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Research Article

Management of Severe Acetabular Bone Loss in Hip Revision Surgery: Clinical and Radiographic Outcomes of Porous Metal Augmentation

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Abstract

Introduction: Restitution of the native center of rotation in revision hip surgery with extensive acetabular defects is a challenge and several solutions showed sub-optimal results in the past. The development of porous metal constructs, cups, and augments increased the possible solutions available for this problem and these materials have shown excellent outcomes in early-to-long-term studies. The objective of this study was to evaluate the presence of early osteointegration signs in radiographic follow-ups of metal porous augments in acetabular revisions with large bone defects performed at our center.

Methods: We retrospectively evaluated 22 hips at a minimum follow-up of three years. The mean age was 72 ± 10 years (38-86 years). There were 10 males and 11 females, 15 right and 7 left hips. Based on Paprosky classification, five defects were classified as IIB, two as IIC, nine as IIIA and six as IIIB. The patients were clinically and radiographically evaluated at two weeks, four weeks, twelve weeks, six months and yearly after the surgery. Radiographic osteointegration signs were assessed according to Moore criteria.

Results: At a mean follow-up of 66.4 ± 4.29 months (range, 36-99 months), the HOOS score increased from 39.97 ± 20.24 to 74.50 ± 19. The Likert's satisfaction and pain scales improved from 42.00 ± 12.81 and 59.00 ± 24.90 to 86.50 ± 19.54 and 25.00 ± 17.32, respectively. The final position of the hip center was in average 15.57 ± 9.72 mm lower ($p < 0.001$) and 4.07 ± 6.63 mm lateral ($p < 0.05$) compared to the preoperative hip center. In 17 hips (85%) the final hip centre was lower than preoperatively. Only one patient had a difference in sequentially measured cup-angles superior to 3°. The same patient was the only one with also radiolucent lines greater than 1 mm around the cup (zone 2 and 3 of DeLee and Charnley). However there were no radiolucent lines around the augments and the patient did not have relevant pain or impairment. A superolateral buttress was found in thirteen hips (65%), medial stress-shielding in four hips (20%), an inferomedial buttress in nine hips (45%) and radial bone ingrowth in one hip (5%). Heterotopic calcification was present in twelve hips (60%). One hip (5%) required an early re-operation because of acute periprosthetic infection.

Conclusion: All the augments showed good osteointegration as identified by absence of radiolucent lines. Porous metal augments with their modularity and form not only provide a reliable fixation, but also assist the surgeon to reconstitute the center of rotation of the hip in the desired position, improving abductor function and overall patient satisfaction. Porous metal augments constitute a proven solution for severe acetabular defects. This is a level IV study.

Keywords: Acetabular Bone; Hip Revision Surgery; Radiographic; Porous Metal

Introduction

Total hip arthroplasty (THA) has been considered the surgery of the 20th century [1] and nowadays about one million patients are submitted to hip replacement every year. Therefore, the number of revision surgeries performed is also expected to rise as life expectancy and functional demands increase and the average age at the first procedure decreases [1]. The major causes for a THA revision surgery have been thoroughly identified being aseptic loosening the most frequent, followed by instability and infection [2,3]. In revision surgery, acetabular fixation is particularly demanding as there can be extensive bone loss. These defects were classified by Paprosky in 1994 [2] and historically large defects were buttressed with contoured structural allograft. With the development of porous metal constructs, cups and augments, the trend has changed as these materials have shown excellent outcomes in early-to-long-term studies [2-20] and are easier to apply due to their modularity and immediate availability in the operating room.

Due to its thrombogenic properties [2], pore size, high resistance to friction and mechanical stability [2] porous metal allows and promotes bone ingrowth at the surface of the implant. These properties have led to a decrease in the loosening rates in revision surgery from up to 70% with the allograft montage [4] to 5.6% [12].

The goal of this study was to evaluate the presence of early osteointegration signs in early radiographic follow-ups of metal porous augments in acetabular revisions with large bone defects performed at our center.

Material and Methods

We retrospectively analyzed records of patients submitted to acetabular revision from 2012 to 2019. Twenty-six revisions were identified in which modular trabecular metal augments were used (Trabecular Metal from ZimmerBiomet, Warsaw, Indiana; Gription from DePuy Synthes, West Chester, Pennsylvania and Tritanium from Stryker). Four patients were excluded due to insufficient follow-up as they died of causes not directly related to the surgery. Therefore 22 revisions corresponding to 21 patients (one patient had bilateral hip revision surgery) were included in our study. The mean age was 72 ± 10 years (38-86 years). There were 10 males and 11 females, 15 right and 7 left hips. The reason for the revision was aseptic loosening in 18 hips, infection in 3 hips, and instability in 1 hip. Femoral revision was performed in 14 hips (63,6%). Based on Paprosky classification, 5 defects were classified radiographically and intraoperatively as IIB, 2 as IIC, 9 as IIIA, and 6 as IIIB - table 1.

Patient demographics	
Gender (proportion of men)	10 (45%)
Age (range)	72,68 (38-86)
American Society of Anesthesiologists (ASA) Classification	
ASA 1 (n)	1
ASA 2 (n)	13
ASA 3 (n)	8
Paprosky Classification	
IIB	5
IIC	2
IIIA	9
IIIB	6
Diagnosis	
Asseptic loosening (n)	18
Infection (n)	3
Instability (n)	1

Table 1: Patient demographic characterization, ASA classification, Paprosky acetabular defect classification and diagnosis.

Surgical technique

The surgeries were performed by the two orthopedic surgeons dedicated to hip pathology for more than ten years - senior authors (AS and DS).

Previously to the surgery, antero-posterior (AP) and lateral radiographs were analyzed. If there was any doubt regarding the extent of the defect a pelvic computed tomography was performed. Intraoperatively, the aim was to place the cup in a position similar to the normal hip center while avoiding excessive tension at neurovascular structures.

After a thorough debridement and preparation of the neo-acetabular cavity and with a trial cup in situ, the remaining defect was evaluated and it was reamed until a correct size augment could be used. Bone graft was used as a supplement to fill further the defect in 4 hips: lyophilized bone allograft in 2 and autologous bone graft in the other 2 hips. In 15 hips only one augment was used to fill a superior defect. In 4 hips one augment and a buttressing plate to the posterior column were used. In 3 hips two augments were used: in 2 of them both augments were necessary to fill a superolateral defect while in the other one augment was placed in a superolateral position and one in an anteroinferior position. The augments were fixed with screws (1 to 3 screws) until good stability was achieved and the cup-facing facet was covered in gentamycin impregnated-cement [1]. Cement was also used in the interface between augments when two were used. The cup diameter necessary to create press-fit was determined intraoperatively and was 50 to 64 mm depending on the patients' anatomy and defect size. The cup was then pressed fit and multiple screws were placed supplementing initial fixation (1 to 3 screws) if needed for additional stability. The femoral head size was 36mm in 18 hips, 32 mm in 2 and 28 mm in the remaining 2 hips. In the pos op period partial weight bearing was encouraged as soon as tolerated. The average hospital stay was 14.8 ± 2.9 days - table 2.

Radiological and clinical follow-up

The patients were clinically and radiographically evaluated at the outpatient clinic at two 2 weeks, 4 weeks, 12 weeks, 6 months and yearly after the surgery. The Portuguese version of Hip disability and Osteoarthritis Outcome Score LK 2.0 (HOOS) [1,2] and Likert's satisfaction and pain scales (0-100) were filled by the patient before the surgery and at the yearly follow-ups. Serial pelvic AP and lateral radiographs of the affected hip were standardly analyzed after calibration using the femoral head size. The position of the center of the hip was measured as described by Massin., *et al.* [1] after confirming the quality and comparability between radiographs - the difference in the vertical distance between the tear drop line and obturator line had to be inferior 4 mm. The distances

Surgery duration and hematic losso	
Duration in minutes (range)	170,6 (72-309) min
Hematic loss in mL (range)	1126 (400-2400)
Femur revision	16 (73%)

Table 2: Surgery duration and hematic loss. Femoral revision was associated with increased duration and hematic loss.

between the center of the hip to vertical (A) and horizontal lines (B) crossing at the lower end of the tear drop were measured. A and B distances were also divided by the pelvic height (ischiatic tubercles to the iliac crest) according to John and Fisher [1]. The cup implantation angle (α-angle) was also measured as the angle between the cup and the tear drop line figure 1 and 2. Acetabular cup stability was evaluated by several aspects: absence of any measurable difference in distances A and B in serial radiographs; variation in α-angle lesser than 3º; absence of radiolucent lines with 1 mm or greater in the three zones of DeLee and Charnley or its progression, according to Zicat., *et al*. [2] and the presence of osteointegration signs as described by Moore., *et al*. [2] figure 3. The presence of heterotopic ossification was evaluated according to Brooker's Classification.

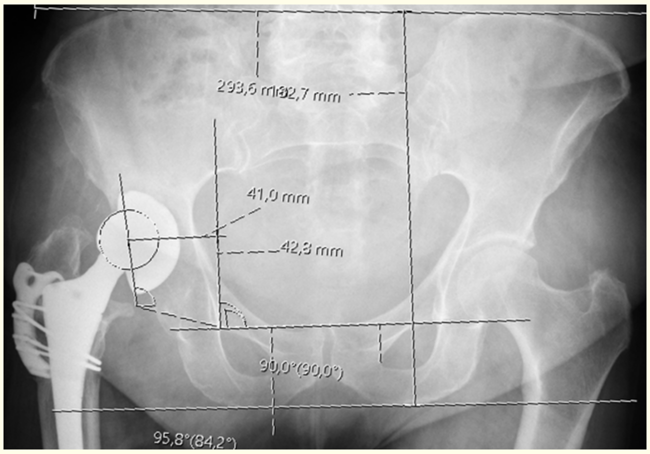

Figure 1: Measurement of the α-angle and position of the cup using the tear drop line as a reference in a preoperative radiograph.

Statistical analysis

Statistical analysis was performed using the SPSS software (SPSS version 22, IBM, Chicago, Illinois, USA). Data distribution was evaluated by the Shapiro-Wilk test. The quantitative variables were expressed as mean+/- standard deviation. *T-student or Wilcoxon test* were used to compare preoperative and postoperative outcome with a *significance* interval of 95% ($p < 0.05$).

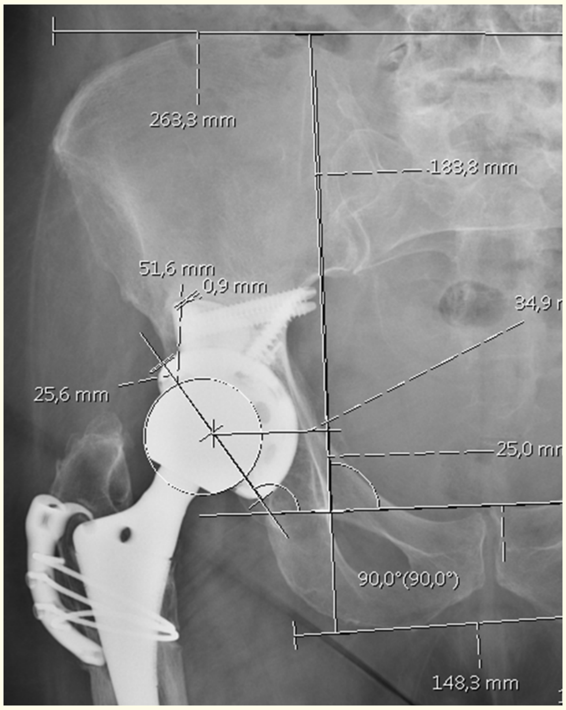

Figure 2: Same measurements in a radiograph from the same patient five years after surgery. The radiographs were considered comparable if the difference in the vertical distance between the tear drop line and obturator line was inferior to 4 mm.

Figure 3: Evaluation of the presence of osteointegration criteria. There is no radiolucency. A superolateral buttress (red arrow), medial stress-shielding (blue arrow), and an inferomedial buttress (orange arrow) are present.

Results

The average follow-up was 66.4 ± 4.29 months (range 36-99 months). The Hip disability and Osteoarthritis Outcome Score LK 2.0 (HOOS) improved from 39.97 ± 20.24 to 74.50 ± 19.29 at the last assessment ($p < 0.001$). The Likert's satisfaction and pain scales improved from 42.00 ± 12.81 and 59.00 ± 24.90 to 86.50 ± 19.54 and 25.00 ± 17.32, respectively.

The mean hip center position pre-operatively was 36.59 ± 10.62 mm (18.43 ± 5.77% of pelvic height) vertically and 37.92 ± 8.61 mm (19.05 ± 4.78% of pelvic height) horizontally in relation to the lower point of the ipsilateral tear drop. In the first post-operative radiographs, the mean hip center position was located 22.16 ± 8.78mm (11.21 ± 4.69% of pelvic height) superior and 34.41 ± 6.12 mm (17.36 ± 3.37% of pelvic height) lateral to the same reference point. On the last follow-up, the mean hip center was 21.58 ± 8.59 mm (10.96 ± 4.62%) vertical and 34.42 ± 5.85 mm (17.41 ± 3.17%) horizontal, similar to the immediate post-operative control ($p > 0.05$). At the last control, the hip center was on average 15.57 ± 9.72 mm lower ($p < 0.001$) and 4.07 ± 6.63 mm lateral ($p < 0.05$) compared to the preoperative hip center. In 19 hips the final hip center was lower than preoperatively figures 4 and 5, table 3.

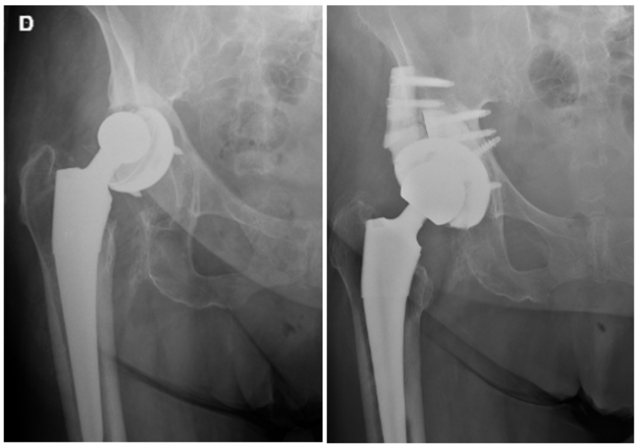

Figure 4 and 5: In this patient, the position of the hip center after surgery was 36 mm inferior and 6 mm lateral compared to the preoperative position. Clinically the patient presented an improvement in the HOOS score from 34 to 92 points.

Cup stability criteria and osteointegration signs	
Variation in α-angle <3º	21
Absence of radiolucency lines >/= 1mm	21
Superolateral buttress	15
Medial stress shielding	5
Inferomedial buttress	10
Radial bone ingrowth	1

Table 3: Radiographic evaluation of the cup position in relation to the tear drop.

The mean α-angle was 49.29 ± 7.66° immediately after the surgery and 50.05 ± 7.46° at the last control ($p > 0.05$). Only 1 patient had a difference in the α-angles superior to 3°. The same patient was the only one with also radiolucent lines greater than 1 mm around the cup (zone 2 and 3 of DeLee and Charnley). However, there were no radiolucent lines around the augments and the patient did not have relevant pain or impairment (HOOS Score 87.5 and Likert pain scale 2).

Regarding other osteointegration signs as described by Moore., *et al.* superolateral buttress was found in 15 hips (68%), medial stress-shielding in 5 hips (23%), an inferomedial buttress in 10 hips (45%) and radial bone ingrowth in 1 hip (5%) table 4.

Heterotopic classification was present in 14 hips (64%): 6 were classified as a Brookers' grade I, 4 as grade II, 3 as grade III and 1 as grade IV. The patient with a grade IV heterotopic calcification had a HOOS score of 63.13.

One hip required an early re-operation because of acute periprosthetic infection. It was treated with debridement, change of the mobile parts, antibiotics, and implant retention (DAIR) with success. No revision surgery was performed because of aseptic loosening.

	Cup height in mm (±SD)	Cup height in % of pelvic height (±SD)	Cup horizontal position in mm (±SD)	Cup horizontal position in % of pelvic height (±SD)
Pre-operative	36.59 ± 10.62	18.43 ± 5.77	37.92 ± 8.61	19.05 ± 4.78
Initial post operative	22.16 ± 8.78	11.21 ± 4.69	34.41 ± 6.12	17.36 ± 3.37
Last post operative	21.58 ± 8.59	10.96 ± 4.62	34.42 ± 5.85	17.41 ± 3.17

Table 4: Cup stability criteria and osteointegration signs.

Discussion

Restitution of the native center of rotation in revision hip surgery with extensive acetabular defects is a challenge and several solutions showed sub-optimal results in the past: bone graft impaction plus mesh presented high revision rates (up to 28% revision rate after 7 years [1]); the utilization of jumbo cups in cases with great defects may lead to the loss of bone stock and cup implantation in a higher position leading to deficient biomechanics [1], it's also associated with poorer fixation when there is less than 50% of contact with host bone [1]; structural allograft showed a low rate of osteointegration associated with a high rate of revision

[27], together with the need for an extended iliac stripping for adequate fixation with cumulative morbidity.

Porous metal augments have shown promising results with some studies presenting survival rates ate 5 years above 95% [8,9]. The secret behind these results rely on the ultrastructure of the titanium (Gription from DePuy Synthes, West Chester, Pennsylvania and Tritanium from Stryker) or tantalum (Trabecular Metal from Zimmer Biomet, Warsaw, Indiana), the pore size, its thrombogenic properties, the high friction coefficient plus the possibility to easily fix it with screws creating an environment of "absolute" stability which promotes osseointegration. *Vutescu*., *et al.* [1]. showed that there is no clinical differences in survival rate between tantalum and titanium in primary or revision hip arthroplasty. In our study, there was no revision for aseptic loosening at the minimum three year follow-up. All the augments showed good osteointegration as identified by the absence of radiolucent lines (100%) and there was no statistical difference between augments made of titanium or tantalum. Superolateral buttress was the second most frequent radiographic sign present (68%). The remaining signs were less prevalent but it could be justified by local conditions: the medial stress shielding is difficult to identify because in cases with severe bone loss, as were most of the studied cases, there is no bone stock remaining medially capable of producing the macroscopic radiographic effect. The same principle can be applied to the inferomedial buttress sign and radial bone ingrowth. Considering the cups, only one case showed early signs of aseptic loosening but the patient was asymptomatic, so the surgeon chose to wait before revising the hip. In this case the cup was fixed only to the augment with cement and pressed fit to the acetabulum but there were no screws. According to Beckmann., *et al.* the fixation of the cup to the augment with cement is the best construct in terms of stability. The same authors also pointed that adding screws to the interface between cup and augment had no benefit. Solomon., *et al*. [1]. pointed out that the majority of the proximal translation and sagittal rotation occurred within the first 6 weeks as measured by radiostereometric analysis and rose the hypothesis that inferior screws are important to prevent cup migration as this extra fixation point to the pubic or ischiatic ramus allows for a three-point support and prevents rotation centered on iliac fixation. This idea was further developed in biomechanical studies in which augments were placed in an inferior position [1].

Porous metal augments with their modularity and form not only provide a reliable fixation but also assist the surgeon to reconstitute the center of rotation of the hip in the desired position, the eccentric fixation of one or two augments superiorly pushed down the center of rotation allowing better hip biomechanics, improving abductor function and overall patient satisfaction. Achieving the same result with a cup and cage construct or with a jumbo cup is demanding. In our study, the hip center was in average 15.57 ± 9.72 mm lower post-operatively. Early signs of osteointegration were also found in every patient. These results are similar to those found in the literature [9,16].

This work has several limitations: it is a retrospective evaluation and the study group is heterogeneous regarding the type of defect and causes for revision. Also, both the number of cases included and the time of follow up could be greater.

Conclusion

Porous metal augments constitute a proved solution for severe acetabular defects: their structural and physical properties are associated with low rate of aseptic loosening and their modularity allow for patient specific tailoring which helps the surgeon to restore the center of rotation of the hip to the desired position. Formal radiographic follow-up can be used to identify early signs of osteointegration.

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