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ORIGINAL PAPER

Major acetabular defects: outcomes of first revision total hip arthroplasty using Kerboull cross-plate with allograft and cemented dual mobility cup at a maximum follow-up of fourteen years

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Abstract

Background The use of dual mobility cups (DMC) has been shown to reduce hip instability after revision surgery. For severe acetabular bone loss, reconstruction with a Kerboull cross-plate and bone allograft would contribute to restoring native hip position and bone stock. Only two papers reported on the combination of Kerboull cross-plate with bone allograft and cemented DMC in revision total hip arthroplasty (THA).

Methods This is a monocentric retrospective study (28 cases) of first-time revision THA using such a construct in American Association of Orthopaedic Surgeons (AAOS) grade III and IV acetabular bone defect. Detailed demographic, clinical and radiographic results were recorded and evaluated.

Results With a mean follow-up of six ± 3.63 years, no case of instability was reported. The modified Harris Hip Score (mHHS) was 88.4 ± 10.1. No hook fracture or mechanical failure was observed. Non-progressive radiolucent lines were recorded. Osteointegration of the allografts was observed in all cases with a mean Grodet score of 7.9 ± 0.97.

Conclusions In first revision THA, the use of a Kerboull cross-plate with allograft and a cemented DMC in AAOS grade III and IV acetabular bone defects demonstrated excellent clinical and radiological outcomes with no recorded cases of dislocation or mechanical failure.

Keywords Revision total hip arthroplasty · Aseptic loosening · Hip dislocation · Dual mobility cup · Kerboull cross-plate · Bone allograft

Introduction

The two major causes of revision total hip arthroplasty (THA) are loosening and instability [1, 2]. Multiple concepts such as acetabular retentive cups and large diameter femoral heads were designed to resolve these complications. These designs have been shown to reduce instability, yet at the expense of an increase in wear rates and aseptic loosening [3, 4]. In parallel, the concept of "non-constrained" dual mobility cups (DMC) developed by Gilles Bousquet in 1974, has shown promising results in increasing hip stability and range of motion along with a decrease in wear rate and aseptic loosening [5–8, 9, 10].

Another major challenge is the reconstruction of extensive acetabular bone defects and restoring the native hip centre of rotation [4, 11]. Multiple modalities have been developed to address major bone defects, these ranges from acetabular Jumbo cups that does not require acetabular bone grafting to reinforcement cages such as the Muller-ring, Ganz ring and the Burch Schneider cage. These cages have been proven to be effective in acetabular defect reconstruction, however, at the expense of an increased rate in aseptic loosening [11–13].

Kerboull et al. described a technique using an acetabular reinforcement cross-plate coupled with both structural and morselized allograft in segmental and cavitary defects [14].

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This reconstruction technique automatically restores the native acetabular position and provides excellent secondary allograft osteointegration [15, 16].

There are only few studies in the literature that reported the outcomes of the use of a cemented DMC in an anti-protrusio reinforcement cage [17–22]. However, only two studies reported outcomes of patients undergoing revision THA using exclusively a Kerboull cross-plate with bone allograft and a DMC [20, 21].

The purpose of this study is to document the midterm outcomes of the use of a Kerboull cross-plate associated with bone allograft and a cemented DMC in first revision THA with major acetabular bone defects.

Methods

This is a monocentric continuous retrospective observational study where the data was collected prospectively. All charts of patients hospitalized between January 2006 and May 2020 who had a first revision THA using a Kerboull cross-plate and allograft with a contemporary cemented DMC were retrieved and analyzed. The approval from the Ethical committee of our institution was granted prior to the conduction of the study. The clinical and radiological evaluations were performed by two independent observers. The inclusion criteria were set as follows: (a) patients with only one previous THA, (b) use of the Kerboull cross-plate, (c) use of allograft, (d) use of a contemporary cemented dual mobility cup, (e) revision should include at least the acetabular component, (f) a minimum follow-up period of two years. Exclusion criteria were set to as: (a) more than one hip revision THA, (b) use of a non-DMC, (c) use of a reconstruction cage other than the Kerboull cross-plate, (d) no use of bone allograft, (e) revisions due to an infection (f) Kerboull cross-plate used for an acetabular fracture. The used bone graft from femoral head allografts was treated using the Marburg bone bank system and stored at − 80 °C [23].

The radiological evaluation was conducted with standard parameters and included all patients. It was based on standing X-rays performed pre-operatively, immediate post-operatively, at 6 weeks, and at last follow-up. Radiolucent lines and osteolysis of the reconstructed acetabulum were assessed using the classification of DeLee and Charnley [24]. The Gruen and Johnston classifications were used for assessment of peri-prosthetic femoral radiolucency [25, 26].

Graft osteointegration was evaluated using the Grodet et al. classification with a score ranging from 0 to 9 [27] (Table 1). When the score is at least 6, the graft is considered integrated while a score of 0 reflects complete lysis of the graft. The modified Harris hip score (mHHS) was used for function evaluation of the living patients at the time of last follow-up.

Surgical technique

All patients were in strict lateral decubitus position. A postero-lateral approach was used in all cases. When a femoral osteotomy was needed, it was performed in accordance with the standard extended trochanterotomy principles and fixed with at least two cerclage wires or cables. In all cases, a structural and morselized allograft was applied to reconstruct the acetabular bone defects. The original design of the Chrome-Cobalt Kerboull cross-plate with its four branched hemispheric configuration (Groupe Lepine, Genay, France) was placed using the “cross technique” with insertion of a cemented contemporary DMC in all constructs [28]. After the preparation of the acetabular cavity, the hook was positioned on the superior border of the obturator foramen, with the palette being parallel to the floor. This automatically gives an acetabular inclination angle of 45°. The gap between the palette and the acetabular roof is then filled with a single structural bone graft. The Kerboull cross-plate palette is fixed using 4.5 mm cortical screws. The remaining acetabular defects are filled with morselized bone allograft and packed between the interstices limiting the cross-plate micromotion. Finally, we insert a downsized cemented DMC insuring a sufficient cement mantle. The DMC is always applied; as such, its superior border is flush with the plane of the palette. Figures 1, 2, 3 and 4 showed a case of THA revision with Kerboull plate, graft and DMC. Post-operative rehabilitation protocol with passive and active motion exercises was initiated the next day of surgery. Following a strict non-weight bearing period of three weeks, partial weight bearing was allowed for an additional three weeks.

Statistical analysis

Statistical analysis was conducted with the StatsDirect software (Cambridge, UK). For continuous variables, mean values with their standard deviations (SD) were reported. Frequency values were calculated for dichotomous variables. Correlation was performed with univariate and multivariate regression analyses. Significance was set for *p*-values of less than 0.05.

Results

Patient sample demographics

The total sample comprised of 27 patients (2 males and 25 females) including 28 hips (17 right and 11 left). The mean age was 66.1 ± 18.5 years. The mean American Society of Anesthesiologists (ASA) score was 2.11 ± 0.69. The initial

Table 1 Characteristics of the sample

Patient	Side	Sex	Age	ASA score	Initial etiology	Etiology for revision	Years to revision	Follow-up period
1	Right	Female	72	2	Femoral neck fracture	Recurrent dislocation	5	3
2	Left	Female	82	3	Femoral neck fracture	Aseptic Loosening	18	12
3	Right	Female	57	2	Dysplasia	Aseptic loosening	10	10
4	Right	Female	72	2	Femoral neck fracture	Recurrent dislocation	12	9
5	Right	Female	46	1	Femoral neck fracture	Aseptic loosening	7	9
6	Left	Female	86	1	Femoral neck fracture	Aseptic loosening	18	9
7	Right	Female	72	2	Femoral neck fracture	Aseptic loosening	1	5
8	Left	Male	56	3	Femoral neck fracture	Aseptic loosening	14	3
9	Right	Female	84	2	Femoral neck fracture	Aseptic loosening	15	5
10	Right	Female	85	3	Osteoarthritis	Aseptic loosening	10	3
11	Right	Female	38	2	Avascular necrosis	Aseptic loosening	18	2
12	Left	Female	58	2	Femoral neck fracture	Recurrent dislocation	3	2
14	Right	Female	47	3	Avascular necrosis	Aseptic loosening	15	2
15	Right	Male	63	3	Avascular necrosis	Aseptic loosening	10	5
16	Left	Female	82	3	Femoral neck fracture	Aseptic loosening	8	7
17	Right	Female	72	2	Femoral neck fracture	Aseptic loosening	10	14
18	Right	Female	73	3	Femoral neck fracture	Aseptic loosening	0	3
19	Right	Female	90	2	Femoral neck fracture	Aseptic Loosening	16	3
20	Right	Female	86	2	Femoral neck fracture	Aseptic Loosening	8	3
21	Left	Female	48	3	Avascular necrosis	Aseptic loosening	17	2
22	Left	Female	70	2	Osteoarthritis	Aseptic Loosening	25	2
23	Left	Female	46	1	Dysplasia	Aseptic loosening	2	12
24	Right	Female	81	2	Osteoarthritis	Aseptic Loosening	14	2
25	Right	Female	64	2	Osteoarthritis	Aseptic Loosening	15	2
26	Left	Female	67	1	Dysplasia	Aseptic loosening	13	5
27	Left	Female	72	1	Femoral neck fracture	Aseptic loosening	4	6
28	Left	Female	75	2	Avascular necrosis	Aseptic loosening	4	4
29	Right	Female	67	2	Dysplasia	Aseptic loosening	23	12

etiology of the primary surgery before revisions was diverse: 15 femoral neck fractures, four hip dysplasia, four osteoarthritis, and five osteonecrosis. Causes of revision were as follows: 25 aseptic loosening (3 were associated with instability) and three recurrent dislocations. Figure 5 shows the flowchart of the study.

Revision THA characteristics

The mean time for revision was 11.3 ± 6.47 years. The mean follow-up period was six $\pm$ 3.63 years. Three patients were deceased at last follow-up after a mean period of 6.0 ± 5.2 years; the cause of death was not related to the hip revision surgery. Data from their last follow-up was included in the analysis. The femoral stem was changed in 23 cases (19 uncemented and 4 cemented). Extended trochanteric osteotomy was conducted in seven cases (25%). Seven patients had a femoral head size of 22.2 mm while the other 21 had a femoral head size of 28 mm; six inserted heads were in ceramic and 22 in cobalt-chrome alloy. The choice for the smaller head was dictated when the cup size was inferior to 48, while the 28 mm head was used for cup sizes 48 and above. The pre-operative AAOS classification of acetabular bone defects were as follows: twenty-five Grade III and three Grade IV. Based on the Paprosky classification, the defects were as follows: twelve 2B, twelve 3A and four 3B. The cross plate was used with insertion of a contemporary cemented DMC: 16 Quattro, (Groupe Lepine, Genay, France), 12 Avantage (Zimmer Biomet, Indiana, USA). The mean acetabular DM cup size was 48.5 ± 1.62. The sample's characteristics are shown in Table 1.

Outcomes

No intra-operative or post-operative neurovascular complications were reported following the use of this acetabular

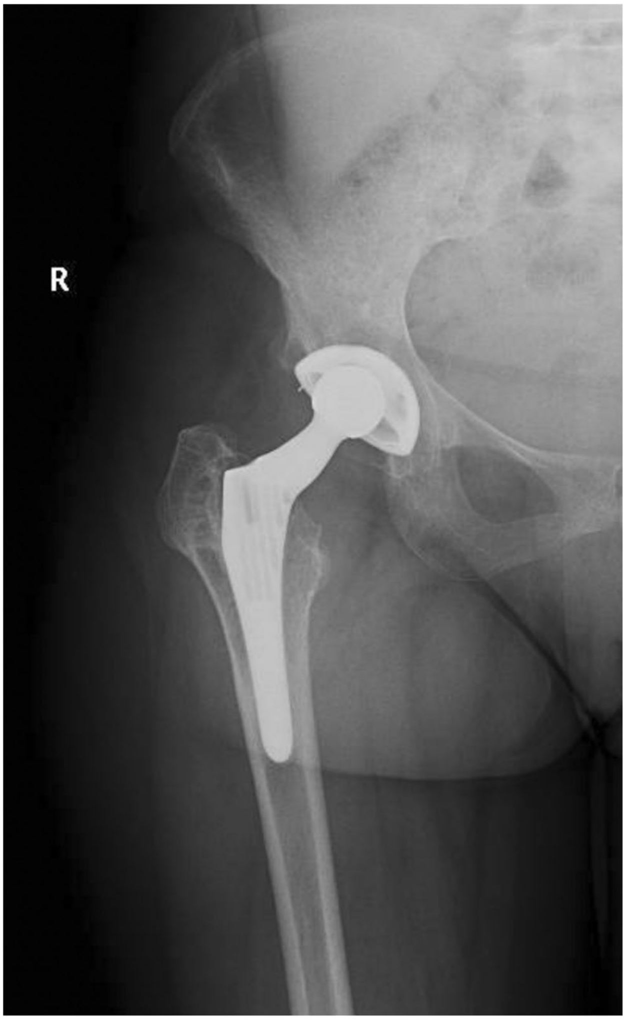

Fig. 1 Pre-op AP view

Fig. 2 Pre-op lateral view

reconstruction technique. No case of acetabular or intraprosthetic dislocation, and aseptic loosening was recorded. In one case, the per-operative culture was positive, and the patient was treated with a long course of IV antibiotics. The mean mHHS score of the 24 living patients was 88.4 ± 10.1.

The mean acetabular cup inclination angle is of 43.1° ± 5.94°. Using the DeLee and Charnley classification [24], radiolucent lines on the acetabular side were found in two cases, both in zone I. However, the observed radiolucent lines were less than 1 mm thick and were non-progressive during the follow-up period. On the femoral side, radiolucent lines were recorded in five cases: four in Gruen zone I and one in Gruen zones I and VII [25].

There was no case of fracture at the junction between the palette and the vertical limb of the Kerboull cross-plate. No hook fracture or displacement was noted. Four screws were inserted to fix the Kerboull cross-plate in twenty-six cases; in one of these cases, there were two broken screws at final follow-up (7 years). In two cases, the palette was fixed with three screws. One of which had three broken screws at final follow-up (5 years), with complete bone integration (Grodet score of 9) and no reported complications.

In relation to the osteointegration of the acetabular bone construct using the Grodet score [27], all cases were scored 6 or above with a mean value of 7.9 ± 0.97.

Discussion

In revision total hip arthroplasty, acetabular reconstruction presents two major challenges. First is the reconstruction of the acetabular bone defects restoring native hip center of rotation, improving hip biomechanics, and second to decrease post-operative instability [11, 29, 30].

Acetabular reconstruction remains a challenge in revision surgery due to extensive bone loss. Multiple modalities have been developed to compensate for the bone defect

Fig. 3 Post-op AP view

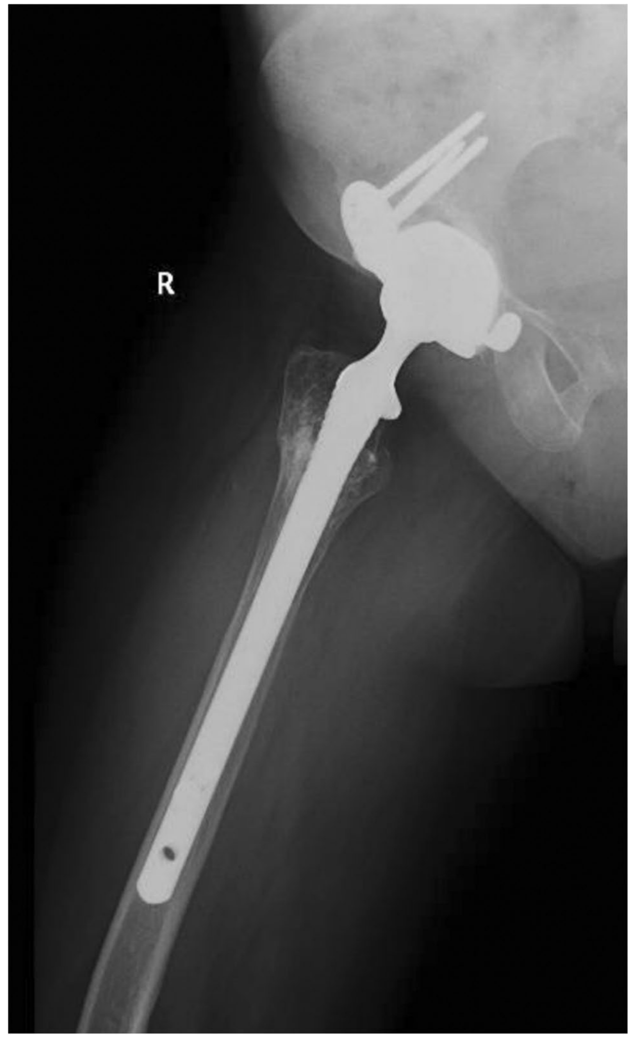

Fig. 4 Post-op lateral view

and restore native hip anatomy. For instance, the use of acetabular Jumbo cups that do not require bone grafting; however, they reported a high rate of revision failure due to aseptic loosening with an increased rate of iliopsoas impingement. Additionally, jumbo cups fail to restore the native center of rotation [31, 32]. Another option of acetabular reconstruction is with trabecular metal augments that allow for the insertion of larger femoral heads but at higher cost [31, 33]. More so, both options remain highly controversial since they do not restore the acetabular bone stock particularly in AAOS grade III and IV acetabular defects [31, 32, 34]. The use of a metal reinforcement cage with bone allograft impaction filling the defects would allow the restoration of the bone stock and the center of rotation while providing a stable fixation of the acetabular cup [12, 20, 21, 35]. The four reinforcement cages most used in revision THA are Muller ring, Burch-Schneider cage, Ganz ring and the Kerboull cross-plate [11, 36]. Using a cemented DMC in a Muller or Burch-Schneider ring, Lebeau et al. demonstrated a rate of aseptic loosening of 6.4% at a mean follow-up of 6.5 years [37]. This rate is three times higher than that found by Langlais et al. (2.2%) using a DMC cemented in a Kerboull cross-plate [21]. Because of its open armature, the Kerboull cross-plate is the only reinforcement cage that provides mechanical support to the allograft without completely unloading it, hence, protecting the allograft from resorption [13, 14]. In addition, due to its hemispherical design, the Kerboull cross-plate is deeper than both the Muller and the Ganz cages. This yields a greater coverage of the cup, restoring the hip center of rotation and decreasing the hip joint reactive forces.

Our findings are in line with the only two studies using the same acetabular reconstruction. Wegrzyn et al. documented a survival rate of 96% at 7.4 years of follow-up when using the Kerboull cross-plate and bone allograft with a cemented DMC [20]. While Langlais et al. reported

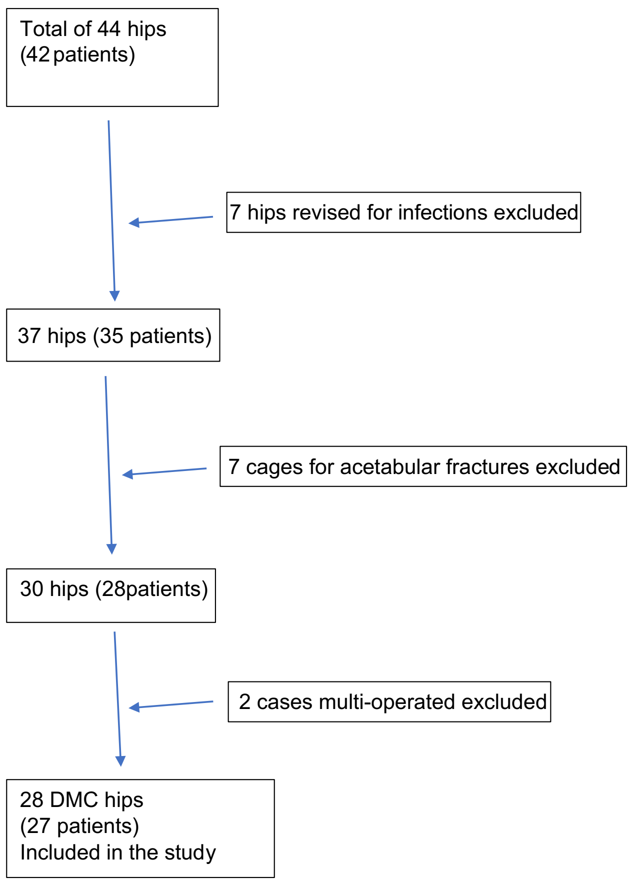

Fig. 5 Flowchart of the study

a survival rate of 94.6% at 5 years of follow-up with a 1.1% incidence of dislocation [21].

In revision THA, instability is another challenge for reconstructive surgeons. Reported dislocation rates using standard cups could be as high as 25% and depends on multiple risk factors [38–41]. Different options were implemented to target this complication such as the use of constrained acetabular devices or large diameter heads. Constrained acetabular devices were found to be suboptimal solutions for instability owing to a higher polyethylene liner wear and acetabular cup loosening with failure rates reaching up to 42.1% at ten years follow-up [42, 43]. Biomechanically, large diameter heads (≥ 36 mm) were found to increase wear of highly crossed linked polyethylene when compared to smaller heads (< 32 mm) [3, 44]. While both options are currently limited to salvage cases, recent literature has been consistently showing the beneficial use of DMC in revision THA [42–47] with dislocation rates ranging from 0 to 8.7% [42, 44, 48]. In addition, Prudhon et al. and Adam et al. demonstrated lower wear rates in DMC when compared with large femoral heads and retentive cups [8, 49].

At a mean follow-up of 6 ± 3.63 years with no case lost to follow-up, no dislocation or aseptic loosening has occurred in our series. On the other hand, Tanaka et al. reported an instability rate of 9.5% at five year follow-up with cementation of an all-polyethylene component in a Kerboull cross-plate [50]. When compared to standard cups using the same acetabular construct, Assi et al. reported a dislocation rate of 23% in standard cups versus 0% with DMC [22].

In relation to mechanical failure, Wergrzyn et al. reported one case of acetabular construct failure 62 months post-operatively mainly related to a technical error [20]. No cup failure or changes in the mean acetabular cup inclination angle was noted in our study. The single case in which all screws were broken was observed in a patient where three screws were inserted to fix the palette. This patient showed no signs of mechanical failure at last follow-up of five years. These results were in line with the study performed by Makita et al. which reported two cases of screw breakage (3%) with no acetabular cup migration [31]. Since the breakage occurred after complete osteointegration of the bone graft (Grodet 9), it is very likely that it was due to corrosion at the junction between the head and the axis of the screws.

No cases of palette/hook fracture/displacement were observed on radiographic evaluation at last follow-up. As described by Assi et al. [28], we believe that bending the palette is not recommended and should be kept horizontal to maintain an automatic cross-plate inclination of 45° and to avoid weakening the junction. In addition, a proper impaction of the morselized allograft under the hook and on the acetabular floor should be performed. This technique enhances the primary stability of the cross-plate thus decreasing the stress shield on the hook and palette. This was consistent with a finite analysis study performed by Kaku et al. in which he demonstrated that filling the gap behind the cross-plate with adequate morselized bone graft reduced the stress on the Kerboull cross-plate and screws, especially in large bone defects [35].

With this construct, our series reports satisfactory osteointegration of the allografts in all cases with a minimum Grodet score of 6. As far as we know, it is the first study to conduct an objective evaluation of the allograft osteointegration using radiological analysis. Kerboull et al. Langlais et al. and Wegrzyn et al. reported comparable excellent results in terms of graft osteointegration and construct longevity [14, 20, 21]. Similar osteointegration results were not observed in series using reinforcement devices other than the Kerboull cross-plate [36, 37].

Furthermore, we systematically downsize the acetabular cup by 2 sizes in relation to the Kerboull cross-plate. This allows proper cement filling and prevents metallic contact between the DMC and the cage, as well as increases acetabular cup coverage, thus reducing risk of femoral neck impingement.

The mean mHHS score at last follow-up was found to be 88.4 ± 10.1. This good functional outcome of such construct has been supported by Wergzyn et al. who reported a significant improvement of the mHHS score; from 53 ± 19 pre-operatively to 79 ± 13 at last follow-up [20].

Our study presents some limitations, mainly its retrospective design and the lack of a control group. In addition, due to the numerous inclusion/exclusion criteria, the study population was small involving 28 hips in which three patients were deceased at a mean follow-up period of 6.0 ± 5.2. Yet, our series is unique regarding the sample homogeneity including only first-time revision THA cases with major acetabular bone defects and the exclusive use of the same acetabular construct placed by a single senior surgeon. Furthermore, the mean follow-up period was less than ten years reflecting a midterm follow-up; however, it is one of the longest follow-up period using such construct. Finally, two different DMC brands were inserted and most of our cases underwent femoral stem revision. We believe that such factors are unlikely to impact our clinical results; since all acetabular cups were contemporary DMC (comparable designs), and femoral stem revision was conducted using systematically a standardized technique.

In conclusion, in the first revision THA, the use of Kerboull cross-plate with allograft and a contemporary cemented DMC in AAOS grade III and IV acetabular bone defect, demonstrated excellent clinical and radiological outcomes with no recorded cases of dislocation or mechanical failure. The Kerboull plate-DMC construct provides perfect graft osteointegration with an ideal centre of rotation and no dislocation.

Author contribution CA and KY designed the study, JM and KB extracted the data, KY analyzed the data, all authors contributed to the discussion and revised the manuscript.

Data availability Data is included in the table.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate The Lebanese American University's ethical committee approved the study. This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of medical center approved this study. Informed consent was obtained from all individual participants included in the study.

Consent for publication Patients signed informed consent regarding publishing their data and photographs.

Conflict of interest The authors declare no competing interests.

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