ORIGINAL ARTICLE

Revision total hip arthroplasty using a reconstruction cage device and a cemented dual mobility cup

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\textbf{Summary}

\textit{Introduction:} The main causes of total hip arthroplasty (THA) revisions are loosening and instability. Dual mobility cups were introduced to prevent instability, but their behavior during revisions with acetabular reconstruction has not been assessed.

\textit{Hypotheses:} Use of a dual mobility cup cemented in a acetabular reconstruction cage device limits the risk of instability and does not hinder the acetabular fixation during THA revisions.

\textit{Objectives:} The objective of this study was to test this hypothesis on a retrospective series of 96 revisions.

\textit{Patients and methods:} At a mean follow-up of 41 months (range, 1–101 months), we analyzed a continuous series of 96 revisions using a reconstruction device (70 Kerboull\textsuperscript{TM} cross-plates, six Burch-Schneider\textsuperscript{TM} antiprotrusio cages, 20 custom-fit Novae ARM\textsuperscript{TM} cages associated in all cases with a Novae Stick dual mobility cup cemented into the cage). Fifteen patients died at a mean follow-up of 22 months (range, 1–66 months) and four patients were lost to follow-up at a mean follow-up of 16 months (range, 9–27 months). These were acetabular revisions involving major bone loss, with 62 stage III and 26 stage IV cases on the SOFCOT classification. Eighty-seven patients (87.5\%) underwent structural bone allografting.

\textit{Results:} The mean Merle d'Aubigné score increased from 9.6 ± 3.06 (range, 2–16) preoperatively to 15.5 ± 2.32 (range, 7–18) at the follow-up. Ten dislocations (10.4\%) occurred, five of which were delayed over three months after the index procedure (5.2\%), but there were no intraprosthetic dislocations. At the follow-up, the X-rays showed eight hardware failures, including one cross-plate fracture, one hook fracture, and one flange fracture. Analysis of the radiological position of the cup showed a mean lowering of 15.6 mm and a 9.4 mm lateralization compared to the preoperative position. One revision for aseptic loosening and another for septic loosening were performed. Taking all-cause acetabular component exchange as a criterion, the survival rate at 8 years was 95.6\% (95\% CI, 93.3–97.7\%) and 99.3\% (95\% CI, 98.9–99.6\%) if the endpoint was aseptic acetabular exchange.

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Discussion. — This study confirms the advantage of dual mobility cups during acetabular reconstruction cemented in antiprotrusio cages as a way to limit, without eliminating, the risk of dislocation. Therefore cemented fixation of dual mobility cups in cages appears to be a reliable short-term option.

Level of evidence. — Level IV, therapeutic retrospective study.

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Introduction

The two main causes of total hip arthroplasty (THA) revisions are loosening and implant instability [1,2]. THA revision poses three specific problems:

(1) primary fixation and secondary osteointegration, which is in a bone that is by definition sclerotic and reworked is often uncertain;
(2) the presence of bone deformities that must be reconstructed to optimize implant fixation over the long-term;
(3) postoperative implant instability, which is more frequent after prosthesis revision because of wide and repeated surgical incisions and in certain cases extended synovectomies. Dual mobility technology has proven its efficacy in preventing dislocations, but although it is often used in revision surgery, the literature today has few reports on this use [2].

The use of antiprotrusio cages associated with bone grafting [3—13] in acetabular reconstructions is reliable because primary fixation and good secondary osteointegration are obtained despite the presence of substantial bone loss. Similarly, dual mobility in situations of prosthesis revision [2,13] can reduce the risk of postoperative implant instability. We propose an original technique for surgical acetabular revision associating acetabular reconstruction antiprotrusio cages and cemented dual mobility cups. We hypothesized that the use of a cemented dual mobility cup in an antiprotrusio cage would limit the risk of instability and would not hinder acetabular fixation during THA revisions. This hypothesis was tested by the retrospective analysis of a homogenous and continuous series of 96 acetabular revisions using this original technique.

Table 1 Etiologies of acetabular revision.

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Series (n = 96)</th>
<th>Kerboul™ (n = 70)</th>
<th>Burch-Schneider™ (n = 6)</th>
<th>ARM™ (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurrent dislocation</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Acetabular loosening</td>
<td>41</td>
<td>28</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Femoral loosening</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bipolar loosening</td>
<td>36</td>
<td>27</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Intraprosthetic dislocation</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fracture compromising acetabular fixation</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Stiffness and wear</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sciatic irritation</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure 1  Acetabular reconstruction combining bone graft and custom-fit ARM™ antiprotrusio cage.

Figure 2  Novae Stick™ cup: dual mobility cup to be cemented into an antiprotrusio cage.

Figure 3  Novae ARM™ cage: custom-fit cage derived from a Burch-Schneider™ cage.

when the antiprotrusio cage was a filling cage; in the other cases, it was associated with a structural graft. In 81 cases (89%), this was an allograft, in seven cases (7.7%) it was an autograft, and in three cases (3.3%) a bone substitute replacement. Partial substitution of the pelvis was used in one case (Fig. 1). Eleven patients (11.5%) had preoperative greater trochanter bone lesions comprising three cases of trochanter malunions and eight missing trochanters.

The cup (Fig. 2) cemented in an antiprotrusio cage was the Novae Stick™ dual mobility type (SERF, Décines, France) in stainless steel, existing in nine odd-numbered sizes ranging from 45 to 61 mm in diameter. The ultra-high-molecular-weight polyethylene (UHMWPE) insert was mobile in its convexity with the metal-back and in its concavity with the prosthetic head. We used 54 heads 22.2 mm in diameter (56.3%) and 42 heads 28 mm in diameter (43.7%).

Three types of antiprotrusio cages were used: their distribution in relation to acetabular lesion severity [14] is presented in Table 2. We used 70 Kerboull™ cross-plates (Stryker Pusignan, France), particularly in bone destruction stages II and III. The six Burch-Schneider™ cages (Zimmer, Etupes, France) and the 20 custom-fit ARM™ cages (SERF, Décines, France) (Figs. 1 and 3) were used in stage IV and certain severe stage III cases. There were a few exceptions in this series with the use of a Burch-Schneider™ cage in

<table>
<thead>
<tr>
<th>Acetabular destruction: SOFCOT classification</th>
<th>Series</th>
<th>Kerboull™</th>
<th>Burch-Schneider™</th>
<th>ARM™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Stage 2</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Stage 3</td>
<td>62</td>
<td>59</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Stage 4</td>
<td>26</td>
<td>4</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>70</td>
<td>6</td>
<td>20</td>
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</tbody>
</table>
a stage II patient who presented a fracture of a former Kerboull™ cage. The ARM™ cages were used preferentially over the Burch-Schneider™ cages, which were used when the custom-fit ARM cage was not available. The ARM™ cage was custom-fit based on plain X-rays and a CT scan.

**Surgical technique**

The approach was posterolateral, except in one case in which a trochanterotomy was revised. The choice between the different metallic cages was made in relation to the stage of acetabular bone destruction according to the SOFCOT score [14] provided by preoperative imaging studies. No osteosynthesis was associated with stage IV procedures, because osteosynthesis was performed in a single procedure by mean of the flanges screwed respectively into the iliac wing and the ischium. The Novae Stick™ cup was cemented (cement added with gentamicin).

**Evaluation method**

The patients had radiological and clinical assessment 45 days postoperative, at 3 months, 6 months, 1 year, and then every 2 years. The clinical evaluation conducted preoperatively and at the last follow-up aimed to calculate the Postel Merle d’Aubigné (PMA) score [15] associated with the Charnley [16] and Devane et al. [17] classifications.

The radiological assessment was carried out preoperatively, postoperatively, and at the last follow-up based on AP X-rays of the pelvis and AP and lateral images of the hip. Radiologically, preoperative acetabular bone loss was classified according to the SOFCOT classification [14], and this classification was re-evaluated intraoperatively. We retained the intraoperative classification for the analysis, using the preoperative classification for planning the procedure and choosing the cage.

As for the cup, we searched for and located the radiolucent lines, the osteolysis zones, and the bone cysts as detailed by De Lee and Charnley [18]. The heterotopic ossifications were classified according to Brooker et al. [19]. The radiological classification was completed by an analysis of the implant position using Dicomeasure™ software (View Tec, St Maurice, France), which had already been validated [20–22].

The reference point was the hip’s center of rotation, based on the center of the implant head. The cup position was defined in relation to the lines of Köhler’s teardrop, less sensitive to pelvis rotation according to Wetherell et al. [23] and Massin et al. [24]. The horizontal position was defined by the distance from the orthogonal projection from the center of the head on the line from the teardrops and the pubic symphysis. The vertical position was defined by the distance from this projection (Fig. 4). Given the inaccuracies related to producing the X-rays, we randomly assigned a threshold of 5 mm to define migration.

**Statistical analysis**

The statistical tests, carried out using StatView 5.0 software (Abacus Concepts, Inc, Berkeley, CA, U S A), included univariate parametric tests with the significance level set at \( P < 0.05 \). We analyzed cup survival using an actuarial model (with a 95% confidence interval [CI]), with the definition of failure being revision for any cause and then taking aseptic revision.

**Results**

**Clinical results**

The mean follow-up of the series was 41 months ± 29 (range, 1–101 months). The mean preoperative PMA score was 9.6 ± 3.06 (range, 2–16) with a median at 10. The mean items for pain, mobility, and gait were 2.67, 3.94, and 3.02 points, respectively. At follow-up, the mean PMA score was 15.5 ± 2.32 (range, 7–18) with a median of 16, for a mean increase of 5.9 points (\( P < 0.05 \)). At follow-up, the mean items for pain, mobility, and gait were 5.43, 5.57, and 4.52 points, respectively. The modifications in the Charnley score can be explained by the aging of the population, with a reduction in the number of Charnley A patients and an increase in the number of Charnley C cases (\( P < 0.05 \)) (Table 3). On the other hand, the changes in the Devane score showed a gain in terms of activity, with the appearance of grades IV and V (\( P < 0.05 \)) (Table 4).

**Complications**

Fifteen patients presented an early complication, only seven of whom required a second intervention: six early dislocations (before 3 months postoperative) including three surgical reductions of dislocation, five infections (four superficial infections resolved with antibiotic treatment and one

<table>
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<th>Table 3</th>
<th>Charnley [16] score progression (( P &gt; 0.05 )).</th>
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<tbody>
<tr>
<td></td>
<td>Charnley A</td>
</tr>
<tr>
<td>Preoperative (%)</td>
<td>32 (33.3)</td>
</tr>
<tr>
<td>Last follow-up (%)</td>
<td>23 (24)</td>
</tr>
</tbody>
</table>
deep infection requiring surgical lavage, which resolved the infection), one greater trochanter fracture requiring osteosynthesis, one hematoma requiring evacuation, and two cases of sciatic paralysis related to management of stage IV substance loss. This occurred in a case with the lower flange and the screws of the ARM™ cage impinging with the sciatic nerve requiring early replacement of the cage (with a Burch-Schneider™ cage). In the other case (a Burch-Schneider™ cage), the paralysis resolved spontaneously but sciatic irritation persisted, requiring later cage replacement (a custom-fit ARM™ cage).

Six late complications were observed: five late dislocations (after 3 months) and one periprosthetic femoral fracture requiring plate osteosynthesis.

In total, dislocation was observed in ten patients (10.4%): six patients (6.5%) presented an early dislocation and five patients (5.2%) presented a late dislocation; of the latter patients, one had already presented an early dislocation. These ten patients included four who had stage IV acetabular destruction, four with stage III lesions, and two with stage II lesions. In the subgroup of early dislocations, three patients out of six presented stage IV acetabular destruction, 11.5% of the dislocations observed in the group of patients with stage IV acetabular lesions. The patient who presented late recurrence of an early dislocation also had a stage IV preoperative lesion. In six patients out of ten who presented late or early dislocation, the greater trochanter was missing. Of the patients with a preoperative trochanteric defect, 54% presented dislocation (early in most cases). No correlation was found between the cup size and the onset of an episode of dislocation.

This series includes four implant revisions (4.2%): one Kerboull™ cross-plate rupture with aseptic loosening, one case of septic loosening, and two cases of sciatic impingement. The cross-plate rupture was observed at 98 months of follow-up and required placing a Müller cage. Septic loosening was observed at 37 months of follow-up and occurred after several ineffective lavages. At the last follow-up, the patient had not undergone reimplantation. Two cases of sciatic impingement were observed: one in the immediate postoperative period (replacement of the oversized ARM™ cage with a Burch-Schneider™ cage) and one revised at 37 months of follow-up (replacement of an oversized Burch-Schneider™ cage with a custom-fit ARM™ cage).

We observed eight material ruptures (screw or cage): the above-mentioned Kerboull™ cross-plate fracture with aseptic loosening, one hook breakage, and one lower flange fracture on an ARM™ cage. Other than the cross-plate fracture with loosening, these eight material breakages did not cause migration of the rotation center greater than 5 mm.

### Radiological analysis at the last follow-up

On the acetabular side, we observed two cases of osteolysis: two in De Lee and Charnley zone 1 and one in zone 2. We observed 17 cases of heterotopic ossifications distributed into ten stage I, three stage II, and four stage III according to Brooker et al. [19].

The preoperative and postoperative implant position was studied (Fig. 4) to assess the change applied to the new center of rotation. This showed the validity of this assembly in terms of recentering the hip on cups that were often in protrusion and raised by lateralizing the hip’s center of rotation by a mean 9.4 ± 6.6 mm and lowering it a mean 15.6 ± 11 mm. Reconstruction using an antiprotrusio cage associated with a dual mobility cup made it possible to obtain a mean cup inclination of 48° ± 7.51° (range, 30°—65°).

Migration of the center of rotation greater than 5 mm was observed in six cases, including the two cases of loosening mentioned above (one septic and one aseptic), involving four Kerboull™ cross-plates and two ARM™ cages. Other than these two cases of revised loosening, these migrations occurred early, during the first year, did not evolve further, and were asymptomatic at the last follow-up. Other than these six cases, no significant variation was observed between the immediate postoperative images and at the last follow-up in terms of mean inclination values and center of rotation position, confirming that the acetabular assembly did not significantly migrate.

### Survival rate

Taking all-cause implant ablation as a criterion, the actuarial survival rate at 8 years was 95.6% (95% CI, 93.3—97.7%) (Fig. 5). Taking revision for aseptic loosening as the definition of failure, the actuarial survival rate at 8 years was 99.3% (95% CI, 98.9—99.6%).

### Discussion

The study hypothesis was confirmed, i.e., a low rate of dislocation and few acetabular fixation failures despite the inclusion of patients with mostly severe bone loss. This technique makes it possible to recenter the hip (by lowering and lateralizing the hip’s center of rotation), thus increasing the lever arm of the gluteus medius muscle. The favorable results on the gait item (4,52) of the PMA score at follow-up confirm the effectiveness of repositioning the center of rotation. This finding is confirmed in terms of the Devane activity score [17], which evolved for the greater part of the population toward a higher stage, showing improvement in activity. Similarly, even though the bone lesions in the

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**Table 4** Progression of Devane et al. [17] activity score (P < 0.05).

<table>
<thead>
<tr>
<th></th>
<th>Grade I</th>
<th>Grade II</th>
<th>Grade III</th>
<th>Grade IV</th>
<th>Grade V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative (%)</td>
<td>3 (3.1)</td>
<td>74 (77.1)</td>
<td>14 (14.6)</td>
<td>5 (5.2)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Last follow-up (%)</td>
<td>5 (5.2)</td>
<td>28 (29.2)</td>
<td>47 (48.9)</td>
<td>12 (12.5)</td>
<td>4 (4.2)</td>
</tr>
</tbody>
</table>
patients studied were for the most part severe, the 8-year survival rate was 95.6% (95% CI, 93.3–97.7%), suggesting that this technique is reliable.

The rate of implant instability during revision of total hip replacement is highly variable in the literature, up to 33% [25–29]. Considering acetabular destruction comparable to the present series, more recent publications show a dislocation rate varying from 12.3 to 17.2% [30–32]. For the majority of AAOS stage III patients (23/31), Bostrom et al. [30] observed a 16% dislocation rate at a mean 30 months of follow-up. Pieringer et al. [31] report a 17.2% rate during the analysis of 64 reconstructions using the Burch-Schneider™ cage at a mean follow-up of 50.3 months. We report 10.4% dislocations, with 5.2% late dislocations in the present series, which remains lower than the rates that have been reported in the literature. This is even more interesting in that our patients presented many negative factors in terms of postoperative implant instability [13]. In this study, one patient out of two who presented a dislocation no longer had the greater trochanter and more than one-third of the patients had severe stage IV acetabular lesions.

The all-cause rate of acetabular revision described in the literature concerning antiprotrusio cage reconstructions varies from 5 to 24% and the aseptic loosening rate from 2.5 to 12% [4,30,31,33,34]. The results of the present study come within a quite favorable range with a 4.2% revision rate and a 1% aseptic loosening rate. Cageless revisions with jumbo cups give all-cause acetabular revision rates varying from 1.11 to 11.6% [32,35–37]. The results reported herein are therefore comparable, conditional on this study’s relatively short follow-up. However, the bone destruction stages treated with the jumbo cup are often more moderate, which may contribute to explaining the good results reported [32,35–37]. Thus, this assembly associating a dual mobility cup and an antiprotrusio cage gives clinical results and short-term survival that are satisfactory and comparable to other results reported in the literature.

However, this study’s limitations stem from its retrospective nature. In addition, the follow-up is short, with the inclusion of the last patients giving a minimum follow-up of 1 year and a maximum follow-up of 8 years. Early death for some at 1 month postoperative also reduces this follow-up period. All these factors lead to a short follow-up period, which undoubtedly does not bring out all of the causes of failure. Finally, we performed no complementary osteosynthesis of the pelvis in stage IV patients, considering that fixation was ensured by the cage, which joined the iliac wing and the ischium. The durability of this assembly must be confirmed with time given the limited follow-up period in this study.

Conclusions

The advantages of acetabular revisions with antiprotrusio cages and the value of dual mobility cups were evaluated separately in terms of quality of fixation and prevention of instability. This study is the first to confirm the value of associating these two concepts for THA acetabular revisions with severe bone loss. It confirms the validity of the association of these two methods in the management of severe bone lesions, giving a limited dislocation rate without creating a harmful effect in terms of fixation.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


