

Reconstruction of Severe Acetabular Bone Defects Using a Multi-cup Technique in Revision and Complex Primary Total Hip Arthroplasty

Tihui Wang

drwth82@sina.com

Mindong Hospital Affiliated to Fujian Medical Univesity

Zhenbao Lu

Mindong Hospital Affiliated to Fujian Medical Univesity

Hui Wang

900th Hospital of PLA Joint Logistic Support Force

Hongwei Xu

Mindong Hospital Affiliated to Fujian Medical Univesity

Jinqing Wu

Mindong Hospital Affiliated to Fujian Medical Univesity

Xu Wang

Mindong Hospital Affiliated to Fujian Medical Univesity

Research Article

Keywords: Total hip arthroplasty, Acetabular defects, Cup-on-cup, Multi-cup

Posted Date: April 7th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9072985/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Objective: This study aimed to report the mid- to long-term clinical and radiographic outcomes of the multi-cup technique for treating severe acetabular bone defects in revision and complex primary total hip arthroplasty.

Methods: A retrospective review was conducted on 26 patients (28 hips) who underwent revision total hip arthroplasty (THA) using the multi-cup technique from 2014 to 2023. According to the Paprosky classification, the acetabular defects were type IIC 8 case, type IIIA 11 cases and type IIIB 9 cases (3 cases with pelvic discontinuity). Based on the number of the acetabular cups. The patients were divided into the double-cup and triple-cup group. Patients were followed clinically and radiographically for a mean of 6 Years.

Results: The mean Harris Hip Score (HHS) improved from 32.0 preoperatively to 86.3 at the last follow-up. The Merle d'Aubigné-Postel scores for pain and walking improved from 2.6 to 5.3 and from 2.2 to 4.1, respectively. Compared with the contralateral side, The mean superior displacement of the hip centre of rotation (COR) was corrected from 36.5 mm pre-operatively to 0.3 mm post-operatively. Similarly, the mean post-operative medial displacement was corrected from 8.9 mm to 1.4 mm. Furthermore, the efficacy of correcting COR(upward/downward and inward/outward displacement) in the triple-cup group was superior to the double-cup group($p < 0.05$). Two patients of triple-cup group experienced a dislocation three weeks and three months post-operatively, respectively; One patients of double-cup group experienced an intra-operative Vancouver type B2 periprosthetic femoral fracture, and periprostheses joint infection, respectively. Three patients exhibited a non-progressive radiolucent line in the acetabular zone C, which remained stable at the last follow-up. All patients showed no evidence of component migration or loosening.

Conclusion: The multi-cup technique can be a viable alternative for severe bone defects in revision and complex primary THA which resulted in acceptable clinical and radiographic outcomes at the mid- to long-term follow-up. Compared with the double-cup technique, the triple-cup technique showed advantage in restoring the hip COR but disadvantage in dislocation.

Introduction

Severe acetabular bone loss with or without pelvic discontinuity poses a substantial challenge in the management of revision and complex primary total hip arthroplasty (THA). Achieving implant stability in these situations requires special considerations or specialized implants. Sufficient initial fixation and biological osseointegration were both important for the effectiveness of reconstruction. Some options, including the use of cup-cages, oblong or jumbo cups, impaction bone grafting or structural allografts^[1, 2], and custom triflanged components^[3, 4], were employed to address the severe acetabular bone defects. Each of these techniques has unique indications, often related to patient factors, such as anatomy and function. A systematic review indicated that compared

with impaction bone grafting or custom implants, metal augmentation and jumbo implantation resulted in superior outcomes^[5, 6]. Inadequate initial stability and suboptimal biomechanical reconstruction may lead to early failure because the shape and size of the severe acetabular bone defects usually make the use of a jumbo cup with metal augments extremely difficult, especially for pelvic discontinuity. Acetabular reconstruction with acetabular distraction is another technique that has shown promising durability at the 5.1- to 13.5-year follow-up. Four (26.7%) patients required reoperation, only two of whom had indications related to the acetabular construct, leading to an overall survival rate of 86.7%^[7]. A promising treatment strategy that addresses major acetabular defects, including pelvic discontinuity, is the cup-on-cup technique. The cup-on-cup construct utilizes one or more extra acetabular cups as an augment to address the severe acetabular bone defects. The advantages of this solution include initial stable fixation and restoration of the hip centre of rotation (COR). This technique provides the advantages of cost-effectiveness and convenience. Few studies in the current literature have reported on the outcomes of the cup-on-cup technique, and most of these have reported short- to mid-term outcomes and severe acetabular defects. Du^[8] reported on 6 hips with a mean age of 59 years and investigated the outcomes of the cup-on-cup technique to address severe acetabular bone defects, with a mean follow-up of 42 months (range 36 to 52). The mean Harris Hip Score improved significantly at the last follow-up. There was no evidence of component migration at the last follow-up. Liu^[9] compared double-cup constructions with a Jumbo cup and augments at a mean of 39 months and demonstrated that the double-cup is a reliable revision technique for the reconstruction of severe acetabular bone defects. However, so far as we know, there was relatively few literatures which has reported three acetabular cups for reconstructing the severe acetabular bone defects. This study showed the mid- to long-term clinical and radiographic outcomes of multi-cup treating severe acetabular bone defects in revision and complex primary THA. The results are as follows.

Materials and Methods

Clinical Data

Our institution approved the research ethics for our study (Approval No. K2025123001). A retrospective review of our total hip revision database was performed to identify all total hip revision surgeries performed when a multi-cup technique was implemented from 2014 to 2023. the patients were divided into double-cup group and triple-cup group based on the number of the reconstructing acetabular cup. A minimum follow-up time period of 2 years was required.

The inclusion criteria comprised (i) a Paprosky type IIC, IIIA or IIIB acetabular defect, (ii) revision THA performed using the described multi-cup technique, and (iii) a minimum follow-up of 2 years. The exclusion criteria were (i) pre-operative periprosthetic fracture, (ii) revision for tumour, (iii) patient refusal, (iv) death or loss to follow-up, and (v) incomplete radiographic data.

In our series, 28 multi-cup were identified in 26 unique patients . The cohort consisted of 12 males and 14 females, two patients performed both hip revision(Fig 5). The mean age were 66.3 ± 13.8 in the double-cup and 67.4 ± 10.5 years in triple-cup group, respectively($p>0.05$). The BMI were 21.4 ± 2.5 in the double-cup and 22.8 ± 3.1 kg/m² in triple-cup group, respectively($p>0.05$). The time to surgery were 12.4 ± 6.1 in the double-cup and 13.5 ± 7.2 years in triple-cup group, respectively($p>0.05$). All revisions were performed for aseptic loosening. Defects were defined according to the Paprosky classification^[10], and the acetabular defects were type IIC 8 case, type IIIA 11cases and type IIIB 9 cases (3 cases with pelvic discontinuity). The cementless acetabular component with multiple holes (DePuy Synthes, USA) was used in 12(70.6%)of the double-cup and 9(81.8%)of the triple-cup group, respectively. The rest was used the multihole cup of the Zimmer Biomed(29.4% of the double-cup group and 18.2% of the triple-cup group). The mean clinical and radiographic follow-up was 74.5 ± 9.6 in the double-cup group and 72.8 ± 8.3 months in triple-cup group, respectively, with no patients lost to follow-upTable 1.

Table 1 Patient characteristics

Parameters	Double-cup (n=17)	Triple-cup n=11	P value
Mean follow-up (months)	74.5 ± 9.6	72.8 ± 8.3	0.278
Age years	66.3 ± 13.8	67.4 ± 10.5	0.231
BMI (kg/m ²)	21.4 ± 2.5	22.8 ± 3.1	0.198
Sex n			0.367
Male	8(50%)	4(40%)	
Female	8(50%)	6(60%)	
Revision or complex primary THA (n)			0.285
Revision total hip arthroplasty (rTHA)	14(82.4%)	11(100%)	
Complex total hip arthroplasty (cTHA)	3(17.6%)	0(0%)	
Implant manufacturers n			0.168
Depuy Synthes	12(70.6%)	9(81.8%)	
Zimmer Biomed	5(29.4%)	2(18.2%)	
Time-to-surgery years	12.4 ± 6.1	13.5 ± 7.2	0.450

Procedure of acetabular reconstructon by multi-cup and Post-operative Management

All surgeries employed a standard posterolateral approach, including 3 patients who underwent a prior Hardinge approach. Femoral component extraction required extended trochanteric osteotomy (ETO)

in 4 patients. Acetabular reconstruction began with removal of the failed cup and all fibrous/necrotic tissue using curved osteotomes, carefully avoiding iatrogenic fracture or defect enlargement.

After the defect geometry was assessed with progressively larger hemispherical reamers, definitive reaming created a hemispherical bone bed aiming for a 1–2 mm press fit while preserving the anterior and posterior columns. A key step was the implantation of an inner acetabular shell into the primary defect as a structural augment secured with multiple screws for initial stability (**Fig. 1A**). Its placement was planned so that it did not compromise the definitive outer cup.

The acetabulum was then reassessed for the outer cup, which was positioned to restore the centre of the native hip. Intra-operative fluoroscopy was used for localization. The true anatomical acetabular position was identified using landmarks such as the transverse acetabular ligament and the obturator foramen (**Fig. 1B**).

A multihole acetabular component allowed supplemental screw fixation, preferentially targeting the pubic and ischial columns. Antibiotic-loaded bone cement was subsequently used to reinforce the cement-prosthesis interface (**Fig. 1C**).

After the anteversion and abduction angles were adjusted to achieve a secure press fit, the porous outer cup was implanted into the true acetabulum until the cement worked out (**Fig. 1D**).

The third multihole cup was fixed to the outer cycle of the acetabular, by adjusting the right angle and bony coverage. The screws were fixed to the ischial and pubic. Then the cement was filled to the gap between the second and third multihole cups.

Peri-operative Management

Incision drains were placed in seven patients and removed within 24–48 hours. All patients received 24 hours of intravenous antibiotic prophylaxis post-operatively. Anticoagulation was initiated on post-operative day one with subcutaneous low-molecular-weight heparin, which was transitioned to oral rivaroxaban upon discharge for 5 weeks.

Rehabilitation commenced with quadriceps strengthening and active knee range of motion exercises on the first day post-operatively. Full weight-bearing with two walkers began on the first post-operative day over the subsequent 3 months.

Clinical Outcome Assessment

Surgical parameters, including operative time and prosthesis details, were recorded. Patients were followed up at 1, 3, 6, and 12 months post-operatively and annually until the last follow-up. Clinical outcomes were assessed using the Harris Hip Score (HHS) and the modified Merle d'Aubigné-Postel Scale for pain and walking function^[11]. All post-operative complications were documented.

Radiographic Assessment

Pre-operative acetabular defects were classified according to the Paprosky system, with intra-operative confirmation by the senior author. Post-operative radiographs were evaluated independently by two observers. Measurements included pre-operative and final follow-up vertical and horizontal displacement of the hip COR relative to the contralateral side. Radiographs were also assessed for signs of loosening (radiolucent lines >2 mm, component migration, or screw fracture) or infection, as defined by Moore et al.^[12].

Statistical Analysis

Continuous data are presented as the mean ± standard deviation, and categorical data are presented as the frequency (percentage). The Kruskal–Wallis test was used for nonparametric continuous variables, and the chi–square test was used for categorical variables. Radiographic measurements were performed by three independent observers. All analyses were conducted using SPSS version 26.0, with a p value <0.05 considered statistically significant.

Results

Clinical Outcomes

A total of 26 patients (28 hips) underwent revision and complex primary THA using the double (17/28) or triple (11/28) cup reconstruction technique from 2014 to 2023. All procedures were performed by a single senior surgeon. The mean operative time was 134.7 ± 17.3 minutes, The double-cup group showed shorter operation time comparing with the triple-cup group(122.3 ± 16.4 vs 145.1± 24.0 min, p<0.05). The cup diameter were 47.8± 3.5, 44.3± 5.6 and 61.8 ± 4.7 mm for the inner, middle and outer cup, respectively. There were no significantly difference between the two group(p>0.05). The ceramic-polyethylene(COP) was used for most of the patients (64.7% of double-cup group and 81.8% of triple-cup group). The exclusive indication for revision was aseptic loosening, with no evidence of periprosthetic joint infection. The implant details are listed in Table 2.

Table 2 Parameters during the operation

Parameters	Double-cup (n=17)	Triple-cup (n=11)	Total (n=28)
Operative time (min)	122.3 ± 16.4	145.1 ± 24.0 [#]	134.7 ± 17.3
Diameter of the cup			
Inner cup diameter (mm)	46.1 ± 4.9	48.7 ± 6.2	47.8 ± 3.5
Middle cup diameter (mm)	/	44.3 ± 5.6	44.3 ± 5.6
Outer cup diameter (mm)	62.5 ± 6.8	60.3 ± 5.2	61.8 ± 4.7
Friction interface			
Ceramic-polyethylene(COP)	11 (64.7%)	9 (81.8%)	20 (71.4%)
Ceramic-ceramic(COC)	6 (35.3%)	2 (18.2%)	8 (28.6%)

[#] compared with double-cup group, $p < 0.05$.

Clinical outcomes improved significantly at the final follow-up. The mean Harris Hip Score increased from 32.0 ± 11.3 pre-operatively to 86.3 ± 5.4 post-operatively ($p < 0.01$). The double-cup group was from 36.0 ± 15.2 to 88.4 ± 7.0 ($p < 0.01$), and the triple-cup group was from 25.0 ± 10.1 to 84.1 ± 6.7 ($p < 0.01$). Similarly, the modified Merle d'Aubigné-Postel scores also showed marked improvement: the mean pain score increased from 2.6 (range 2–4) to 5.3 (range 2–6) ($p < 0.01$). The double-cup group was from 2.7 to 5.5 ($p < 0.01$), and the triple-cup group was from 2.5 to 5.1 ($p < 0.01$). The mean walking score improved from 2.2 to 4.1 ($p < 0.01$), the double-cup group was from 2.4 to 4.3 ($p < 0.01$), and the triple-cup group was from 2.0 to 4.0 ($p < 0.01$).

Imaging Results

A significant correction in the position of the hip COR was achieved. Compared with the contralateral side, the mean pre-operative superior displacement of the hip COR (34.4 ± 15.3 mm) was effectively restored to the near-anatomical position post-operatively (0.4 ± 2.3 ; $p < 0.01$) in the double-cup group; while from 38.1 ± 17.0 to 0.2 ± 2.6 in the triple-cup group ($p < 0.01$). Furthermore, the efficacy of triple-cup group was superior to the double-cup group (0.2 ± 2.6 vs 0.4 ± 2.3 , $p < 0.05$). Similarly, the mean pre-operative medial displacement (8.4 ± 3.1 mm) was converted to a slight mean lateral displacement of 1.2 ± 1.6 mm post-operatively in the double-cup group ($p < 0.01$). while from 9.3 ± 2.3 to 1.9 ± 1.1 in the triple-cup group ($p < 0.01$). Furthermore, the efficacy of triple-cup group was superior to the double-cup group (1.9 ± 1.1 vs 1.2 ± 1.6 , $p < 0.05$). The mean abduction angle of the definitive acetabular component was 42.8 ± 3.2 and 40.2 ± 3.1 in the double-cup and triple-cup group, respectively. and the mean anteversion angle was 24.0 ± 2.1 and 22.0 ± 3.4 in the double-cup and triple-cup group, respectively. Showed no significantly difference ($p > 0.05$). Three patients exhibited a non-progressive radiolucent line in the acetabular zone C, which remained stable at the last follow-up. as shown in Table 3.

Table 3 Radiographic data before surgery and at final follow-up

Parameters	Double-cup (n=17)	Triple-cup (n=11)	Total (n=28)
Preoperative upward displacement of COR (mm)	34.4 ± 15.3	38.1 ± 17.0	36.5 ± 19.2
Postoperative upward/downward displacement of COR (mm)	0.4 ± 2.3**	0.2 ± 2.6**#	0.3 ± 2.5**
Preoperative inward displacement of COR (mm)	8.4 ± 3.1	9.3 ± 2.3	8.9 ± 2.6
Postoperative inward/outward displacement of COR (mm)	-1.2 ± 1.6**	-1.9 ± 1.1**#	-1.4 ± 1.8**
Abduction angle	42.8 ± 3.2	40.2 ± 3.1	41.6 ± 2.9
Anteversion angle	24.0 ± 2.1	22.0 ± 3.4	23.0 ± 2.5

Note: COR, joint center of rotation; + means the center of rotation upward or inward; - means the center of rotation moves downward or outward. ** compared with pre-operatively, $p < 0.01$. # compared with double-cup group, $p < 0.05$.

Complications

Acetabular component osseointegration was assessed using the criteria described by Moore et al.^[12]. At the final follow-up, one of the reconstructions in the triple-cup group met the radiographic criteria for failure and dislocation due to the technique faulty, revised by double-cup. Three patients exhibited a non-progressive radiolucent line in acetabular zone C, which remained stable at the last follow-up. The complication rate was 14.3%. A patient experienced intra-operative Vancouver type B2 periprosthetic femoral fracture, which was managed with a revised femoral stem and cerclage wire, and X-ray showed radiographic union at 4 months post-operatively. The total dislocation rate was 7.1% (2/28); However, the two dislocation cases all in the triple-cup group (18.2%, 2/11), the first patient experienced recurrent dislocation 3 months post-operatively because of suboptimal anteversion of the acetabular component, which was revised by increasing the anteversion of the acetabular liner without recurrent dislocation. The other one was a 54-year-old female (Fig 3), demonstrated dislocation of the hip because of the outer cup was unstable at 3 weeks postoperatively. **Performing the acetabular revision, remove the second cup, use the acetabulum burr to deepen the socket, re-adjust the acetabular angle and install the third multi-hole cup (the same one).** There was no evidence of aseptic loosening, instability, periprosthetic fracture, or osteolysis throughout the follow-up period. One patient (3.8%) developed a deep infection within 3 weeks after surgery (Fig 4). A DAIR (debridement, antibiotics and implant retention) procedure was performed in

combination with a 6-week course of antibiotics, which successfully eradicated the infection, as shown in Table 4.

Table 4 Clinical outcomes and complications

Parameters	Double-cup (n=17)	Triple-cup (n=11)	Total (n=28)
Harris Hip Score (HHS)			
Pre-operatively	36.0 ± 15.2	25.0 ± 10.1	32.0 ± 11.3
Post-operatively	87.4 ± 7.0**	85.1 ± 6.7**	86.3 ± 5.4**
Modified Merle d'Aubigné-Postel Pain score			
Pre-operatively	2.7 (2–4)	2.5 (1–4)	2.6 (2–4)
Post-operatively	5.5 (3–6)**	5.1 (2–6)**	5.3 (2–6)**
Modified Merle d'Aubigné-Postel Walking score			
Pre-operatively	2.4 (1–3)	2.0 (1–3)	2.2 (1–3)
Post-operatively	4.3 (1–6)**	4.0 (1–6)**	4.1 (1–6)**
Complication	2 (11.8%)	2 (18.2%)	4 (14.3%)
dislocation	0 (0%)	2 (18.2%) [#]	2 (7.1%)
Periprosthetic fracture (PFFs)	1 (5.9%)	0 (0%)	1 (3.6%)
Periprostheses joint infection (PJI)	1 (5.9%)	0 (0%)	1 (3.6%)

** compared with pre-operatively, p < 0.01. [#] compared with double-cup group, p < 0.05.

Typical cases

Case 1

Case 2

Case 3

Case 4

Discussion

Reconstruction of severe acetabular bone defects represents a major challenge in revision and complex primary total hip arthroplasty. Achieving a stable construct with adequate initial fixation for

osseointegration and restoring the native hip COR are crucial for optimizing biomechanics and long-term survival. Jumbo cups^[13], impaction bone grafting^[1, 2], and custom triflanged components^[3, 4] were used to address the severe acetabular bone loss. A systematic review indicated that metal augments and jumbo cups showed superior outcomes compared with impaction bone grafting or custom implants^[5, 6]. Nevertheless, the gold standard treatment for severe acetabular defects remains undefined.

In this study, a multi-cup technique in which one or more extra acetabular cups were used as augments to address severe acetabular bone defects was analysed.

This technique provides the advantages of cost-effectiveness and convenience, and demonstrated 100% survivorship for aseptic loosening, with a mean follow-up of 6 Years. Similar survivorship from loosening was noted by Jonathan^[14], who retrospectively reviewed 20 double-cup cases at a mean follow-up of 2.4 years at a single institution and reported no revisions for acetabular loosening and no cases of aseptic loosening. Radiographically, the technique reliably restored the hip COR to a near-anatomical position^[15-17]. Du^[8] reported that the mean vertical position of the hip rotation centre changed from 60.9 mm pre-operatively to 31.7 mm post-operatively, and that the mean horizontal position changed from 33.6 mm pre-operatively to 38.9 mm post-operatively. Li^[15] reported that the post-operative average upwards displacement was 0.2 ± 3.3 mm compared with that on the contralateral side. These outcomes were similar to our results. Clinically, significant improvements were observed in the Harris Hip Score^[6, 16] and modified Merle d'Aubigné-Postel score^[16] for pain and walking. Zhang^[18] reported that mHHS, UCLA, SF-36, LLD, and the hip COR had significantly improved at the last follow-up, which was an average of 61 months, when double trabecular metal cups alone or combined with impaction bone grafting were used for complex acetabular defects.

Jonathan^[14] reported a 25% dislocation rate within the first year after surgery, and most were acetabulum-only revisions. In this study, the dislocation rate was 7.1%, which was obvious lower to the previous research, perhaps because there was no partial revision of hip. However, the two dislocation cases all in the triple-cup group, the complication rate was 14.3%. the first patient experienced recurrent dislocation 3 months post-operatively because of suboptimal anteversion of the acetabular component, which was revised by increasing the anteversion of the acetabular liner without recurrent dislocation. The other one was a 54-year-old female(Fig 3), demonstrated dislocation of the hip because of the outer cup was unstable at 3 weeks postoperatively. Performing the acetabular revision, remove the second cup, use the acetabulum burr to deepen the socket, re-adjust the acetabular angle and install the third multi-hole cup(the same one). Similar complications were noted by Del Gaizo et al.^[19] when they evaluated their experience with the use of augments for Type IIIA defects, although they also reported excellent clinical outcomes. In this study, a nonprogressive radiolucent line was observed in three patients (10.7%) within 6 months post-operatively, but these patients did not meet the loosening criteria. Furthermore, the radiolucent line remained stable. Du^[8] reported that the radiolucent line was noted in one of six hips (16.7%), and the radiolucent line was smaller than 1 mm in zone C three months after surgery.

Although there were more literatures to describe the cup-on-cup technique to treat severe acetabular bone defects, there is still limited knowledge regarding factors that cause surgeons to perform either double-cup or triple-cup. In this study, the patients were divided into double-cup group and triple-cup group based on the number of the reconstructing acetabular cup. A minimum follow-up time period of 2 years was required. Compared with the double-cup technique, the triple-cup technique showed advantage in restoring the hip COR but disadvantage in dislocation. In the triple-cup group, a 54-year-old female(Fig 3), demonstrated dislocation of the hip because of the outer cup was unstable at 3 weeks postoperatively. Performing the acetabular revision, remove the second cup, use the acetabulum burr to deepen the socket, re-adjust the acetabular angle and install the third multi-hole cup(the same one). Based on our experience, the outer cup should be contacted with more host bone and fixed the screws to the ischium and pubis to ensure the primary mechanic stability; if not, the long screws connected with the holes of the outer cup and middle or inner cup could be performed with the cement to obtain the primary stability by preplanning. The cup diameter were 47.8 ± 3.5 , 44.3 ± 5.6 and 61.8 ± 4.7 mm for the inner, middle and outer cup, respectively. In our opinion, the diameter of the outer cup with multihole should be large enough, which was allowed to achieve socket fixation or three-point fixation of acetabular; at the mean time, it can be fixed as a bridging steel plate in case for Parprosky type IIIB acetabular bone defects with pelvic discontinuity after extending the pelvic. The diameter of the inner cup was decided by the defect morphology at the top of the acetabular, the mean diameter was 47.8 ± 3.5 mm in our study, and the fixing screws should be long enough to obtain stability of the basic cup. The middle cup was considered as metal augments, which was connected with the inner and outer cup, the position should be fixed deeply enough and the diameter not too large(44.3 ± 5.6 mm); otherwise, it may affect the normal placement and stability of the outer cup, In case 2(Fig 3), the outer cup of the triple-cup group was unstable at 3 weeks postoperatively and revised as double-cup, perhaps due to the improper position of the middle cup.

A notable advantage of this technique is its cost effectiveness. At our institution, the implant cost for extra cup constructions is substantially lower than that for metal augments, cup-cages and custom-triflanged components. This economic benefit, combined with the technique's inherent mechanical stability and extensive ingrowth surface, offers a compelling practical advantage. This has been reported in previous research^[8, 17, 18].

The limitation of this study was the retrospective design, which introduces potential selection bias and unmeasured confounders inherent to observational analyses. Second, the statistical power was constrained by the small cohort size and lack of long-term outcomes. However, owing to the standardized clinical and radiological follow-up protocol and the excellent documentation by the orthopaedic surgeons of our institution, all required patient data were available for the current analysis.

This study has several limitations. First, the relatively small sample size from a single-center may decrease its statistical power to detect significant differences in outcomes and complications. Second, the retrospective design introduces potential selection bias and unmeasured confounders inherent to observational analyses. Third, The confounding factors of the patients will affect the accuracy of the

comparative study. Further high-quality long-term studies are expected to explore these unsolved problems.

Conclusion

The multi-cup acetabular reconstruction technique provided reliable mid- to long-term fixation at a mean follow-up of 6 Years. This technique effectively restored the native hip COR and was associated with significant, sustained improvements in clinical function. These findings support its role as an effective, safe, and cost-efficient surgical option for severe acetabular bone defects in revision and complex primary total hip arthroplasty. Compared with the double-cup technique, the triple-cup technique showed advantage in restoring the hip COR but disadvantage in dislocation.

Declarations

Acknowledgements

The authors thank all participants that agreed to participate in this study.

Authors' contributions

Conceptualization: Tihui Wang, Zhenbao Lu; formal analysis and investigation: Hui Wang, Hongwei Xu; writing-review and editing: Jinqing Wu, Tihui Wang; resources: Xu Wang, Tihui Wang. All authors read and approved the final manuscript.

Funding

This work was supported by the Ningde Municipal Program for the Development of National Clinical Key Specialty Cultivation .

Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Affiliated Mindong Hospital of Fujian Medical University Ethics Committee. All participants signed informed consent forms.

Clinical trial number

not applicable.

Consent for publication

Not applicable.

Conflict of interests

The authors declare that they have no competing financial interests.

Author details

¹Department of Orthopedics, Mindong Hospital Affiliated to Fujian Medical University, Ningde 355000, Fujian, China

²Department of Orthopedics Surgery, 900th Hospital of PLA Joint Logistic Support Force, Fuzhou, 350000, Fujian, China

References

1. Bunting A C, Costi K, Chimutengwende-Gordon M, et al. Staged Revision Hip Arthroplasty With Femoral Impaction Bone Grafting for Prosthetic Joint Infections: Radiostereometric Analyses and Clinical Outcomes at Minimum 5-Year Follow-Up[J]. The Journal of arthroplasty, 2023,38(12):2716-2723.
2. Klimko A, Andronic O, Lu V Y Z, et al. Graft incorporation and stem subsidence in femoral impaction bone grafting for revision hip arthroplasty: a systematic review and meta-analysis of 2514 hips[J]. Archives of orthopaedic and trauma surgery, 2025,145(1):501.
3. Nees T A, Hariri M, Müller C T, et al. Implantation Accuracy of Custom-Made Acetabular Components With Iliac Stem Fixation for Large Bone Defects in Hip Revision Surgery[J]. Orthopaedic surgery, 2025,17(11):3159-3168.
4. Broekhuis D, Tordoir R, Vallinga Z, et al. Custom triflange acetabular components for large acetabular defect reconstruction in revision total hip arthroplasty: a systematic review and meta-analysis on 1218 patients[J]. EFORT open reviews, 2023,8(7):522-531.
5. Mancino F, Cacciola G, Di Matteo V, et al. Reconstruction options and outcomes for acetabular bone loss in revision hip arthroplasty[J]. Orthopedic reviews, 2020,12(Suppl 1):8655.
6. Malahias M, Ma Q, Gu A, et al. Outcomes of Acetabular Reconstructions for the Management of Chronic Pelvic Discontinuity: A Systematic Review[J]. The Journal of arthroplasty, 2020,35(4):1145-1153.
7. Salimy M S, Minutillo G T, Melnic C M, et al. Acetabular Distraction: Promising 5-Year Outcomes for the Treatment of Chronic Pelvic Discontinuity[J]. The Journal of arthroplasty, 2024,39(9S1):S188-

S193.

8. Du Y, Liu Y, Sun J, et al. Reconstruction of Paprosky type IIIB acetabular bone defects using a cup-on-cup technique: A surgical technique and case series[J]. *World journal of clinical cases*, 2020,8(7):1223-1231.
9. Liu Q, Zhang R, Ma R, et al. Outcomes of a Double-Cup Construct to Treat Paprosky 3A and 3B Acetabular Defects at a Mean of 39 Months[J]. *The Journal of arthroplasty*, 2024,39(11):2841-2848.
10. Paprosky W G, Cross M B. CORR Insights?: Validity and reliability of the Paprosky acetabular defect classification[J]. *Clinical orthopaedics and related research*, 2013,471(7):2266.
11. Vre S, Sandvik L, Madsen J E, et al. Comparison of distribution, agreement and correlation between the original and modified Merle d'Aubigné-Postel Score and the Harris Hip Score after acetabular fracture treatment: moderate agreement, high ceiling effect and excellent correlation in 450 patients[J]. *Acta orthopaedica*, 2005,76(6):796-802.
12. Moore M S, McAuley J P, Young A M, et al. Radiographic signs of osseointegration in porous-coated acetabular components[J]. *Clinical orthopaedics and related research*, 2006,444:176-183.
13. Wang Q, Wang Q, Liu P, et al. Clinical and radiological outcomes of jumbo cup in revision total hip arthroplasty: A systematic review[J]. *Frontiers in surgery*, 2022,9:929103.
14. Webb J E, McGill R J, Palumbo B T, et al. The Double-Cup Construct: A Novel Treatment Strategy for the Management of Paprosky IIIA and IIIB Acetabular Defects[J]. *The Journal of arthroplasty*, 2017,32(9S):S225-S231.
15. Li W, Liu D, Liu X, et al. Application of Intraoperative Individualized Cup Combination-Cup-on-Cup Technique in Severe Acetabular Defects[J]. *Orthopaedic surgery*, 2024,16(11):2853-2861.
16. Chiarlone F, Cavagnaro L, Zanirato A, et al. Cup-on-cup technique: a reliable management solution for severe acetabular bone loss in revision total hip replacement[J]. *Hip international : the journal of clinical and experimental research on hip pathology and therapy*, 2020,30(1_suppl):12-18.
17. Wu X, Xu W, Tian M, et al. Cup-on-cup technique to manage severe protrusio acetabular defects[J]. *Annals of the Royal College of Surgeons of England*, 2018,100(7):e181-e184.
18. Zhang X, Li Z, Wang W, et al. Mid-term results of revision surgery using double-trabecular metal cups alone or combined with impaction bone grafting for complex acetabular defects[J]. *Journal of orthopaedic surgery and research*, 2020,15(1):301.
19. Del Gaizo D J, Kancherla V, Sporer S M, et al. Tantalum augments for Paprosky IIIA defects remain stable at midterm followup[J]. *Clinical orthopaedics and related research*, 2012,470(2):395-401.

Figures

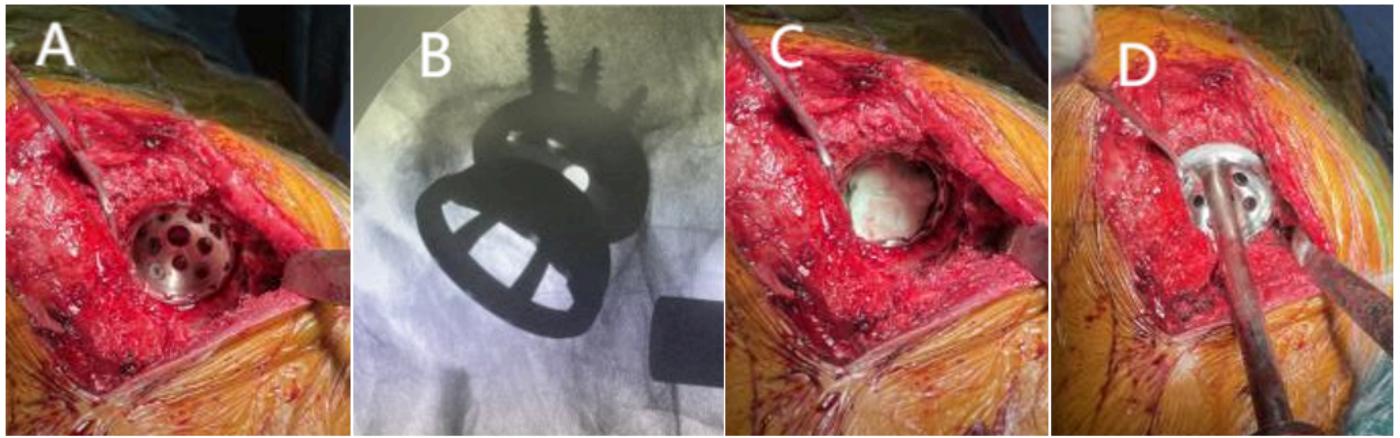


Figure 1

(A) Positioning of the augment (inner) cup to address the acetabular bone defect without compromising the placement of the definitive outer cup. (B) Intra-operative fluoroscopy was used for localization. The true anatomical acetabular position was identified using landmarks such as the transverse acetabular ligament and the obturator foramen. (C) Antibiotic-loaded bone cement was used to reinforce the cement-prosthesis interface. (D) After the anteversion and abduction angles were adjusted to achieve a secure press fit, the porous outer cup was implanted into the true acetabulum.

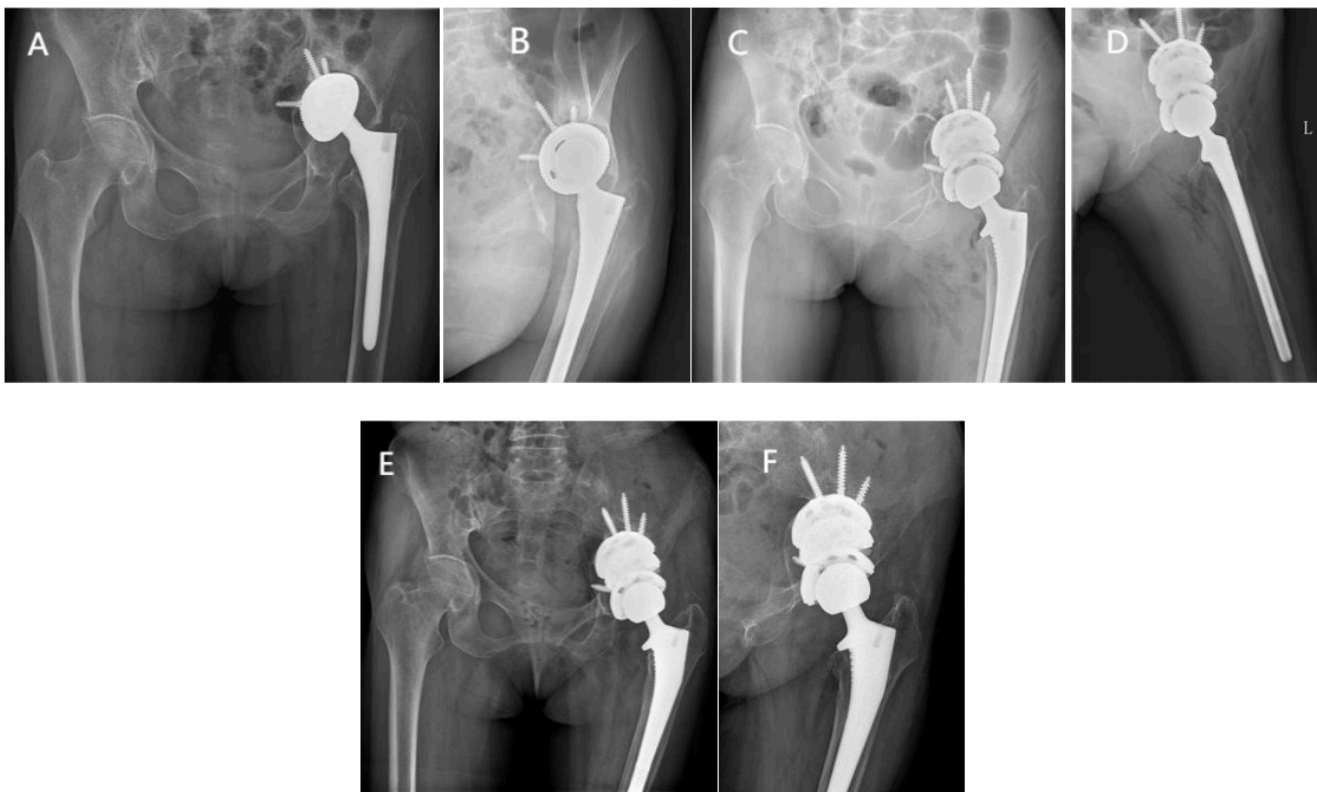


Figure 2

Pre-operative and post-operative radiographs of an 81-year-old female patient. **(A, B)** Pre-operative radiographs demonstrating a Paprosky type IIIB acetabular defect in the left hip. **(C, D)** Immediate post-operative radiographs showing reconstruction using a multi-cup construct. The space between the cups was filled with bone cement, and the hip ROC was restored by the extra two augment-cups. **(E, F)** Radiographs at the 5-year follow-up demonstrated stable component positioning without radiolucent lines and no evidence of aseptic loosening, instability, fracture, or osteolysis. No revision surgery was required.

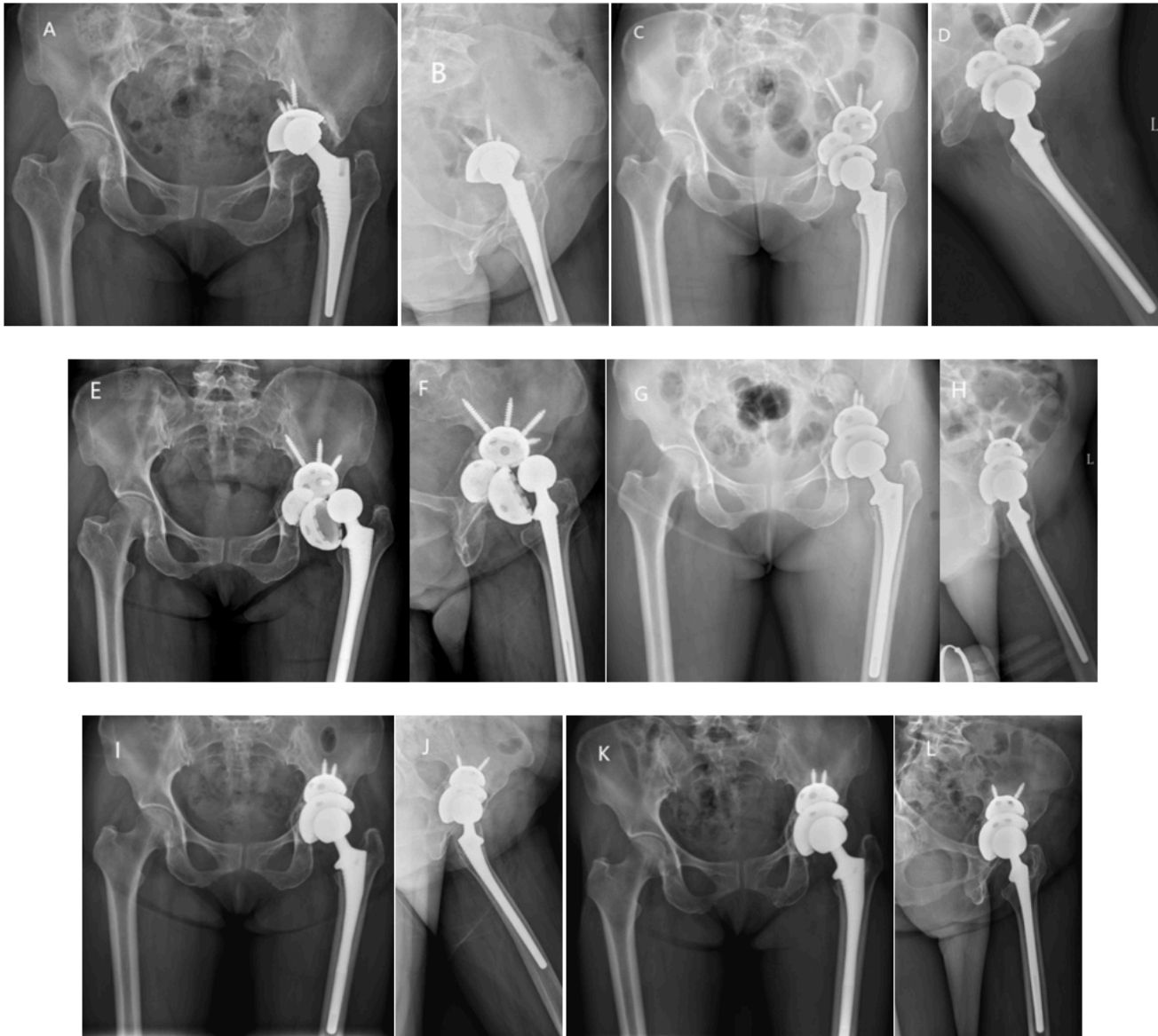


Figure 3

Pre-operative and post-operative radiographs of a 54-year-old female patient with left hip Paprosky type IIIB acetabular defects. **(A/B)** Pre-operative radiograph. **(C/D)** Immediate post-operative radiograph showing reconstruction using a multi-cup technique in the left hip, with bone cement applied between the cups and the hip ROC was restored by the extra augment cup. **(E/F)** Follow-up radiographs at 3 weeks demonstrated dislocation of the hip because of the outer cup was unstable. **(G/H)** Performing the

acetabular revision, remove the second cup, use the acetabulum burr to deepen the socket, re-adjust the acetabular angle and install the third multi-hole cup (the same one). then fix the gap between the two cups with bone cement. (I/J) Follow-up at 1 years. There was no recurrent hip dislocation, the outer cup was stable. (K/L) Follow-up at 7 years. There was no evidence of aseptic loosening, instability, periprosthetic fracture, or osteolysis throughout the follow-up period.



Figure 4

Pre-operative and post-operative radiographs of a 68-year-old male patient with left acetabular severe bone defects due to post-traumatic chronic osteomyelitis. (A/B) Pre-operative radiograph. (C/D) Immediate post-operative radiograph showing reconstruction using a multi-cup technique in the left hip, with bone cement applied between the cups, the femur was reconstructed with wagner stem and lateral plate. (E/F) Developed deep infection with culturing of coagulase-negative staphylococci 3 weeks after surgery. and a DAIR (debridement, antibiotics and implant retention) procedure was performed in

combination with 6-week course of antibiotics, which successfully eradicated the infection. **(G/H)** Follow-up at 1 years. demonstrated heterotopic ossification beside the greater trochanter and the inner acetabular cup. There was no evidence of infection, instability and periprosthetic fracture. **(I/J)** Follow-up at 6 years. There was no evidence of aseptic loosening, instability, periprosthetic fracture, or osteolysis throughout the follow-up period.

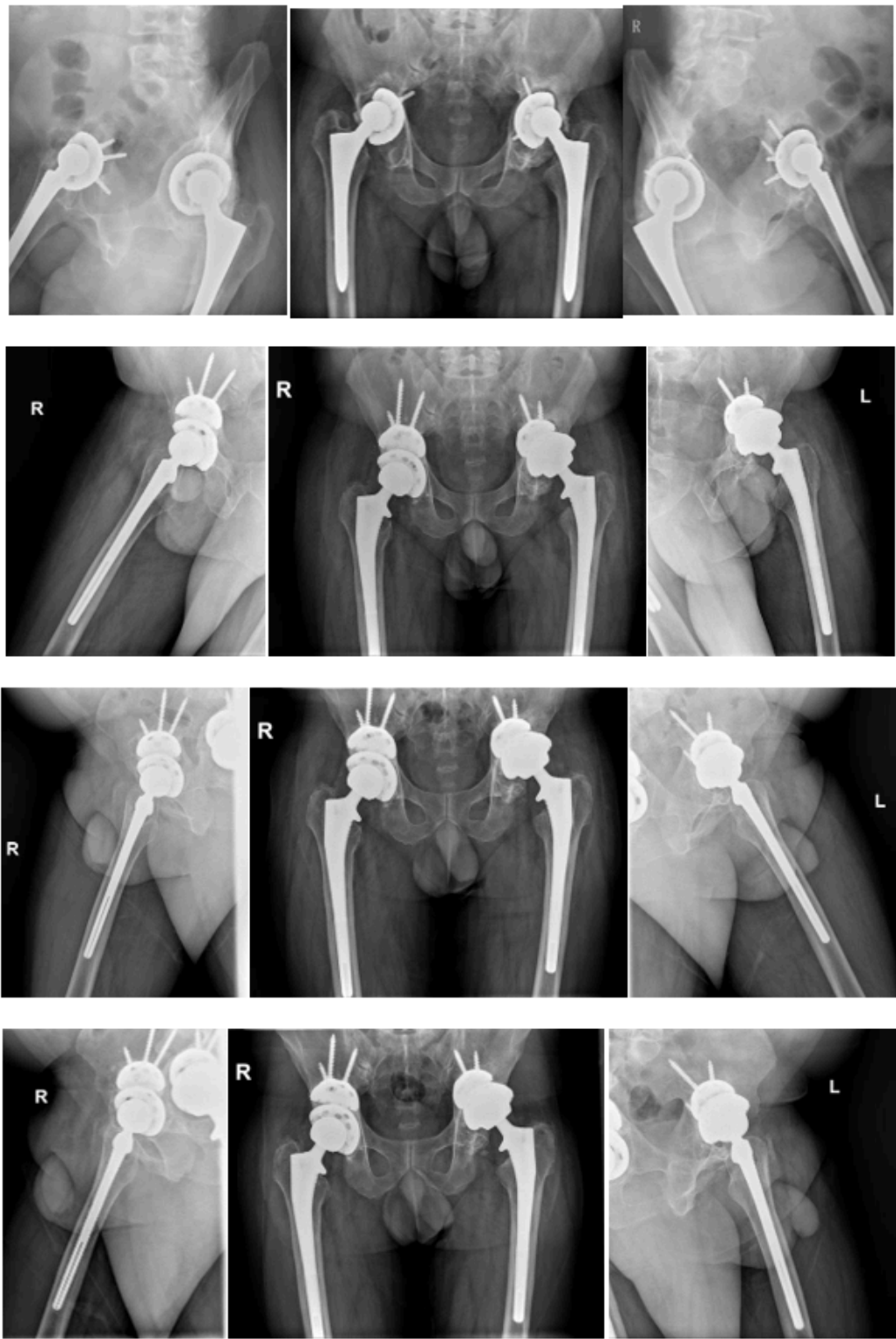


Figure 5

Pre-operative and post-operative radiographs of a 62-year-old male patient with left acetabular severe bone defects due to post-traumatic chronic osteomyelitis. **(A/B/C)** Pre-operative radiograph. **(D/E/F)** Immediate post-operative radiograph showing reconstruction using a double-cup technique in the both hips by simultaneous rTHA, with bone cement applied between the cups, the right COR was normal, the left was 1 centimetre higher. **(G/H/I)** Follow-up at 1 years. There was no evidence of instability and periprosthetic fracture. **(J/K/L)** Follow-up at 5 years. There was no evidence of aseptic loosening, instability, periprosthetic fracture, or osteolysis with both the hips.