Archives of Orthopaedic and Trauma Surgery
https://doi.org/10.1007/s00402-024-05541-w

HIP ARTHROPLASTY

The role of acetabular cement augmentation in 2-stage revision arthroplasty for prosthetic joint infection of the hip

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Received: 3 April 2024 / Accepted: 3 September 2024

Abstract

Introduction In the treatment of chronic prosthetic joint infection (PJI) of the hip, two-stage exchange arthroplasty is commonly employed. Various spacer designs, including Hemi-Spacers and Articulating Spacers, are utilized during this process. However, these spacers are associated with a high rate of mechanical complications and pose a risk of progressive bone loss. This study aims to compare these two types of spacers in terms of mechanical complications, center of rotation (COR) restoration, and preservation of acetabular bone stock.

Materials and methods From 2019 to 2022, patients who underwent two-stage exchange arthroplasty for hip PJI across three hospitals were retrospectively reviewed. Data including demographic, clinical, and microbiological information were collected. Radiographic imaging was analyzed to measure acetabular bone erosion, COR, and periacetabular bone resected. Additionally, the average surgical time in the first and second stages, mechanical complications, and the mean duration of the inter-stage period were recorded.

Results Forty patients were divided into two groups: Group A (Articulating Spacer, $n=23$) received a preformed femur spacer with acetabular cement augmentation, while Group B (Hemi-Spacer, $n=17$) received a preformed femur spacer alone. Acetabular cement augmentation slightly prolonged the first stage but facilitated a faster second stage during subsequent reimplantation. Spacer dislocation rates were 8.7% in Group A and 17.6% in Group B during the interstage period. Radiographic analysis revealed a statistically significant greater degree of acetabular erosion in Group B. A significant difference in Vertical-COR differential was observed, with a more proximalized revision cup compared to the primary cup in Group B, and Horizontal-COR values closer to the native hip in Group A.

Conclusions Dynamic spacers with acetabular cement augmentation help preserve peri-acetabular bone stock and prevent progression of acetabular bone erosion during the inter-stage period. Additionally, these spacers reduce the dislocation rates, making reimplantation easier and leading to better restoration of hip biomechanics during the second procedure.

Keywords Periprosthetic joint infection · Hip · Two stage revision · Dynamic spacers · Complications · Hip center of rotation · Acetabular bone stock

Introduction

Total joint arthroplasty (TJA) is the gold-standard treatment for end-stage osteoarthritis associated with pain and disability [1]. Among various prosthetic replacements, Total Hip Arthroplasty (THA) represents the most successful procedure, providing clinically significant improvements in Patient-Reported Outcomes (PROs) [2]. The incidence of periprosthetic joint infection (PJI) in THA ranges between 0.5 and 3%, representing the third cause of THA revisions [3]. The growing number of TJAs performed each year results in an increased rate of PJIs, which affect the

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Published online: 11 September 2024

economic burden of the healthcare system [4]. This complication has a significant impact on the patient quality of life [5–8], morbidity and mortality [9, 10], with even worse outcomes than breast cancer [11]. Currently, two-stage exchange represents the treatment of choice for chronic PJI [12, 13], with a reported success rate of more than 80% [14–20]. Multiple spacer design options may be implanted and classified into two main groups: Static and Dynamic [21]. Recently, a new classification system for hip spacers has further divided Dynamic spacers into two categories: Hemi-spacer (comparable to a fixed-head hemiarthroplasty) and Articulating spacer (comparable to a THA, with articulation within the spacer) [22]. These types of spacers are affected by a high rate of mechanical complications, with dislocation being the most frequently reported [23] with an average rate of 10.8% (0-41.7%) [24]. Furthermore, there is a non-negligible risk of progressive bone loss and acetabular erosion [25, 26].

In literature, there is still little evidence of the superiority of one method over the others [25–28]. The purpose of this study is to compare these two different types of dynamic spacers (Hemi and Articulating) in order to assess mechanical complications, center of rotation (COR) restoration, and preservation of acetabular bone stock. Our hypothesis is that acetabular cement augmentation in hip two-stage revision, besides allowing better functionality with a lower risk of dislocation in the inter-stage phase, may preserve periacetabular bone stock, resulting in easier preparation of the acetabulum and improved COR restoration during reimplantation.

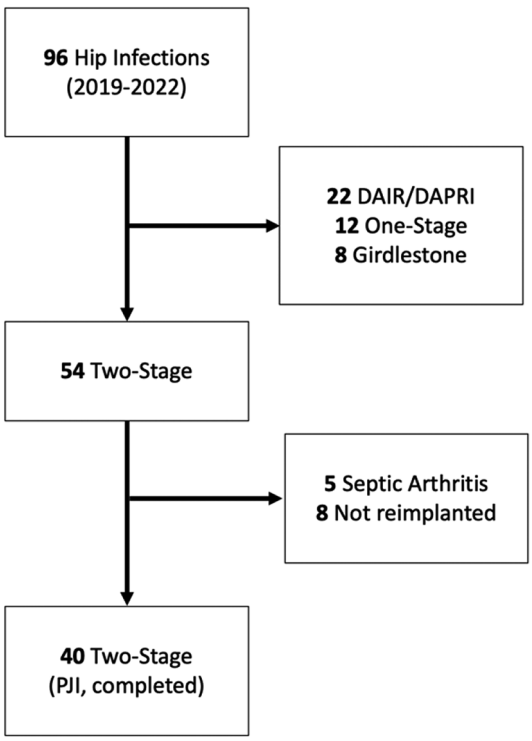

Fig. 1 Patient inclusion flow diagram

Methods

A multicenter analysis was conducted between January 1st, 2019, and December 31st, 2022, on all patients who underwent two-stage exchange arthroplasty for hip PJI, retrospectively reviewed from the databases of three highly specialized centers. The inclusion criteria were a definite diagnosis of hip PJI according to the 2018 ICM [26] criteria and completion of a two-stage revision procedure with complete documentation. We excluded PJIs treated with a one-stage procedure, resection arthroplasties (Girdlestone), two-stages for septic arthritis, and patients who did not complete the second approach (Fig. 1). Demographic and clinical data such as age, sex, Body Mass Index (BMI), comorbidities, and microbiological data with culture results were collected. The average surgical time in the first and second stage procedures, mechanical complications, and mean time of the inter-stage period were recorded. No minimum follow-up (FU) after reimplantation was required because the study analyzed spacers' mechanical complications in the inter-stage phase and evaluated pre- and post-reimplantation radiographs. The cohort of patients was divided into two groups based on the type of dynamic spacer implanted: Group A with a preformed femur spacer plus acetabular cement augmentation (Articulating Spacer) and Group B with a preformed femur spacer alone (Hemi-Spacer).

Surgical technique

In the first stage, after removing the infected implant, a surgical debridement with radical synovectomy was performed. An Extended Trochanter Osteotomy (ETO) was considered in cases of well-fixed femoral stems (integrated cementless stem) or expected difficulties in removing the entire femoral cemented mantle. The existing bone was debrided, and multiple samples were collected for cultures (5 to 8). After copious irrigation, a new sterile field was set up before placing the articulating spacer. Antibiotic cement (Copal G + V, Heraeus Medical, Newbury, UK) was then prepared on a back table to create the acetabular augment. The cement was placed in the cotyloid fossa, ensuring that the sticky phase had passed. This was shaped in situ using a trial head for dual mobility covered by Vaseline, two sizes larger than the preformed femoral spacer head planned (based on the acetabulum diameter), with minimal pressure to avoid excessive infiltration of the cement into the cancellous acetabular bone, ensuring adequate thickness to reduce the risk of breakage (Fig. 2). Furthermore, the excess

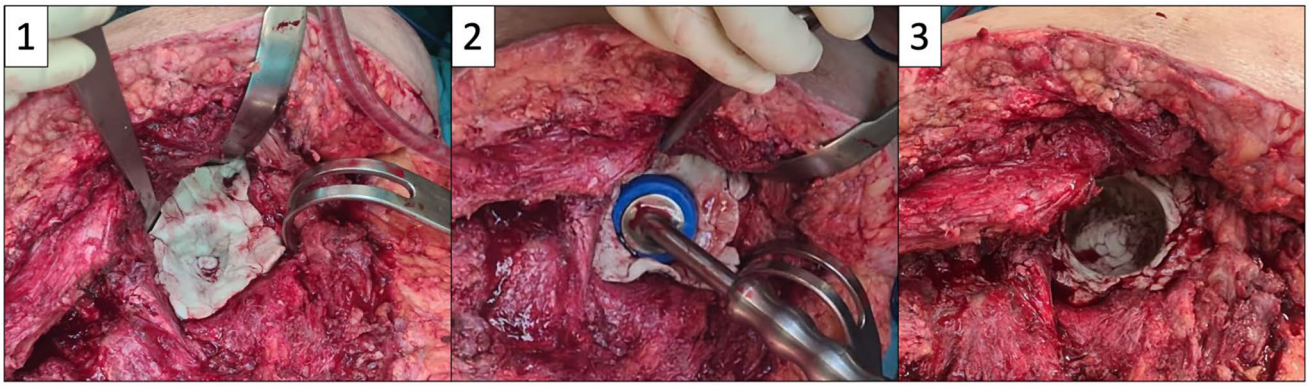

Fig. 2 (1) The cement was placed in the cotyloid fossa (2) Cement was shaped in situ using a trial head for dual mobility covered by Vaseline (3) Shaped Cement Acetabular Augment

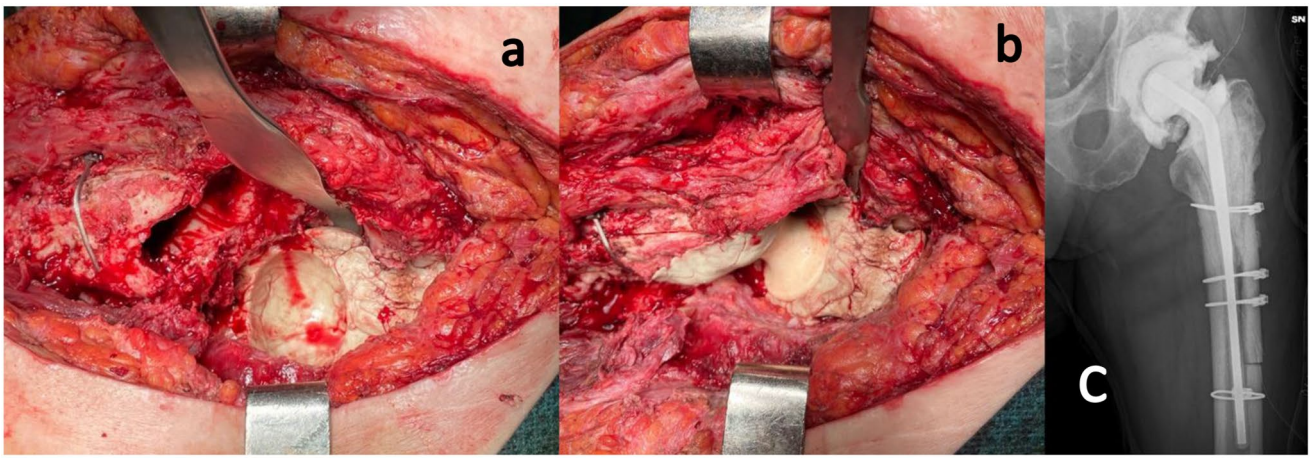

Fig. 3 **a**) Shaped Cement Acetabular Augment. With shoulder at the postero-superior rim. **b**) A preformed femoral spacer (Vancogenx-Space Hip, Tecres SpA, Verona, Italy) cemented in the trochanteric area to provide rotational stability. **c**) Radiograph of articulating spacer composed by a preformed femur spacer plus acetabular cement augmentation

amount of cement was removed, and an additional shoulder was shaped at the postero-superior rim to increase coverage and reduce the risk of dislocation. A preformed femoral spacer (Vancogenx-Space Hip, Tecres SpA, Verona, Italy) was then cemented in the trochanteric area to provide rotational stability. Typically, 2–3 doses of antibiotic-loaded cement were used for each patient: 1–2 for the acetabular augment (depending on the cup size) and 1 for the trochanteric region of the femoral spacer (Fig. 3). Mobilization and partial weight-bearing (with precautions for the postero-lateral approach) were allowed from the second postoperative day. In the second stage, the acetabular cement augmentation was easily removed, often in one piece, and the cup was ready for reimplantation (Fig. 4).

Radiographic Analysis

All radiographic measurements were performed on calibrated images using TraumaCad software (Brainlab AG, Munich, Germany). On the X-rays, the following parameters were measured: (1) acetabular bone erosion, (2) COR analysis, and (3) periacetabular bone resected (PBR).

Acetabular bone erosion was evaluated in the last X-rays performed before the second stage procedure (maximum 1 week before surgery) and classified according to Baker et al. [29]: Grade 0: no acetabular erosion, normal articular cartilage; Grade 1: no acetabular erosion, narrowing of articular cartilage; Grade 2: acetabular bone erosion and early migration; Grade 3: protrusio acetabuli.

In the COR analysis, the vertical (V) and Horizontal (H) CORs relative to radiographic U (teardrop) of the native hip (COR0), the primary implant before explantation (COR1), and the revision implant (COR2) were calculated and compared (Fig. 5). Native hip COR was determined according to the Pierchon's method, reported to be more accurate than the Ranawat's method [30]. Furthermore, the COR differentials of the first implant relative to the native hip (ΔCOR1-0), the revision implant relative to the primary implant

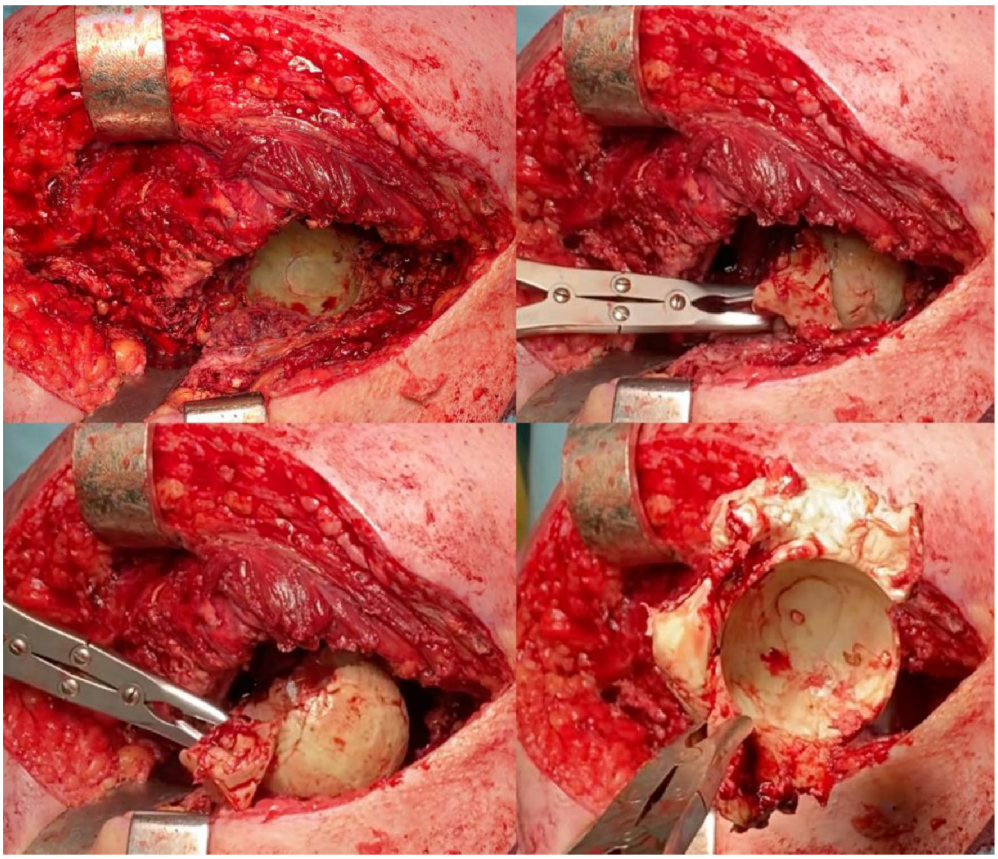

Fig. 4 In the second stage, removal of the acetabular cement augmentation in one piece

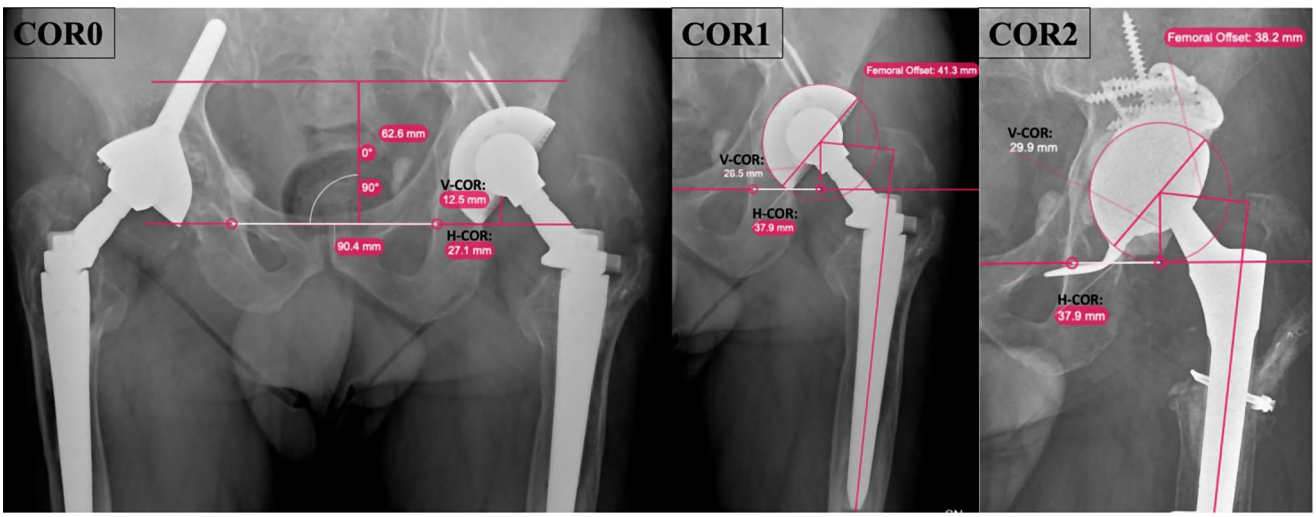

Fig. 5 COR analysis of the vertical (V) and Horizontal (H) CORs relative to radiographic U of the native hip (COR0), the primary implant before explantation (COR1), and the revision implant (COR2)). Native hip COR was determined according to the Pierchon's method

(ΔCOR2-1), and the revision implant relative to the native hip (ΔCOR2-0) were analyzed to evaluate COR migration both vertically (proximalization, distalization) and horizontally (medialization, lateralization) due to possible acetabular erosion related to the type of dynamic spacer implanted.

To quantify the amount of periacetabular bone resected (PBR) between the primary implant and the revision implant, we performed the radiographical analysis according to an article by Suarez-Ahedo et al. [31]. The authors used the size of the acetabular component relative to the patient's native femoral head size as a surrogate for bone

resected. We modified that methodology by calculating the difference in cup diameter between the revision implant and the primary implant with the associated volume of bone lost, allowing us to extrapolate the actual volume of bone resected from one procedure to another and the average revision cup size increase (Fig. 6).

Statistical analysis

Statistical analysis was performed using SPSS statistics software version 25.0 for MACINTOSH (IBM, Armonk, NY). Categorical variables are presented as numbers and percentages. Normally distributed continuous variables were expressed with mean ± standard deviation ($p > .05$) in Kolmogorov–Smirnov test or Shapiro–Wilk test ($n < 30$) values, and continuous variables without a normal distribution were expressed with median values. Categorical variables were assessed using the Chi-square test or Fisher's exact test for statistical significance. Continuous variables were compared using unpaired t-test, continuous and ordinal variables with Mann Whitney test as appropriate. A two- sided p-value < 0.05 was defined to be considered statistically significant.

Results

According to the inclusion and exclusion criteria, 40 patients were enrolled for the final analysis. Group A (Articulating Spacer) included 23 patients, 16 males (70%) and 7 females (30%), with a mean age of 71 years (range: 40–86), and Group B (Hemi-Spacer) included 17 patients, 9 males (53%) and 8 females (47%), with a mean age of 65 years (range: 47–89). Demographic information, microbiological data, and baseline comorbidities are summarized in Tables 1 and 2. The average inter-stage period was 146.57 ± 68.47 days for group A and 131.24 ± 49.34 days for group B, with no significant difference. The mean operative time for the first stage was 182.61 ± 42.23 min for group A and 169.12 ± 43.13 min for group B, respectively, without any significant difference. Similarly, the difference in mean duration of surgery for the second stage (Group A: 132.6 ± 26.41 min; Group B: 144.12 ± 51.61 min) between the two groups was not significant.

During the interstage period, 2 spacer dislocations were observed in group A and 3 in group B; although this result was not statistically significant due to the small number of cases, the percentage is still relevant as it is more than twice as high in the group without acetabular cement augmentation (8.7% vs. 17.6%). In the pre-reimplantation radiographic controls, a statistically significant ($p = .002$) greater

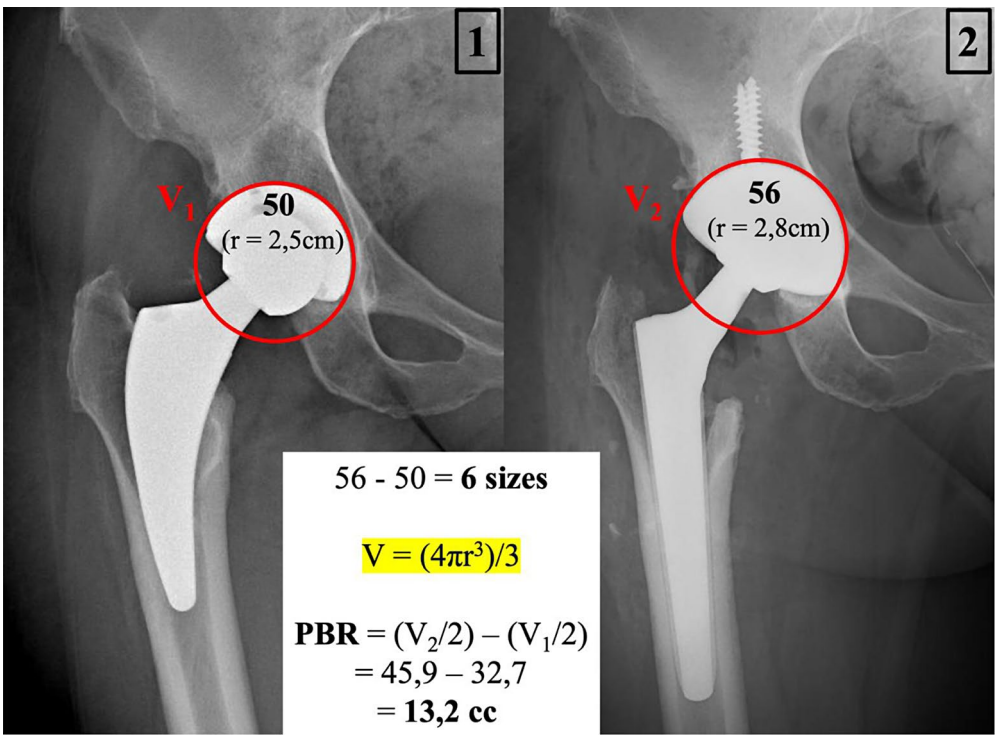

Fig. 6 Measurement of the amount of periacetabular bone resected (PBR) between the primary implant and the revision implant in cc, according to an article by Suarez-Ahedo et al. [31]. The difference in cup diameter between the revision implant and the primary implant with the associated volume of bone lost was calculated

Table 1 Demographic information and Microbiological data for Group A and Group B

Variable	Total	Group A	Group B	*P*-value
Patients	40	23	17	
Age	68.5 ± 12.58	70.56 ± 12.66	65.06 ± 12.14	0.087
Sex				
Male	25	16	9	0.283
Female	15	7	8	
Side				
Right	21	9	12	*0.049*
Left	19	14	5	
BMI	30.3 ± 5.8	29.8 ± 6.9	31.2 ± 5.7	0.457
Microorganism				
Gram +	24	14	10	
Gram–	2	0	2	0.117
Polymicrobial	10	5	5	
Culture Negative	4	4	0	

BMI: Body Mass Index. Significant values $P < .05$ are shown in italics

Table 2 Baseline comorbidities for Group A and Group B

Variable	Total	Group A	Group B	*P*-value
Hypertension	*24*	*14*	*10*	*0.896*
Dyslipidemia	8	5	3	0.749
Diabetes Mellitus	*8*	*4*	*4*	*0.631*
Anemia	4	2	2	1.000
Atrial Fibrillation	*5*	*5*	*0*	*0.061*
ICM	9	6	3	0.707
CKD	*3*	*1*	*2*	*0.565*
Asthma	4	2	2	1.000
COPD	*5*	*2*	*3*	*0.634*
RA	6	1	5	0.067
Hepatitis	*3*	*1*	*2*	*0.565*
Malignancy	3	2	1	1.000

ICM: Ischemic Cardiomyopathy, CKD: Chronic Kidney Disease, COPD: Chronic Obstructive Pulmonary Disease, RA: Rheumatoid Arthritis. Significant values $P < .05$ are shown in italics

degree of acetabular erosion was found in group B (median: 2; range: 1–3) compared to group A (median: 1; range: 1–2).

The results of the horizontal (H) and vertical (V) COR analysis are shown in Tables 3 and 4, respectively. The native hip analysis (COR0) showed comparable average H-COR and V-COR between the two groups, without any significant difference. On the other hand, the primary implant (COR1) showed a significant difference in vertical COR (V-COR1 $p = .015$) between groups A (V-COR1: 22.96 ± 5.87) and B (V-COR1: 19.06 ± 4.64), with a more proximalized cup in group A. Furthermore, analyzing the revision implants (COR2), we reported a significant difference in horizontal COR (H-COR2 $p = .038$) between groups A (H-COR2: 32.00 ± 4.51) and B (H-COR2: 29.59 ± 3.59), with values closer to the native hip for Group A. For V-COR of the revision implant, the difference between groups A (V-COR2: 22.69 ± 4.73) and B (V-COR2: 20.88 ± 4.53) was not significant, with correction of the proximalization found in the primary implant of group A.

The analysis of COR differentials showed that ΔV-COR2-1 in group A (-0.22 ± 5.34) was significantly lower ($p = .049$) than group B (2.29 ± 3.42), suggesting a lower proximalization of the revision cup in group A (Table 5). This result, which might be a consequence of acetabular erosion in group B, was further validated by the analysis of the ΔV-COR1-0, considering that group A (8.78 ± 6.18) had a significant ($p = .025$) higher proximalization of the primary cup from the native hip COR than group B (5.18 ± 4.59). As a result, the revision implant of Group A (V-COR2) achieved a result comparable to Group B. The remaining differentials were statistically comparable. Finally, we found no statistically significant differences between the two groups in terms of bone resected, both for the sizes added to the revision cup (A: 6.35 ± 3.28; B: 5.88 ± 2.96) and periacetabular bone resected (A: 17.57 cc ± 9.47; B: 14.49 ± 8.14).

Table 3 Horizontal (H) COR analysis of Group A and Group B with significant P-values highlighted

	H-COR0	H-COR1	H-COR2	ΔH-COR1-0	ΔH-COR2-0	ΔH-COR2-1
Group A	31.65±3.56	30.35±4.48	32.00±4.51	-1.57±4.59	0.17±4.84	1.78±4.05
Group B	31.41±2.85	28.47±3.00	29.59±3.59	-3.06±2.33	-1.71±4.44	1.2±3.96
P-value	0.410	0.071	*0.038*	0.114	0.108	0.336

Significant values $P < .05$ are shown in italics

Table 4 Vertical (V) COR analysis of Group A and Group B with significant P-values highlighted

	V-COR0	V-COR1	V-COR2	ΔV-COR1-0	ΔV-COR2-0	ΔV-COR2-1
Group A	14.17±1.56	22.96±5.87	22.69±4.73	8.78±6.18	8.61±4.65	-0.22±5.34
Group B	13.82±1.18	19.06±4.64	20.88±4.53	5.18±4.59	7.12±4.51	2.29±3.42
P-value	0.221	0.015	0.115	0.025	0.158	0.049

Significant values $P < .05$ are shown in italics

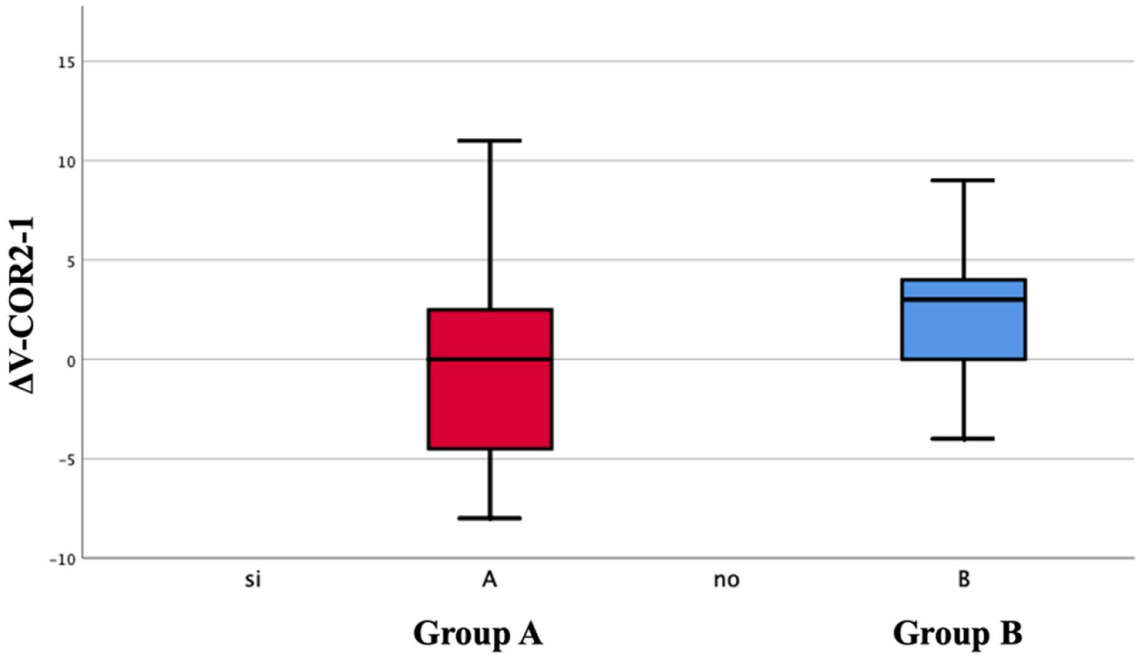

Table 5 Box plot distribution of ΔV-COR2-1 between Group A and Group B

Discussion

Bone loss is one of the greatest challenges in hip revision surgery, particularly in case of two-stage revision for PJI, where the risk of bone loss is compounded by the double surgical insult. The present study reveals that acetabular cement augmentation is beneficial in preserving periacetabular bone stock, reducing acetabular erosion during the inter-stage period, and facilitating reimplantation with improved restoration of hip biomechanics and mobility, as well as a reduced risk of dislocation. These benefits are particularly pronounced when the inter-stage period is longer than expected. To the best of our knowledge, this study is the first to analyze acetabular bone stock during two-stage revision using 3 radiographic parameters (Baker classification, COR analysis, and periacetabular bone resected), comparing hemi- and articulating spacers.

Various techniques for articulating hip spacers have been described in the literature. Weiss et al. introduced a novel technique using antibiotic cement reinforced with screws to bypass medial wall defects as an acetabular augment [32]. Systems like PROSTALAC were developed to coat a stem with antibiotic cement and couple it with a cemented polyethylene acetabular component, offering functionality similar to THA [33]. Although the results were encouraging [34], more surgical time was required, and some parts of the implant were not covered by the antibiotic cement mantle (neck, head, and polyethylene cup), potentially allowing biofilm growth. Custom-made articulating spacers (CUMARS) have been developed, featuring a standard all-polyethylene acetabular component [35] and Exeter v40 stem (Stryker Orthopaedics, Mahwah, NJ, USA) implanted with highly concentrated antibiotic cement, providing rotational and longitudinal stability while allowing for easy extraction. This procedure, similar to the "Hoffmann technique" [36], can achieve a true 1.5-stage revision, by changing to a conventional cementing technique, offering the possibility to avoid the second stage procedure. This long-term spacer approach is suitable for elderly patients with low functional demands or multiple comorbidities who might not undergo a second surgery. For more active and younger patients, reimplantation of a definitive prosthesis remains an option, with the advantage of having a functional spacer that ensures stability (referred to as delayed spacers). Despite concerns about possible reinfection due to the presence of polyethylene and the significant economic impact, authors reported a low complication rate (9.4%) and an eradication rate of 88.7% at final follow-up over an average spacer duration of 3.3 years [37]. Another variation, the "ENDO-Spacer" by Lausmann et al. [38], involves implanting a downsized stainless steel straight stem with a dual mobility liner into a cement socket.Our preferred method involves using a preformed femur spacer (Vancogenx-Space Hip, Tecres SpA, Verona, Italy) articulated with a handmade cement cup, creating a cement-on-cement interface. This approach aims to preserve acetabular bone stock, reduce the risk of dislocation, and increase the surface area of antibiotic cement for local antibiotic elution.

Burastero et al. [27], reported that the acetabular spacer technique reduced the inter-stage complication rate (6.45%

with acetabular spacer vs. 17.5% without acetabular spacer) and improved hip biomechanics restoration. Moreover, a significant difference in spacer dislocation between groups was observed, suggesting a crucial role of acetabular cement spacer in preventing complications [27]. Our study found that the risk of dislocation was more than doubled (8.7% vs. 17.6%) without acetabular cement augmentation. Additionally, Burastero et al. [27] noted a significant reduction in operative time for the second stage procedure due to greater preservation of acetabular bone stock. Accordingly, in our study, the first stage was approximately 13 min longer in Group A (with cement augmentation) compared to Group B (without augmentation), but the second stage was about 12 min shorter in Group A. This data showed that acetabular cement augmentation procedure extended the duration of the first stage, but made the cup reimplantation time shorter in the second stage. These differences in operating time did not significantly impact overall surgical outcomes. Despite being an established treatment option for PJIs, hip spacers may have several complications. Jung et al. [39] reported an overall complication rate of 58%, with spacer dislocation (17%), spacer fracture (10%), and periprosthetic fracture (14%) being the most common. However, previous studies did not focus on bone loss and acetabular bone erosion during the inter-stage period [24, 39–41]. The novelty of our study is the analysis of the COR due to acetabular bone erosion, using the Baker classification. We found that the hemi-spacer group (Group B) experienced acetabular deficiency progression in approximately 70% of patients during the inter-stage period, contributing to greater proximalization of the COR in the revision implant. Therefore, acetabular cement augmentation might help to restore hip biomechanics by protecting against bone erosion. While some authors [25] suggested that using a preformed femoral spacer for less than 1 year did not cause acetabular erosion, others supported our results of acetabular bone stock wear in spacers without acetabular augmentation [27, 42]. Grosso et al. [28] reported the acetabular defects progression in 43% of cases, associated with a longer time between resection arthroplasty and reimplantation (> 90 days). Complications, particularly spacer dislocation, quadrupled (25% vs. 7%) in cases of acetabular deficiency progression, underscoring the importance of preventing bone loss. The ideal interval between the first and second stages is 2 to 8 weeks, but this is often extended for various reasons [43, 44]. Prolonged inter-stage periods increase the risk of bone loss progression, especially when the spacer remains in situ for more than 90 days 28. In our study, the average time between the 2 stages was over four months for both groups, highlighting the potential for cotyloid damage if a protective acetabular augment is not used.

We analyzed the revision implant COR displacement compared to both the native COR and the COR of the primary implant. We found that vertical displacement of the COR between the first and second stages (ΔV-COR2-1) and restoration of the horizontal COR in the revision implant (H-COR2) were the most relevant data. Group A exhibited significantly lower proximalization of the revision cup, allowing for better restoration of the vertical COR in the revision cup, despite significant proximalization of the primary cup in this group compared to Group B. Additionally, the revision cup was less medialized in Group A, closer to the native hip's horizontal COR. Acetabular cement augmentation likely contributed to restoring hip biomechanics by protecting the cotyloid fossa from bone erosion, both vertically and medially. Lastly, while bone resection was slightly greater in Group A (17.57 cc ± 9.47) compared to Group B (14.49 cc ± 8.14), this difference was not statistically significant. This finding conflicts with our hypothesis of greater bone sparing in Group A, possibly due to larger starting diameters of primary cups in Group A.

Despite the strengths of our study, including comprehensive radiographic analysis and comparison of different spacer techniques, there are limitations. The retrospective, non-randomized nature of the case series and the relatively small sample size may affect statistical comparisons. All calculations were performed on calibrated radiographs; a systematic CT study would be more accurate in determining bone volume resected. Additionally, variability in surgeon preferences for implant selection and cup size may introduce bias. Nonetheless, our findings provide valuable insights into the role of acetabular cement augmentation in preserving bone stock and restoring hip biomechanics in two-stage hip revision for PJI.

Conclusion

Indeed, two-stage exchange arthroplasty remains a cornerstone in managing complex prosthetic hip infections. While highly effective in eradicating infection, this approach poses challenges such as significant bone loss due to chronic infection and the invasive nature of the procedure. Our study underscores the importance of using dynamic spacers with acetabular cement augmentation, as it preserves peri-acetabular bone stock and significantly reduces the progression of acetabular bone erosion during the inter-stage period. This additional procedure is strongly recommended, especially in cases of a prolonged inter-stage period, to protect the acetabular bone stock. Moreover, this approach improves joint mobility and reduces the risk of femoral spacer dislocation, thereby facilitating subsequent reimplantation with better restoration of hip biomechanics. While our study provides

valuable insights, further research with larger case series and robust analyses is warranted to firmly establish the efficacy of this technique.

Funding The authors did not receive support from any organization for the submitted work.

Data availability All data are available in the main text and tables. Additional information can be provided if solicited.

Declarations

Ethical approval The authors certify that the institution approved the human protocol for this investigation; all investigations were conducted in conformity with ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments. All patients have given their informed consent for participation and there is no financial interest to report.

Consent for publication Obtained.

Conflict of interest All authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Therefore, no benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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