Acetabular Reconstruction Using a Kerboull Cross-Plate, Structural Allograft and Cemented Dual-Mobility Cup in Revision THA at a Minimum 5-Year Follow-Up

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ABSTRACT

The current study aimed to evaluate the outcome of a continuous and prospective series of 61 revision THAs with AAOS grade III and IV acetabular bone defect reconstruction using a Kerboull cross-plate, structural allograft and cemented dual mobility cup (Saturne, Amplitude, Valence, France). At a 7.5-year mean follow-up, no instability was reported after revision. In addition, no failure of the acetabular reconstruction was observed in 98% of the patients with complete allograft osseointegration and no evidence of mechanical rupture of the Kerboull cross-plate and/or loosening of the cemented dual mobility cup. In conclusion, such reconstruction technique demonstrated excellent results at mid-term follow-up in terms of prevention of instability after revision, restoration of the acetabular bone stock, and stable cemented fixation of the dual mobility cup.

Revision total hip arthroplasty (THA) exposes to two major challenges on the acetabular side particularly when reconstruction of severe acetabular bone defect (i.e. grade III and IV of the American Academy of Orthopaedic Surgeons (AAOS) classification) is required [1,2]. The first challenge is related to the acetabular bone stock restoration and the fixation of the acetabular component [1,2]. The second challenge is related to the prevention of THA instability after the revision procedure [3,4]. Indeed, aseptic loosening and periprosthetic infection, instability remains the leading cause of mechanical failure of revision THAs accounting for up to 35% of these failures [3,4]. Kerboull et al described an original technique for AAOS grade III and IV acetabular bone defect reconstruction using a so-called Kerboull acetabular reinforcement cross-plate associated with structural allograft for segmental defect reconstruction and morcelized allograft for filling cavitory defects [5]. The tenets of this technique were to restore an anatomic size and situation of the acetabulum as well as an anatomic center of rotation of the hip [5]. Although excellent survival rate over 92% at 13-year follow-up using mechanical failure as end-point has been reported with cementation of all-polyethylene acetabular components into the Kerboull cross-plate, previous series reported dislocation rates as high as 6% at less than 2-year follow-up and up to 9.5% at 5-year follow-up [5–9]. Other series largely reported the dramatic value and effectiveness of dual mobility acetabular components to prevent and/or to treat instability after revision THA with survival rates up to 96% at 15-year follow-up and restoration of THA stability in more than 95% of the operated patients [10–16]. However, no continuous series to our knowledge prospectively reported the use of dual mobility cups associated with such a construct to reduce the risk of instability after revision THA.

The current series prospectively evaluated at a 5-year minimum follow-up the outcome of revision THA with AAOS grade III and IV acetabular bone defect reconstruction using the Kerboull’s technique with cementation of a dual mobility acetabular component into the Kerboull cross-plate. The purpose of this study was to demonstrate that our technique could combine the excellent mechanical survivorship provided by the original Kerboull’s technique to the effectiveness of dual mobility cup to prevent instability. We hypothesized that such a reconstruction could prevent the risk of instability after THA revision while restoring the acetabular bone stock and ensuring a stable fixation of dual mobility cup.

Patients and Methods

From April 2001 to October 2007, a continuous series of 85 patients (85 hips) who have undergone a revision THA associated with an acetabular reconstruction using a Kerboull cross-plate, structural allograft and cemented dual mobility acetabular component for severe acetabular bone defect (i.e. grade III and IV of the AAOS classification) was prospectively included in our institutional Total Hip Arthroplasty (THA) registry.
Joint Registry. At a minimum follow-up of 5 years, 8 patients were lost to follow-up and 11 patients died of causes that were unrelated to the revision THA. However, for these patients, no instability event or reoperation for mechanical failure of the acetabular reconstruction was reported at a 2.3-year mean follow-up (range: 0.2–4.3 years). One of the deceased patients presented a periprosthetic infection 2 months after the revision and required a Girdlestone procedure since multiple surgical lavages and debridements were unsuccessful. In addition, 5 patients were followed up elsewhere due to geographical distance with our institution. Although no instability or mechanical failure of the acetabular reconstruction was reported during a telephone interview at a 4.9-year mean follow-up (range: 2–7.7 years), none of these 5 patients was included in the current series since the authors were unable to perform the clinical evaluation and to obtain radiographs at latest follow-up. Therefore, a continuous and prospective series of 61 patients (32 women and 29 men) was included and analyzed in the current study. The exclusion criteria were reconstructions performed in the case of pelvic tumors, irradiated hips, history of acetabular fracture or reconstructions performed with a different acetabular reinforcement device (e.g., Burch-Schneider device) and/or using additional internal fixation of the posterior column of the acetabulum and/or bone autograft. Owing to the French regulation, informed consent of the patients was not required to be included in this study. The mean age at the time of the revision was 67 ± 10 years and the mean BMI was 26 ± 9 kg/m². Indications for index revision THAs are reported in Tables 1 and 2. In 57 patients (93%), no revision surgery had been previously performed. Four patients (7%) had undergone one previous revision: for instability in 2 cases, for recurrent periprosthetic infection in 1 case, and for aseptic loosening of the cup related to polyethylene wear in 1 case. The overall mean time between the index and revision THAs was 14 ± 9 years.

All revisions were performed through a posterolateral approach under general anesthesia by two experienced surgeons at our institution. Both acetabular and femoral components were revised in 48 hips (79%) and only acetabular component was revised in 13 hips (21%). The revised acetabular component was a cementless metal shell in 32 hips (52%), a cemented all-polyethylene cup in 27 hips (44%), a McKee-Farrar metal-on-metal component in 1 hip (2%) and a dual-mobility cup cemented in the bony acetabulum in 1 hip (2%). After fibrous and granulation tissue debridement, the acetabular cavity was cleaned with pulsatile irrigation. No reaming of the cavity was performed in order to preserve the residual bone stock. Then, the severity of acetabular bone loss was graded according to the AAOS classification and the bone deficiencies were located in order to prepare the reconstruction. The acetabular bone defect was graded AAOS type III in 54 revisions (89%) and AAOS type IV in 7 revisions (11%). The acetabular reconstruction was systematically performed using a Kerboull cross-plate made of 316L stainless steel associated with a structural allograft made of a cryopreserved femoral head according to the technique described by Kerboull et al [Fig. 1A–D] [5]. Cavitary defects were grafted with morselized allograft made of the remaining of the femoral head. Then, a M3ONW dual-mobility cup (Saturne, Amplitude, Valence, France) was cemented into the Kerboull cross-plate with a particular attention to ensure a 2- to 3-mm uniform thickness of the cement mantle (Fig. 1D) [17]. Polymethylmethacrylate bone cement with 0.5 g of active gentamicin (Palacos R+G, Heraeus Medical GmbH, Wehrheim, Germany) was used. The mean diameter of the Kerboull cross-plate was 54 mm (range: 48–64 mm). The mean diameter of the dual-mobility cup was 52 mm (range: 44–60 mm). Post-operative structured physical therapy with passive and active motion exercises of the hip was begun the day after surgery and continued during the hospitalization. Patients were allowed to walk using two crutches or a walker with partial weight bearing on the operated limb during 6 weeks post-operatively and full weight bearing thereafter.

Patients returned for post-operative follow-up visits at 6 weeks, 3 months, 6 months, 1 year and yearly thereafter. Patients underwent a physical examination by the operating surgeon and anteroposterior and lateral radiographs of the pelvis and the operated hip were obtained. The radiographs at 6 weeks were considered as baseline radiographs for follow-up comparison. Clinical evaluation was performed using the Harris hip score. Instability defined as a dislocation and/or a subluxation perceived by the patient was systematically evaluated. Baseline and latest follow-up radiographs were compared for radiological evaluation. The abduction angle of the cup was measured on the baseline and latest follow-up AP radiographs with respect to the landmarks of the teardrop line and the long axis of the projected ellipse of the face of the cup. The presence and progression of radiolucent lines according to the zones described by DeLee and Charnley were evaluated [18]. Definite loosening of the dual-mobility cup was defined as a cup migration or angular rotation exceeding 3 mm or a continuous radiolucent line wider than 2 mm [18]. Osseointegration of the allograft was assessed using the criteria of Conn et al and was defined as similar density of the allograft and host bone with continuous trabecular pattern throughout the graft-host bone junction [19]. The location of the allograft resorption was recorded if occurred. Clinical failure of the acetabular reconstruction was defined as occurrence of instability. Radiographic failure of the acetabular reconstruction was defined as a failure of Kerboull cross-plate (i.e.; rupture of the hook and/or the cross itself) and/or a definite loosening of the cemented dual-mobility cup and/or a resorption of the allograft.

Data are presented as mean ± SD. Comparison of preoperative and last follow-up continuous variables was performed using Student’s t-test with a level of significance set at P < 0.05. Statistical analyses were performed using SPSS 16.0 (IBM Corp., Armonk, NY, USA).

**Results**

The mean follow-up of the series was 89 ± 23 months (range: 60–138 months). The mean Harris hip score improved significantly from 53 ± 19 before the revision to 79 ± 13 at the time of the latest follow-up (P < 0.001) (Table 3). Particularly, improvement was significant for patients’ perceived pain, function and mobility (P < 0.001–0.027) (Table 3). At latest follow-up, 43 patients (70%) had no or slight and occasional pain without compromise in activity. Importantly, no instability (i.e.; dislocation and/or subluxation) has been reported during the patient’s clinical evaluation. No intra-operative vascular or neurologic injury was reported with the use of

![Table 1](https://example.com/table1.png)

<table>
<thead>
<tr>
<th>Underlying Disease</th>
<th>Number of Hips</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip osteoarthritis</td>
<td>45</td>
<td>74%</td>
</tr>
<tr>
<td>Femoral neck fracture</td>
<td>6</td>
<td>10%</td>
</tr>
<tr>
<td>Developmental dysplasia of the hip</td>
<td>5</td>
<td>8%</td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>Paget's disease of bone</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>1</td>
<td>2%</td>
</tr>
</tbody>
</table>

![Table 2](https://example.com/table2.png)

<table>
<thead>
<tr>
<th>Indications for Revision THA</th>
<th>Number of Hips</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aseptic loosening of both components</td>
<td>28</td>
<td>46%</td>
</tr>
<tr>
<td>Periprosthetic joint infection</td>
<td>12</td>
<td>20%</td>
</tr>
<tr>
<td>Aseptic loosening of the cup</td>
<td>10</td>
<td>16%</td>
</tr>
<tr>
<td>Instability</td>
<td>9</td>
<td>15%</td>
</tr>
<tr>
<td>Femoral periprosthetic fracture (Vancouver B2)</td>
<td>2</td>
<td>3%</td>
</tr>
</tbody>
</table>
this acetabular reconstruction technique. Four significant postoperative complications occurred unrelated to the revision procedure: 1 case of deep hematoma requiring surgical drainage two days after surgery, 2 cases of mechanical rupture of a femoral modular revision stem requiring femoral revision at 51 and 59 months postoperatively, and 1 case of periprosthetic femoral fracture (Vancouver C) requiring open reduction internal fixation with plating at 73 months postoperatively.

At the radiographic evaluation, there was no significant difference in cup abduction angle at 6 weeks and at latest follow-up indicating that there was no implant migration (46.7 ± 5.6° vs. 46.3 ± 6.1° respectively, P = 0.729). At latest follow-up, no mechanical failure of the Kerboull cross-plate and complete osseointegration of the allograft were observed in 60 of the 61 acetabular reconstructions (98%) (Fig. 1D). Fifty-eight acetabular reconstructions (96%) presented no radiolucent line around the cemented dual-mobility cup and 1 (2%) presented a non-progressive and less than 1 mm radiolucent line in zone III. Mechanical failure of the acetabular reconstruction occurred in 1 case (2%) 62 months after the revision (Fig. 2A–D). In this case, the index THA was implanted for a femoral neck fracture in a 62-year-old woman and consisted in a cementless metal-on-polyethylene THA. Aseptic loosening of the cup due to polyethylene wear occurred 12 years after the index procedure (Fig. 2A). A first acetabular revision with cementation of a dual mobility cup directly into the bony acetabulum was performed and failed at 13 months with aseptic loosening of the cemented cup (Fig. 2B). Then, a second revision with acetabular reconstruction for AAOS grade III bone defect using a Kerboull cross-plate, structural allograft and cemented dual mobility cup into the cross-plate was performed (Fig. 2C). However, 2 major technical errors were committed during this procedure leading to a failure of the acetabular reconstruction 62 months after the revision (Fig. 2D). First, the Kerboull cross-plate was not tensioned enough as recommended in the surgical technique described by Kerboull et al [5]. Indeed, the three 4.5-mm screws for iliac fixation of the cross-plate above the acetabulum did not put the plate in compression against the pelvic bone and then, even if the inferior hook was properly inserted beneath the teardrop, screwing did not permit enough tensioning of the structure leading to a rupture of the central part of cross and of the hook. Second, the centers of rotation of the Kerboull cross-plate and of the dual mobility cup were not overlapped due to the cementation of a too small dual mobility cup into the cross-plate. Therefore, stress transmission into the construct was not uniform particularly at the dual mobility cup/cement mantle interface leading to an eccentric overstress of the cement mantle resulting in loosening and migration of the cemented dual mobility cup.

**Discussion**

Combining technical difficulties related not only to the reconstruction of severe bone defects and the fixation of the acetabular component but also to a high risk of instability, revision THA remains a challenge particularly in the cases of AAOS grade III and IV acetabular...
bone defect [1,2]. The current series reported our experience of an original acetabular reconstruction technique in such complex cases using a Kerboull cross-plate, femoral head allograft and cementation of dual mobility acetabular component into the cross-plate (Saturne, Amplitude, Valence, France). To the best of our knowledge, no continuous and prospective series in the literature reported the results of such a reconstruction technique with the use of a cemented dual mobility cup [6–12]. At a mean follow-up of 7.5 years, no instability was reported after revision THA. In addition, no failure of the acetabular reconstruction was observed in 98% of the patients with complete osseointegration of the allograft and no evidence of mechanical rupture of the Kerboull cross-plate and/or loosening of the cemented dual mobility cup (Fig. 1D). However, one case (2%) of rupture of the Kerboull cross-plate associated with a definitive loosening of the cemented dual mobility cup was reported 62 months after the revision (Fig. 2A–D). Nevertheless, this mechanical failure was potentially related to two major technical errors with a non-optimal tensioning of the Kerboull cross-plate and an undersized dual mobility cup cemented eccentrically into the cross-plate resulting in un-overlapped centers of rotation responsible for a non-uniform transmission of mechanical stress into the reconstruction (Fig. 2A–D). Therefore, our series confirmed and strengthened the encouraging early results reported by Langlais et al and Hamadouche et al with survival rates up to 96% at 3- to 4-year follow-up without instability or aseptic loosening with the cementation of a dual mobility cup directly into the bony acetabulum or a Kerboull cross-plate during revision THA [11,12]. However, as illustrated in the reported case of failure, we definitely do not recommend cementing the dual mobility cup directly onto the bony acetabulum since major concerns have been raised in the literature that poor results in terms of implant fixation at short-term follow-up can be expected with metal shells directly cemented onto the bony acetabulum [20,21]. In addition, contrary to instability rates as high as 9.5% at 5-year follow-up reported with the cementation of all-PE components into the Kerboull cross-plate, no case of instability was reported in our series highlighting the dramatic effectiveness of dual mobility in term of prevention of instability after revision [10–16].

The use of four major reinforcement devices for acetabular reconstruction during revision THA has been reported in the literature including Kerboull cross-plate, Burch-Schneider anti-protrusio cage and, Ganz and Muller reinforcement rings [2,22]. In a biomechanical study based on finite element modeling of load dispersion into a simulated acetabular reconstruction using a Kerboull cross-plate, Kawanabe et al demonstrated that, contrary to the 3 others reinforcement devices, high stress areas were localized in part of the hook and the bend of the plate but not on the inner side of the device thereby discharging mechanical stress applied onto the load-bearing defects localized at the dome of the cemented acetabular component as well as onto the structural and morselized allografts [22]. Therefore, allografts could be protected from high stresses during the osseointegration process preventing their collapse [22]. In addition, the unique property of load dispersion interface provided by the Kerboull cross-plate makes viable the cementation of metal shells with high modulus of elasticity (~200 GPa) onto the bone reconstruction without the potential concerns of early failure reported with the direct cementation of metal shells onto the bony acetabulum [20,21]. The results of this biomechanical study explained the discrepancies in clinical results observed with the use of these four major acetabular reinforcement devices. Kerboull et al reported survival rate over 92% at 13-year follow-up with use of the Kerboull cross-plate [5,22]. Indeed, this result could be explained by the tenets of the Kerboull’s technique. Placed with a 45° abduction angle the hook inserted beneath the teardrop, the Kerboull cross-plate allows to define the size and shape of the allograft required for the acetabular bone stock reconstruction and automatically restores an anatomical size and location of the acetabulum as well as an anatomical center of
rotation of the hip and gluteus medius lever arm theoretically decreasing the risk of acetabular component loosening [5,8,10]. Moreover, placing the acetabular component at the correct anatomical position decreases the risk of impingement and dislocation [5,23]. Additionally, a reconstruction may benefit any future revisions since structural and morselized allografts restore the acetabular bone stock [5,23]. However, cases of aseptic mechanical failure of the acetabular reconstruction reported by Kerboull et al were all due to a partial or complete resorption of the allograft [5]. Poor quality of the bone stock restoration with inadequate volume and impaction of the allograft accounted for these failures [5]. In contrast, Zehntner and Ganz reported survival rate less than 80% at 10-year follow-up of acetabular reconstructions using a Muller reinforcement ring and emphasized the need to associate systematically an additional internal fixation by plate and screws in the cases of AAOS grade III and IV acetabular bone defect [24]. In addition, Muller reinforcement ring can be only screwed proximally to the pelvic bone and probably did not prevent enough allograft from being overstressed during their maturation process [5,22,24]. Using a Ganz reinforcement ring i.e. a modified Muller reinforcement ring with a hook to be inserted beneath the teardrop, Gerber et al reported similar results with a survival rate of 81% at 10-year follow-up and concluded that this reinforcement device may not be optimal for reconstruction of segmental acetabular bone defects of the medial wall or in case of pelvic discontinuity [25]. Finally, Regis et al reported a survival rate of 87.5% at 12-year follow-up of major acetabular bone defect reconstruction with the use of a Burch-Schneider anti-protrusio cage [26]. However, this technique is highly demanding and requires a wide exposure of the ischium to place the inferior flange [26,27]. This could be at risk of sciatic nerve injury if the inferior flange is screwed to the ischium or obturator nerve injury if the inferior flange is slotted into the ischium [26,27]. In our experience, we recommend the use of a Burch-Schneider anti-protrusio cage only in case of severe pelvic discontinuity that cannot be reconstructed with a Kerboull cross-plate associated to an additional internal fixation by plating of the posterior acetabular column.

The use of cementless porous-coated jumbo cups has been also reported for revision THA with AAOS type III bone defects, and could constitute a straightforward technique for acetabular reconstruction with reported survival rates up to 92% at 14-year follow-up [28–30]. However, Whaley et al and Patel et al reported that revision failures due to acetabular aseptic loosening at mid-term follow-up were essentially encountered in AAOS type III bone defects [29,30]. In addition, using this technique, rates of instability as high as 21% have been reported after revision [28]. Therefore, the use of cementless jumbo cups remains highly controversial and probably not recommended in AAOS type III bone defects, and does not permit to manage AAOS type IV bone defects with pelvic discontinuity even with complementary screw fixation. Other authors reported the use of custom triflange acetabular components to manage AAOS type III and IV acetabular bone defects during revision THA [31,32]. Triflange cups consisted in a custom-designed titanium porous- and/or hydroxyapatite-coated implant with ilial, ischial and pubic flanges. The flanges allow for intimate contact between the implant and the host bone for initial stability while returning the hip center of rotation to its anatomical location. Although excellent results have been reported with low rates of component aseptic loosening at mid-term follow-up, the use of triflange cups remains a costly procedure, requires time of preparation by the manufacturer, and series reporting their long-term outcome are still sparse [31,32]. In addition, rates of instability as high as 25% have been reported, mainly due to the large dissection required to insert this implant, contrary to a Kerboull cross-plate, with possible extensive muscular damages and stretch injury to the superior gluteal nerve from iliac flange placement [31]. Reconstructions using modular trabecular metal implants with hemispherical revision shells and augments represent another validated option to manage AAOS type III and IV bone defects [33–35]. The acetabular defect is progressively sized with hemispherical reamers in the desired location to define the dimension of the cavity until two points of fixation are achieved. Augments of various size and shape could be used to decrease the acetabular volume and to restore a rim to support the revision shell. Then, modular trabecular metal components are secured to the host bone with multiple screws and unitized with bone cement. Additionally, whether the residual bone stock is deemed insufficient to achieve stability of the construct and/or in case of pelvic discontinuity, a so-called “cup-cage” reconstruction could be performed using an anti-protrusion ilio-ischial cage spanning the acetabular defect [36]. Although promising results at short- to mid-term follow-up have been reported with survival rates of 87% to 99.2%, long-term follow-up is necessary particularly regarding the major concern raised by the management of potential periprosthetic infection when trabecular metal implant removal is required after bone ingrowth occurred [34,35]. In addition, high but equivalent costs of modular trabecular metal reconstructions and custom triflange components were reported between $11,250 to $14,500, and $12,500 respectively [34]. In contrast, the total cost of the acetabular reconstruction technique reported in the current study, including the dual mobility cup (Saturne, Amplitude, Valence, France), Kerboull cross-plate, 4 screws, bone cement with gentamycin, and femoral head allograft, was 1,800 Euros ($2,355) at our institution.

Our study presented with some limitations. First, clinical and radiological evaluations were not performed by an independent observer. Although our series was the largest reported in the literature using systematically the Kerboull’s technique associated to the cementation of a dual mobility cup into the cross-plate, our average patients’ follow-up was less than 10 years. In addition, there was no comparison group for the acetabular reconstruction device used or for the acetabular component cemented into the cross-plate. Particularly, the cementation of a constrained liner into the Kerboull cross-plate was not comparatively evaluated. However, concerns have been raised in the literature regarding the use of constrained liners with mechanical failure rates up to 42.1% at 10-year follow-up [37,38]. These major limitations should temper our conclusions regarding the other reconstruction techniques reported in the literature. Particularly, further studies should be designed to prospectively compare acetabular reconstructions using these reinforcement devices to acetabular reconstruction using implants made of porous tantalum. In conclusion, reconstruction of AAOS grade III and IV acetabular bone defect using a Kerboull cross-plate, structural allograft of femoral head and cemented dual mobility cup during revision THA demonstrated effectiveness to prevent instability with no reported dislocation and/or subluxation event, and excellent results in terms of restoration of the acetabular bone stock and stable cemented fixation of the dual mobility cup with a survivorship of 98% at a 7.5-year mean follow-up using mechanical failure as end-point. Therefore, the use of a cemented dual mobility cup in conjunction with the Kerboull’s technique minimized postoperative hip instability and did not have any adverse impact on the longevity and durability of acetabular defects reconstructed using this technique.

References


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