 13 did not receive ≥ 2 years follow-up, and 22 underwent modular component exchange (only head or liner exchange). The final analysis included 119 patients (Fig. 1).

Patient records were analyzed for age, follow-up period, sex, cause of revision, cup and head size, polyethylene (PE) liner and head type, cup position, and postoperative complications. Patients who underwent cup revision were divided into DMC or CC groups, and preoperative

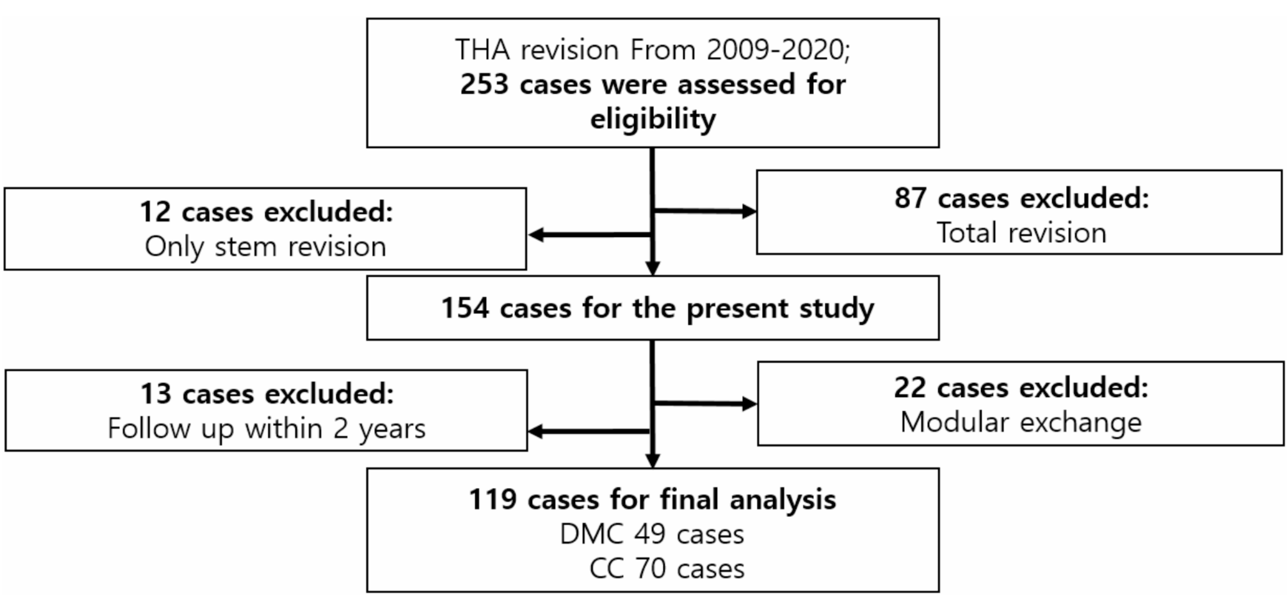

Fig. 1 Flowchart of patient enrollment in this study. THA, total hip arthroplasty; DMC, dual-mobility cup; CC, conventional cup

parameters and postoperative complications were compared between the two groups. The end of follow-up was the endpoint for observation of the time of complications occurrence after revision THA.

Previous arthroplasties were divided into the THA and BH groups. The causes of revision were aseptic loosening (71.3%), periprosthetic joint infection (PJI) (10%), dislocation (17.5%), and trauma(1.2%) for THA, and acetabular erosion (76.9%), PJI (12.8%), dislocation (17.5%), and trauma (2.6%) for BH.

There were no differences between the two groups with respect to age, sex, laterality, or reason for revision surgery. Eighty (67.2%) and 39 (32.8%) patients previously underwent THA and BH, respectively. Aseptic loosening was the most common cause of revision THA (57 patients, 71.3%), followed by BH (30 patients, 76.9%). Of the patients with degenerative lumbar spine disease (DSD), there were ten (20.4%) in the DMC group and thirteen (18.6%) in the CC group (Table 1).

Surgical procedure and rehabilitation

The need for general, spinal, or epidural anesthesia was determined per the American Society of Anesthesiologists classification in collaboration with an anesthesiologist. Preoperative computed tomography was performed on all patients to evaluate acetabular deformity, bone defect, and fracture and plan preoperative templating for implant size and bone graft.

All patients were placed in the lateral decubitus position, and a single surgeon used a posterolateral approach to perform the surgery. During surgery, synovial fluid analysis, bacteriological tests, and frozen sectioning were routinely performed to exclude infections after opening the hip joint. After clearing the surrounding stem during surgery, intraoperative stability was confirmed by gently shaking the stem, and isolated cup revision was performed if there was no motion and the stem was stable. A cementless standard cup (Trilogy®, ZimmerBiomet, Inc., Warsaw, IN, USA) was used for the CC group, and a cementless dual mobility cup (G7®, ZimmerBiomet) was used for the DMC group. There are no specific criteria for choosing between DMC and CC. The Paprosky classification was used to categorize acetabular bone deficiency. Type I 72(60.5%), Type IIA 37(31.1%), Type IIB 6(5.0%), Type IIC 3(2.5%), Type IIIA 1(0.8%), and Type IIIB 0(0.0%) were observed. The bone defect sites were curetted and impacted with allografts. In all cases, strut bone grafting was not performed, as there was no group in which the host bone contact had less than 50%. The bone defect sites were curetted during surgery, and impacted bone grafts using autogenous materials and allografts were performed. For acetabular component fixation, a 1–2 mm press-fit fixation technique and transacetabular screw fixation were performed in all patients. In cases where press-fit was impossible due to peripheral rim defects, line-to-line fitting was allowed,

Table 1 Patient demographics

Characteristic	All	DMC	CC	*P*-value
All cases	119 (100%)	49 (41.2%)	70 (58.8%)	
Age(year),	62 ± 10.5	64 ± 9.94[43–82]	61 ± 9.85[35–83]	0.043
Follow-up(month)	35.8 ± 25.6[24.5 ~ 110]	25.3 ± 15.9[24.5 ~ 72]	36.2 ± 22.6[26 ~ 110]	0.001
Average revision (year)	14.03 ± 9.43[0–35]	15.60 ± 10.14[0 ~ 34]	13.58 ± 9.05[0.2 ~ 35]	0.102
Gender				0.442
Men	77 (64.7%)	30(61.2%)	47(67.1%)	
Women	42 (35.3%)	19(38.8%)	23(32.9%)	
Side				0.665
Right	66(55.5%)	25(51%)	41(58.6%)	
Left	53(44.5%)	24(49%)	29(41.4%)	
THA	80(67.2%)	38(47.5%)	42(52.5%)	
Aseptic loosening	57(71.3%)	26(68.4%)	31(73.8%)	0.595
PJI	8(10%)	5(13.2%)	3(7.1%)	0.370
Dislocation	14(17.5%)	6(15.8%)	8(19.0%)	0.702
Trauma	1(1.2%)	1(2.6%)	0	0.475
BH	39(32.8%)	11(28.2%)	28(71.8%)	
Acetabular erosion	30(76.9%)	9(81.8%)	21(75%)	0.649
PJI	5(12.8%)	1(9.1%)	4(14.3%)	0.662
Dislocation	3(7.7%)	1(9.1%)	2(7.1%)	0.837
Trauma	1(2.6%)	0	1(3.6%)	1
DSD(including fusion)	23(19.3%)	10(20.4%)	13(18.6%)	0.803

DMC, dual-mobility cup; CC, conventional cup; PJI, periprosthetic joint infection; THA, total hip arthroplasty; BH, bipolar hemiarthroplasty; DSD, degenerative lumbar spine disease

Data are presented as mean ± standard deviation[minimum] or number (proportion) and transacetabular screws were fixed in three or more places to ensure stability immediately after surgery. The cup position was aimed at maintaining the native center of rotation. Using preoperative CT scans, the anteversion of the patient was measured. At the start of the procedure, the appropriate anteversion and inclination were determined by comparing the intact bony landmarks with the preoperative CT scans. During the surgery, the accuracy of the cup position was further verified using a portable X-ray or fluoroscope, we aimed to position the beam toward the midpoint of the line connecting the upper symphysis pubis and the anterior superior iliac spine whenever feasible. However, we did not rely solely on intraoperative imaging; instead, we comprehensively positioned the cup by considering the patient's bony landmarks and the guide frame provided by the manufacturer. Stability testing and soft tissue tension evaluation were performed after true component reduction. The capsule, piriformis, and conjoint tendons (short external rotators) were repaired posteriorly using a trochanteric drill hole. In cases where it was difficult to distinguish between the capsule and short external rotators due to previous surgery, the capsule was reconstructed using multiple nonabsorbable sutures with the surrounding tissue without distinguishing between the two structures [17]. Patients started quadriceps setting exercises and partial weight-bearing ambulation using crutches on the first day postoperatively. They maintained ambulation with crutches for 3 months after surgery while limiting hip flexion to 90°.

According to the venous thromboembolism prevention guidelines for hip arthroplasty [18], all patients wore anti-thrombotic stockings on both legs and used intermittent pneumatic compression devices to prevent potential postoperative deep vein thrombosis (DVT) and pulmonary embolism. Low-molecular-weight heparin (4000 units) was administered to all patients, except those at risk of bleeding, from before surgery until the end of their hospital stay; acetylsalicylic acid was administered orally for 6 weeks after discharge [18, 19].

Patients were followed up at 6 weeks, 3, 6, and 12 months, and then annually in an outpatient setting. Clinical evaluations were performed using the modified Harris hip score (HHS) [20]. Following discharge after surgery, radiographic assessments of the hip, including anteroposterior (AP), lateral, and Lorenz views, were conducted during outpatient follow-up visits. Radiolucent lesions ≥ 2 mm around the prosthetic components that were not present immediately postoperatively, or radiolucent lines progressing even if less than 2 mm, were denoted as osteolysis. In addition, Changes in the inclination $> 5^{o}$ and vertical or horizontal migration of the acetabular component ≥ 2 mm were also defined as acetabular component loosening [21].

Statistical analysis

Data were analyzed using the SPSS software (ver. 24.0 for Windows; IBM, Armonk, NY). Categorical variables were presented as frequencies and percentages, and numeric variables as means ± standard deviation. We performed the Shapiro-Wilk test to assess normality. For continuous variables that did not follow a normal distribution, we used the Mann-Whitney U test for analysis. Chi-square tests were used for between-group comparisons, and Fisher's exact test was used when the expected frequencies were small. The Wilcoxon signed-rank test was used to compare the HHS before and after the THA revision. Statistical significance was set at $p < 0.05$.

Result

Patients

Forty-nine (41.2%) and 70 (58.5%) patients were in the DMC and CC groups, respectively. The mean age of the patients at the time of the operation was 62 ± 10.5 years (range, 35–83 years), and the mean time from primary arthroplasty to re-revision surgery was 14.03 years. The overall mean follow-up period for all patients was 35.8 ± 25.6 (range, 24.5–110 months), and the DMC group had a shorter mean follow-up period than the CC group for historical reasons ($p = 0.001$). BMI was 24.05 ± 3.37 in the total group, 23.96 ± 3.36 in the CC group, and 24.25 ± 3.39 in the DMC group ($p = 0.367$).

Operative data and complications

The average cup size used during cup revision was 55.91 ± 4.46 mm, and the head size was an average of 30.1 ± 3.14 mm (outer bearing size for DMC), with significant differences between the two groups ($p = 0.007$, $p < 0.001$). The cup-head ratio was 1.26 ± 0.03 (range, 1.17–1.30) and 1.7 ± 0.2 (range, 1.5–2.4) for the DMC and CC groups, respectively ($p < 0.001$) (Table 2). In the CC group, the PE options used were standard in 38 (54.3%) cases and elevated in 32 (45.7%). A vitamin E-infused highly cross-linked PE dual-liner was used in the DMC group in all cases. Cup position and liner type, including anteversion (DMC: 19.05°±1.70, CC: 18.62°±1.34) and inclination (DMC: 42.54°±1.52, CC: 43.96°±1.41), were not significantly different between the two groups.

Re-revision was performed in four (8.1%) and 14 (20.0%) patients in the DMC and CC groups, respectively. Aseptic loosening (8 cases), dislocation (6 cases), and PJI (3 cases) were the most common causes of re-revision. Dislocation was significantly different between the two groups, with no occurrence in the DMC group ($p = 0.042$). Three patients underwent complications-associated surgery three or more times after re-revision. Among these, two cases were attributed to PJI, and one case was due to trauma. One year postoperatively, the modified HHS was 90.42 (DMC) and 89.56 (CC),

Table 2 Operating data

Characteristics	All 119 (100%)	DMC 49 (36.8%)	CC 70 (63.2%)	*P*-value
Cup size	55.91 ± 4.46[44 ~ 66]	57.14 ± 4.02[48 ~ 66]	55.26 ± 4.77[44 ~ 66]	0.007
Head size	30.1 ± 3.14[22 ~ 36]	45.29 ± 2.96[38 ~ 54]	32.67 ± 3.08[28 ~ 36]	0.001>
Under 28 mm	2	2	0	
28 mm		47	27	
32 mm	25	0	25	
36 mm	18	0	18	
Head-neck ratio	-	3.77 ± 0.24[3.34 ~ 4.17]	2.7 ± 0.26[2 ~ 3]	0.001>
Cup-head ratio	-	1.26 ± 0.03[1.17 ~ 1.30]	1.7 ± 0.2[1.5 ~ 2.4]	0.001>
Liner				0
Standard	38(31.9%)	0	38(54.3%)	
Elevated	32(26.9%)	0	32(45.7%)	
Dual mobility	49(41.2%)	49(100%)	0	
Prosthetic femoral head				0.001>
Metal	51(42.9%)	12(24.5%)	39(55.7%)	
Ceramic	68(57.1%)	37(75.5%)	31(44.3%)	
Cup position				
Anteversion	18.79°±1.50	19.05°±1.70	18.62°±1.34	0.053
Inclination	43.41°±1.61	42.54°±1.52	43.96°±1.41	0.079

DMC, dual-mobility cup; CC, conventional cup

Data are presented as mean ± standard deviation [minimum] or number (proportion)

* The head size in this table indicates the poly-insert outer diameter as a measured value in the case of the DMC

Table 3 Complications and clinical results in the two groups

Reason for re-revision			DMC(49)	CC(70)		*P*-Value	
Total			4(8.1%)	14(20.0%)		0.761	
Aseptic loosening			1(2.0%)	7(10.0%)		0.237	
PJI			2(4.1%)	1(1.4%)		0.568	
Dislocation			0	6(7.2%)		0.042	
Periprosthetic fracture			1(2.0%)	0		0.412	
Variable		Before	Follow-up time(year)				
			1	2	3	4	*P*-Value
DMC	mHHS	46.31	90.42	91.32	90.82	87.17	0.321
CC	mHHS	49.53	89.56	87.52	85.31	84.22	

DMC, dual-mobility cup; CC, conventional cup; PJI, periprosthetic joint infection.; mHHS, modified Harris hip score; DMC, dual-mobility cup; CC, conventional cup

* There was no significant difference in HHS scores between the two groups

indicating a satisfactory score; however, no statistical significance was observed (Table 3).

Discussion

This study investigated and analyzed the differences in outcomes and complications between DMC and CC in patients who underwent isolated cup revision and those who required revision THA. Our study showed four (8.1%) cases of complications after using DMC and 14 (20.0%) after using CC. Among the complications, dislocation showed a statistically significant difference between DMC and CC groups, but no difference was observed in the clinical outcomes between the two groups. This finding is consistent with the authors' hypotheses.

The most important finding of our study was the low dislocation rate with the use of DMC in revision THA. Khatod et al. [22] reported that instability was the most common indication for revision THA (49.8%), and some reports have shown revision rates due to instability, with dislocation rates of 14.6–22.5% for revision and 14–21% for re-revision [3, 23]. We did not include cases of total revision because many studies have reported a low dislocation rate with DMC in total component revision THA. In addition, the surgeon can adjust the stem version or offset to prevent dislocation with relatively many options in total component revision. However, the parts the surgeon can adjust in isolated cup revision are few. Furthermore, studies on DMC in isolated cup revision are rare [24]; therefore, we conducted a study on isolated cup revision, a frequent type of partial arthroplasty.

According to Hartzler et al. [25], a 3.5-year follow-up was performed on a large head (≥ 40 mm) and DMCs; the dislocation rate was three times higher in the CC group than in the DMC group. The revision rate due to dislocation was approximately seven times higher in the CC group. Similarly, Chalmers et al. [26] observed a lower dislocation rate in the DMC group after a 2-year follow-up of a group with a head size of ≥36 mm and a group that had converted to DMC after BH.

DMCs improve stability using a jumbo cup and a constrained acetabular component. The constrained acetabular component increases the risk of aseptic loosening in DMCs, reduces the arc of motion without impingement, and is related to the locking system breakage [27, 28]. These complications often require revision THA [29]. Large femoral heads and jumbo cups increase the jump distances and improve stability. However, in our study, a low cup-head ratio ($p < 0.001$) in DMCs compared to CCs increased the jump distance and reduced the dislocation rate, whereas a high head-neck ratio ($p < 0.001$) in DMCs compared to CCs increased the arc of motion. Our study also observed one case of aseptic loosening in the DMC group.

The problem with large heads is an increase in the contact area, which increases volumetric wear and the risk of thin PE damage [30]. Previously, long-term survival has been problematic with the conventional PE used in DMCs because of this issue; however, modern DMCs and new-generation PEs reduce intraprosthetic dissociation (IPD) and wear particles [31]. This is achieved using a highly cross-linked PE (HXLPE) liner and a 28 mm large femoral head, an optimized capture mechanism of the head, a non-hemispherical shell to reduce impingement with soft tissue, and a porous coating to improve osteointegration. The G7 Cup used in our study was designed to reduce wear using a relatively small inner diameter head compared to conventional THA, which uses HXLPE with vitamin E for oxidative stability and irradiation for wear resistance and mechanical strength improvement. No cases of IPD were observed in this study.

When using DMC, a large outer head is used, which portends fretting and corrosion at the femoral head taper and stem trunnion junction as the length of implantation increases and trunnion flexural rigidity decreases, particularly in mixed-metal taper-trunnion designs [32]. Fretting and corrosion increase the metal wear debris and ion concentration, initially derived from the bearing surface [33, 34]. Recent studies have reported severe fretting and corrosion in tapers composed of cobalt-chromium alloy modular necks and titanium alloy stems [35]. Cobaltism can lead to tinnitus, vertigo, blindness, deafness, cardiomyopathy, hypothyroidism, and peripheral neuropathy [36]. Although studies on DMC have reported fretting and corrosion similar to those in traditional modular THA systems, characteristic fretting and corrosion, as seen in metal-on-metal systems with cobalt-chromium alloy modular necks and titanium alloy stem, have not been reported, and DMC is considered safe [37, 38]. However, additional research and follow-up are needed. Our study also confirms that blood metal ion levels should be checked annually in patients to monitor these concerns.

Sappey-Marinier et al. [39] reported a high risk of periprosthetic fractures after using DMC, with periprosthetic fractures likely to occur approximately 12 times more than in those with CC. However, in our study, the number of periprosthetic fracture complications was minimal, and we could not find a relationship between DMC and CC.

This study has several limitations. First, we acknowledge the potential for selection bias owing to the retrospective study design. To minimize selection bias, we included all patients who underwent THA revision between 2009 and 2020 in the study group. Second, the number of patients in the entire cohort was relatively small, which could have led to an attrition bias. This study did not analyze the impact of spinopelvic issues. In patients with spinopelvic problems, careful attention to cup position is particularly important. In this study, the frequency of degenerative spine conditions was similar between the two groups during the preoperative assessment. With a larger patient cohort in future studies, it will be possible to analyze outcomes considering the spinopelvic relationship. Finally, the follow-up period for DMC was relatively short, and continuous follow-up is necessary to determine long-term survival.

This study establishes the benefits of DMC over CC in isolated cup revision. DMC can be a good option, providing stability and reducing postoperative dislocation and re-revision THA, even in cases of isolated cup revision, compared to CC. DMC is a good option for THA revision when a relatively large head cannot be used. However, close monitoring is necessary to address problems associated with using a large head.

Conclusion

This study suggests that the benefits of DMC over CC in isolated cup revision. DMC can be a good option, providing stability and reducing postoperative dislocation and re-revision THA, even in cases of isolated cup revision, compared to CC. DMC is a good option for THA revision when a relatively large head cannot be used. However, close monitoring is necessary to address problems associated with using a large head.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08553-8.

Supplementary Material 1

Acknowledgements
None.

Author contributions
Tae Woo Kim: wrote the original draft and analyzed the data.Min Uk Do: performed data analysis and curation and reviewed and edited the manuscript. Kyeongbaek Kim: performed data visualizations and curation.Jae Jin Kim: performed data visualizations and curation.Kuen Tak Suh: performed the software validation and data curation. Won Chul Shin: conceptualized the project, performed all necessary administration, and reviewed and edited the manuscript.

Funding
The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the principles of the Declaration of Helsinki and strengthening the reporting of observational studies in epidemiology (STROBE) guidelines for cohort studies, and Pusan National University Yangsan Hospital institutional review board (No. 05-2023-040) approval was obtained. Informed consent was obtained from all patients. This observational study was conducted at a tertiary hospital based on a retrospective review of consecutively collected clinical and radiologic data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Disclosure
The authors did not receive any outside funding or grants in support of the study or during the preparation of this work. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which the authors, or a member of their immediate families, are affiliated or associated.

Clinical trial number
Not applicable.

Received: 15 January 2025 / Accepted: 18 March 2025
Published online: 29 March 2025

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