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Cup-on-cup technique: a reliable management solution for severe acetabular bone loss in revision total hip replacement

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Abstract

Background: The management of acetabular bone loss is a challenging problem in revision total hip arthroplasty (rTHA). The goals of treatment are a stable acetabular fixation, implant stability, and restoration of hip centre of rotation. This study aims to report clinical, radiological outcomes and complications at short-term to mid-term follow-up of the cup-on-cup technique in the management of severe acetabular bone loss in rTHA.

Methods: We retrospectively reviewed the records of patient receiving rTHA performed with double porous tantalum cup technique in a single Joint Replacement Unit from 2014 to 2017. Objective and subjective clinical scores (Harris Hip Score, Oxford Hip Score, and visual analogue scale), radiological parameters (centre of rotation, leg-length discrepancy, heterotopic ossification, osseointegration, loosening and radiolucencies) and complications were recorded. We analysed the implant survival rate and periprosthetic joint infection rate.

Results: We included 9 patients (9 hips) with a mean follow-up of 35.3 ± 10.8 months. Functional scores showed a statistically significant improvement at the final follow-up ($p < 0.01$). All patients rated their surgery as satisfactory. The cup-on-cup construct demonstrated radiological osseointegration with the centre of rotation restoration and leg length discrepancy improvement. In 1 patient, periprosthetic joint infection was diagnosed and treated with suppressive antibiotic therapy. No patients underwent acetabular components revision surgery for any reason.

Conclusions: Cup-on-cup technique is a valid and safe solution for reconstruction of selected Paprosky type IIIA and IIIB bone defects with satisfactory clinical and radiographic results at short-term and mid-term follow-up.

Keywords

Acetabular bone defects, cup-on-cup technique, Paprosky IIIA–IIIB, porous tantalum, revision total hip arthroplasty

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Introduction

Total hip arthroplasty (THA) is 1 of the more widely performed procedures in orthopaedic practice with excellent clinical outcomes. Due to the increased frequency of primary hip replacements and greater life expectancy, the number of THA revisions (rTHA) is expected to dramatically increase.[1] In the literature, many surgical strategies have been proposed for the management of severe acetabular defects. In 2016, a systematic review evaluated the effectiveness of different treatment options for large acetabular defects.[2] Porous tantalum (PT) augments and shells demonstrated the most promising results when compared to antiprotrusio cage, bone impaction grafting with mesh, hemispherical implant with hook or flanges and custom-made tri-flange components.[2] In the last decade, PT has gained interest due to high bone biocompatibility and excellent osseointegration.[3,4] Nonetheless, in specific severe acetabular bone loss patterns (i.e. Paprosky Type III

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Table 1. Patient demographics, preoperative diagnosis, Paprosky classification acetabular defect, and follow-up.

Patient No.	Age (years)/ Gender	BMI	Previous hip surgeries (n)	Indication for revision	Paprosky classification	Location of bone defect	Follow-up (months)
1	71/M	38.4	3	PJI hip	III B	upper posterior	58.0
2	75/M	27.3	3	acetabular AL	III B	upper anterior	43.1
3	80/M	29.7	2	acetabular AL	III A	upper anterior	41.0
4	68/M	28.1	1	osteolysis	III A	upper posterior	37.8
5	86/F	30.5	2	acetabular AL	III A	upper anterior	30.7
6	78/F	26.8	3	osteolysis	III A	upper anterior	28.2
7	52/M	29.7	2	acetabular AL	III A	upper anterior	27.5
8	75/F	28.1	2	acetabular AL	III A	upper posterior	26.9
9	69/F	26.8	3	osteolysis	III A	upper posterior	25.0

BMI, body mass index; M, Male; F, Female; PJI, periprosthetic joint infection; AL, aseptic loosening.

A-B defects),[5] the acetabular shape and size often prevent a standard reconstructive surgery with off-the-shelf devices.

The cup-on-cup technique uses a double hemispherical cup to fill the bony defect, providing excellent mechanical support and restores the anatomical centre of rotation (COR) and biomechanics of the final implant.[6] However, the literature available on this technique is somewhat limited.[6–8] Blumenfeld et al.[7] treated 8 patients with severe protrusion acetabular defect and main follow-up (FU) of 28 months reporting 87.5% of good clinical results. Recently, Loppini et al.[8] published their results on 16 hips with type IIIA/IIIB defects. No acetabular revisions were recorded at a mean FU of 34 months.

The purpose of this study is to report the clinical and radiological outcome, together with the survival rate of the cup-on-cup technique for the management of severe acetabular bone defects in hip revisions with a minimum 2-year FU. Surgical technique, indications, and applicability of this technique will be clearly defined.

Methods

We conducted a retrospective review of the data of consecutive rTHA operations performed from January 2014 to March 2017 at our Institution. The Institutional Review Board approved this study (31934/2018). Written and informed consent was obtained from each patient before surgery. All patients gave their written and informed consent for the inclusion in the present study. All procedures were conducted according to the Declaration of Helsinki protocol.

The inclusion criteria were acetabular revision with a cup-on-cup technique for severe bone defect such as Paprosky III A–B with a minimum 2-year FU.[5] Exclusion criteria were the presence of pelvic discontinuity, the use of acetabular augments, cup cages, custom made implants, isolated jumbo or primary cups, and structural bone grafting. Patients with shorter than 2-year FU were excluded as well.

We collected demographics of all patients. The following surgical data were collected: preoperative implant features, number of previous hip surgeries, surgical time, localisation, and grade (according to Paprosky classification) of acetabular bone loss, and final implant features. The acetabulum, intraoperatively, was ideally divided into 4 clock-face quadrants to describe bone loss localisation: 1, upper anterior; 2, lower anterior; 3, lower posterior; 4, upper posterior (Table 1).

Clinical and radiographic evaluation

Clinical outcomes and radiological parameters were measured preoperatively, 2 days postoperatively after drain removal, at 45 days, 6 months, 1 year and at final FU. Clinical and functional scores were evaluated using the Harris Hip Score (HHS), the Oxford Hip Score (OHS) and the visual analogue scale (VAS). Personal satisfaction related to the surgical procedure was rated according to 4 responses: very satisfied, satisfied, fairly satisfied, not satisfied. All patients were evaluated with standing x-rays of the pelvis, anteroposterior (AP) and frog-leg lateral view of the operated hip. 2 orthopaedic physicians (FC and AZ) analysed preoperative and postoperative COR of both hips for each patient, leg-length discrepancy (LLD), radiolucency lines,[9] acetabular tilt, and heterotopic ossification according to Brooker's classification.[10] Disagreement between testers were solved by consensus within all the study group.

Surgical procedure

All procedures were performed by a single surgeon (GB). In all cases, the surgical procedures were performed with an extended posterolateral approach. After removal of the failed acetabular component, a complete debridement of the scarred tissues was performed. 3–6 samples for microbiological analysis were collected by default. The remaining acetabulum was gently reamed to ensure a good grip

Table 2. Definitive prosthetic components.

Patient No.	Buttress cup (size)	Cup (size)	Stem	Liner	BioBall	Complication
1	TM Trilogy (48)	TM Trilogy (58)	CLS 125°	PE elevated 10°	N	Intraoperative femoral fracture
2	TM Trilogy (62)	TMRS (60)	CLS 125°[a]	PE elevated 10°	N	–
3	TM Trilogy (54)	TM Trilogy (66)	Zweymuller[a]	Dual mobility	N	–
4	TMRS (52)	TMRS (58)	CLS 125°	PE neutral	Y	–
5	TM trilogy (54)	TMRS (48)	SP II Lubinus[a]	PE elevated 20°	N	PJI
6	TM Trilogy (54)	TM Trilogy (62)	Wagner SL 265	PE elevated 20°	N	Intra-operative femoral fracture
7	TM Trilogy (64)	TMRS (70)	CLS 145°[a]	Dual mobility	N	–
8	TMRS (52)	TMRS (56)	Corail [a]	PE elevated 10°	N	–
9	TMRS (48)	TMRS (64)	CLS 135°	Dual mobility	N	–

TM, Trabecular Metal (Zimmer Biomet); TMRS, Trabecular Metal Revision Shell (Zimmer Biomet); PE, Longevity Highly Cross-linked Polyethylene (Zimmer Biomet); PJI, periprosthetic joint infection.
[a]Unrevised stem.

for the prosthetic implant. The final decision for the cup-on-cup technique was always validated intraoperatively. In every case in which a standard reconstruction technique (e.g., standard hemispherical cup, jumbo cup, TM augmentation or cup–cage technique) was feasible, the cup-on-cup strategy was aborted.

After anatomical positioning of the trial socket, with restoration of the COR and LLD, we performed under-reaming at the upper-anterior or upper-posterior bone defect to implant the "buttress cup" with a press-fit technique. This secondary hemispherical shell acts as a super-augment that recreates the third point of fixation (frequently the upper one) necessary for the implantation of a hemispherical press-fit cup.[11] This augmentation cup –eventually stabilised with screws – had the double function of filling the bone gap and achieving support for primary fixation of the acetabular socket. As described by Webb et al.,[6] the impaction ring was usually removed with osteotomes, leaving only the PT shell for augmentation. This procedure decreases the risk impingement between acetabular socket and femoral components.

Subsequently, the acetabular socket was implanted with the desired inclination and anteversion, fixed with polymethylmethacrylate cement (Palacos G antibiotic cement, Zimmer, Warsaw, IN, USA) on the "buttress cup" internal face and with press-fit technique on the inferior supportive bone. Cancellous bone screws were used if necessary, to increase the implant fixation. Finally, neutral, 10° or 20° elevated rim cross-linked polyethylene insert or dual-mobility cup was used to achieve optimal implant stability. In 1 patient (11.1%), an acetabular socket revision using the BioBall system (Merete, GmbH, Berlin, Germany) was used to improve the femoral anteversion (Table 2).

In cases of acetabular and femoral component loosening, we performed a total rTHA using a primary stem when possible.[12] The periprosthetic joint infection (PJI) was managed with staged revision with an acetabular spacer to restore anatomical COR as previously described.[13] In all patients, a partial weight-bearing (30%) with crutches was adopted at least for 45 days after surgery. A gentle programme of therapist-assisted rehabilitation was started from the first postoperative day. Antibiotic prophylaxis was carried on case by case, according to indications of the infectious disease team. 1 drain was used in all cases and removed during the second postoperative day. Standard venous thromboembolism prophylaxis with enoxaparin and compression stockings was administered at least for 45 days.

Statistical analysis

Continuous variables were reported as mean ± standard deviation and compared between preoperative and final FU using the Student's *t*-test. Categorical variables were expressed as the number of cases or percentage. For all the analysed data, a 2-tailed p-value < 0.05 was considered statistically significant. Interobserver reliability was evaluated with Cohen's Kappa coefficient.

Results

Demographic features

The cup-on-cup construct was used in 9 hips (9 patients) from January 2014 to April 2017. All patients had a minimum FU of 24 months. The mean FU was 35.3 ± 10.8 months. There were 5 (55.6%) men and 4 (44.4%) women with the average body mass index (BMI) of 29.5 ± 3.6 kg/m2 (Table 1). The mean age at the time of surgery was 72.7 ± 9.6 years. The indication for indexed revision surgery were acetabular aseptic loosening in 5 (55.6%) hips (Figure 1), osteolysis in 3 (33.3%) hips and 1 (11.1%)

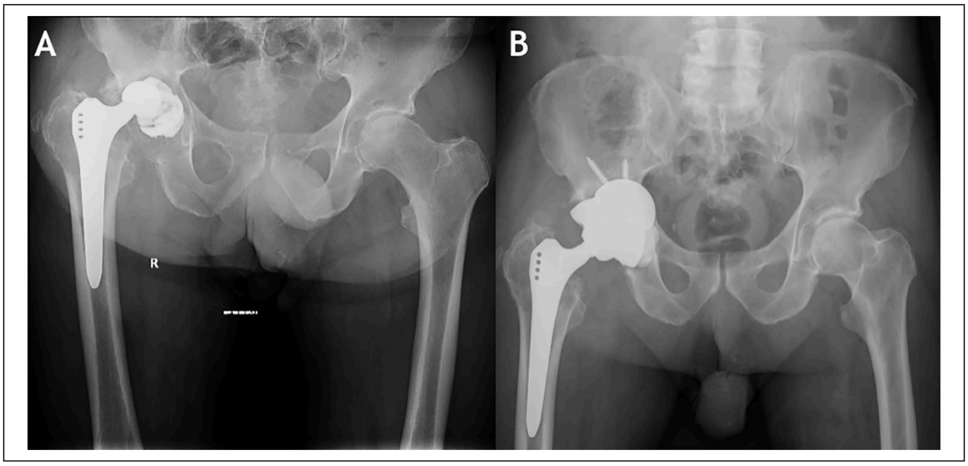

Figure 1. Radiological analysis in a clinical setting of aseptic loosening. A: preoperative x-ray showing massive medial and superior acetabular bone loss. B: 1-year follow-up showing optimal osseointegration and hip biomechanics restoration.

Table 3. Radiological evaluation of COR, LLD, and acetabular tilt.

Patient No.	Preop COR (cran/lat) mm	Postop COR (cran/lat) mm	Contralateral COR (cran/lat) mm	Acetabular inclination	Preop LLD mm	Postop LLD mm	Heterotopic ossification (Brooker)
1	39/37	10/30	18/32	40	−15	5	II
2	46/37	25/45	21/33	45	−30	−5	–
3	36/35	10/38	10/39	45	−26	2	I
4	50/33	21/40	20/36	50	−28	−4	–
5	55/38	21/36	19/35	35	−31	−5	–
6	49/44	18/42	16/33	40	−34	3	–
7	48/62	24/44	20/41	50	−13	5	–
8	51/34	27/36	20/33	45	−27	−5	–
9	49/29	30/32	25/30	40	−22	−2	–

COR, centre of rotation; LLD, leg-length discrepancy.

second-stage re-implantation for PJI. The average number of previous hip arthroplasty surgeries was 2.3 ± 0.7. We included 7 (77.8%) Paprosky Type IIIA and 2 (22.2%) Paprosky Type IIIB acetabular bone defects. Six patients required acetabular component-only revision (mean surgical time, 120 ± 20.9 minutes), while in 3 patients, an rTHA (stem and socket) was performed (mean surgical time, 158.6 ± 22.5 minutes). For radiological parameters, Cohen's kappa coefficients demonstrate a nearly perfect correlation between both testers with all values showing more than 90% of correlation.

Clinical and radiographic outcomes

The mean HHS and OHS increased respectively from 24.3 ± 6.7 and 13.2 ± 6.2 preoperatively to 78.9 ± 9.9 and 38.4 ± 5.3 at the last FU ($p < 0.01$). The mean VAS decreased from 7.2 ± 0.9 to 1.3 ± 0.9 at the last evaluation ($p < 0.01$). All patients declared excellent or good satisfaction (very satisfied or satisfied) after the indexed arthroplasty procedure. All patients reported good hip function, absence of thigh pain, and free walk without crutches or lameness 60 days after surgery, except an 86-year-old woman with multiple comorbidities and BMI >30 kg/m2.

All radiographic controls showed osseointegration of the acetabular components according to Moore's criteria.[14] No cases of loosening have been reported; while we observed 1 (11.1%) case of non-progressive radiolucency in Zone 1.[9] Based on the AP radiographs, we had a statistically significant improvement of the COR from preoperative to postoperative status ($p < 0.01$), with a restoration of anatomical parameters and LLD reduction (Table 3). Heterotopic ossifications were observed in 2 patients (22.2%), without the need to resort to surgery.[10]

Complications

During surgery, 2 intraoperative proximal femoral fractures (22.2%) were reported. In both cases, an rTHA was performed (cup and stem). The femoral fractures were managed with metal cerclages and a partial weight-bearing with crutches for 60 days.

1 patient died during the FU due to comorbidities unrelated to the indexed surgical procedure. No dislocations

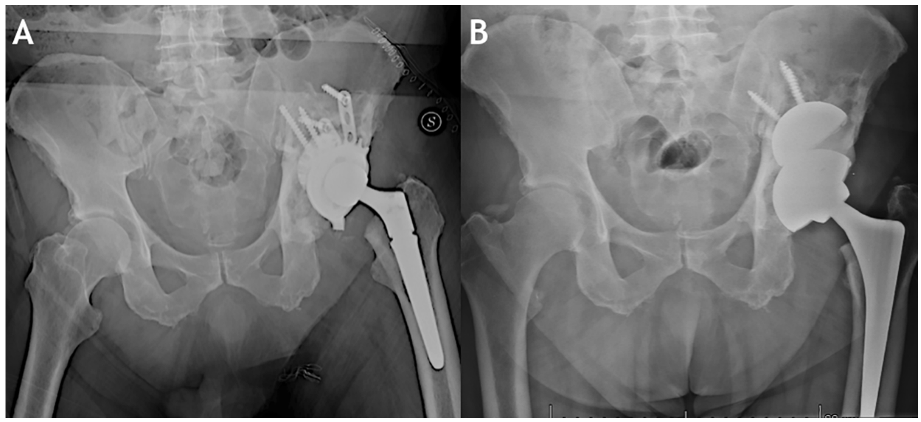

Figure 2. X- ray investigation in case of recurrent dislocation. A: preoperative x-ray with massive bone loss and proximal displacement of center of rotation. B: Postoperative 1-year x-ray depicting optimal hip biomechanics recovery and no implant migration.

and implants aseptic loosening were reported during the FU. 1 patient (11.1%) who had multiple previous hip surgeries and comorbidities developed a PJI 3 months after surgery. In this case, an index surgery was aborted per patient decision, and a chronic suppressive antibiotic therapy was adopted with satisfactory infection control.

No patients underwent acetabular components revision surgery for any reason. The survival rate for overall failure was 88.9%.

Discussion

Treatment of large, complex acetabular defects, such as Paprosky Types IIIA and IIIB, represents a surgical challenge. The aims of the revision hip surgery are to fill the bone loss, to achieve implant stability, and to restore hip biomechanics and the anatomical position of the COR. Different surgical strategies are described in the literature.[15,16] The cup-on-cup technique represents a possible solution in cases of upper-anterior and upper-posterior bone loss as well as for medial cavitary defects (classified as Paprosky Types III defects without pelvic discontinuity). Our indication of this procedure is unidirectional cavitary or roughly hemispherical defects >2.5 cm. We considered multidirectional major bone loss a relative contraindication for this surgical technique because of the increased complexity and the requirement of more than 2 cups. These kinds of defects are better managed with custom devices.

In these selected cases, due to the shape and size of bone loss, the surgical reconstruction with standard augments could be difficult.[8] A PT-coated cup is used as a buttress to fill cavitary defects obtaining a primary stability with press-fit technique, augmented with screws and represented a support for the acetabular socket that is implanted with a hybrid technique (cemented on the augment cup and press-fit on the inferior bone support) augmented with cancellous screws. Secondary stability of the construct is achieved with bone ingrowth due to the large surface area of contact with the host bone. This technique allows to separately manage the two main problems in hip revision surgery: bone loss and stability. The buttress cup is mainly a bone-loss-management device while the second one is focused on achieving the proper anteversion and inclination for proper hip stability (Figure 2).

The technique allows for the restoration of hip biomechanics with the anatomical position of hip COR, correct function of the abductors and restoration of LLD. This surgical strategy in comparison with jumbo cup permits a significant reduction of the cranial migration of hip COR.[17]

The combination of cup and multiple PT augments or cup-cages construct are more expensive than cup-on-cup implant, and a higher risk of failure could be theorised for increased implants interfaces.[8,18] Another surgical strategy to manage extensive bone defect is custom-made implants. This reconstruction philosophy does not allow any intraoperative adjustment of the custom-made device, underlining the importance of preoperative planning accuracy.

Nonetheless, the design process of the custom-device usually takes several weeks with possible worsening of the bony defect.[19] Finally, the cost of custom-made implants is higher than double-cup technique.[8]

As stated before, the decision to perform a cup-on-cup was theorised on accurate preoperative planning but was always validated intraoperative. According to the complexity of this procedure and the multiple situations that a surgeon could face during the operative time, the authors suggest a complete set of off-the-shelf implants and instruments for hip revision to be prepared to every kind of possible surgical solution.

Webb et al.[6] published the largest series of cup-on-cup reconstructions with a mean FU of 2.4 years. The authors reported a survivorship of 100% for aseptic loosening and 80% for any cause of revision. Within the first year after surgery, 25% of patients reported hip dislocation especially when the revision surgery involved the socket side only.

Loppini et al.,[8] with a mean FU of 34 months, reported no patients underwent acetabular components revision surgery for any reason. In our study, with a mean FU of 35.3 ± 10.8 months, we found a survivorship of 100% for aseptic loosening and 88.9% for any cause of revision. Our results seemed to align with the recent literature.

As suggested by Blumenfeld et al.,[7] the cup-on-cup technique has two main concerns that are still a matter of debate. The first one is based on the lateral displacement of COR from the bone-implant interface. This could theoretically produce more shear stresses on the bone-cup interface impairing bone ingrowth. Although this might represent a theoretical problem, tantalum demonstrated excellent osseointegration even in cases of poor residual bone stock.[20,21] The second one relies on the endurance of cement-implant interface but mechanical and clinical studies on similar cementation techniques provide optimal data supporting the stability of such construct.[22,23]

The strengths of this study are present in its use of single surgeon dataset; strict and homogeneous indications to surgery and limited heterogeneity in surgical procedures. Nevertheless, there are several limitations. The lack of a control group prohibits a comparison of the results of this technique with other strategies. Moreover, the small population and short FU contribute to the weakness of the study results. Nevertheless, as previously stated, the indications for cup-on-cup construct are very selective due to the rare and difficult nature of the acetabular bone defect.

We strongly advocate further high-quality long-term studies to better clarify complications, durability, and clinical and radiological results of cup-on-cup technique in rTHA.

The ideal treatment for large acetabular bone defects, such as Paprosky Type IIIA and IIIB has not been established in the literature. In the cup-on-cup technique, a highly porous metal cup is used as a super augment to buttress the massive pelvic bone defect. The hemispheric shell allows for an increased surface area for bone ingrowth and improves the position and the support for the anatomically placed socket and the COR restoration. According to our data, the cup-on-cup technique could be considered a safe and effective surgical strategy for complex bone loss in rTHA. Further high-quality long-term studies would better clarify complications, clinical and radiological results of this promising technique in THA revision.

Declaration of conflicting interests

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