ORIGINAL ARTICLE

Do tantalum components provide adequate primary fixation in all acetabular revisions?

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Summary
Introduction: A number of studies have reported favorable results of cementless fixation in acetabular revisions. Nevertheless, the implant bearing on more than 50% of the patient’s bone and good primary stability are required. The objective of this study was to determine whether the use of tantalum implants could provide stable reconstruction for any type of acetabular revision.

Patients and methods: This study investigated 72 hips (71 patients) implanted with tantalum cups, some with augments, and morselized graft material. The mean age was 60 years (range, 34—84 years). There were 30 males and 41 females. The mean weight was 71 kg (range, 52—102 kg), the mean height was 1.68 m (range, 1.52—1.84 m). Twenty-five revisions were bipolar. Six revisions were performed for infected acetabular loosening. The mean follow-up was 4 years (range, 2—6 years).

Results: The mean Merle d’Aubigné score at follow-up was 15.8 points (range, 9—18 points). According to the Paprosky classification of acetabular bone defects, there were 13 type 1 (18%), 14 type 2A (19.5%), 14 type 2B (19.4%), 23 type 3A (31.9%), and eight type 3B (11.2%) acetabular defects, four of which had pelvic discontinuity. Postoperatively, the position of the hip’s center of rotation in relation to Köhler’s teardrop was 22 mm (range, 5—41 mm) vertically (normal, <25 mm) and 39 mm (range, 13—55 mm) horizontally (normal, <35 mm). The mean acetabular inclination was 40◦ (range, 20◦—63◦). The radiographic analysis found no radiolucent line after 1 year and up to the last follow-up. None of the patients required revision for acetabular loosening. Three hips were revised for instability. Two retentive liners and a dual-mobility cup were cemented in the cups that were left in place.

Discussion and conclusion: Given their mechanical properties (coefficient of friction, porosity), tantalum implants provide a stable primary cementless fixation without compromising the...
Introduction

The technical choices for acetabular reconstruction in revision hip arthroplasty continue to be debated. Cementless fixation provides satisfactory results, but in cases where there is substantial bone substance loss, it is not always possible to obtain primary stability, the guarantee of secondary biological fixation [1–3]. It seems to be accepted that below 50% weightbearing of the cementless implant on the patient’s bone, it is not possible to use primary hemispheric implants. Several options are possible in these cases: using bilobed cups [4], cups implanted with high placement [5,6], or jumbo cups [7]. Another option is to opt for a cemented fixation associated with a reinforcement ring, but the generally favorable results at the short and long terms are not consistently observed, because they are highly dependent on the technical skill of the operator and the quality of the associated graft [8–11].

The characteristics of tantalum and its applications in orthopaedic surgery have been the subject of recent publications. This biomaterial possesses a structure and mechanical properties that are close to trabecular bone with a biocompatibility comparable to that of titanium with porosity on the order of 80% [12–14]. In hip arthroplasty, these properties are intended to be an ideal substitution for bone, with effective distribution of stresses and good osteointegration. Tantalum implants dedicated to acetabular revision are available with material that can fill structural bone loss, as observed intraoperatively, and recent studies have reported encouraging short-term results [15–18].

The objective of the present study was to determine whether the use of tantalum would allow stable cementless reconstruction for any type of acetabular bone loss.

Patients and methods

Patients

Seventy-two hips (71 patients) implanted with tantalum cups by two operators at acetabular revision were included in a multicenter retrospective study. The mean age was 60 years (range, 34–84 years). There were 30 males and 41 females. Their mean weight was 71 kg (range, 52–102 kg); the mean height was 1.68 m (range, 1.52–1.84 m). A total of 39 right sides and 33 left sides were operated. Twenty-five revisions (34.7%) were bipolar. Six revisions (8.3%) were performed for septic acetabular loosening (in two operations). The mean number of revisions per patient was 1.9 and 51% had already had at least one revision before the intervention. The mean follow-up was 4 years (range, 2–6 years).

Prosthesis components

The tantalum revision acetabular implants (Trabecular Metal™ Modular Acetabular System, Zimmer; Warsaw, IN, USA) exist in several versions but with a single set of ancillary instruments. Three-holed cups (the modular cup) or eight-holed cups (the multi-holed cup) in which a highly reticulated, modular polyethylene liner are available for revisions in a wide range of diameters (22, 28, 32, or 36 mm) and heights (with or without 10° elevated). A cup in which the insert can be cemented (acetabular shell) as well as a Burch-Schneider reinforcement ring are also available. Augments to fill structural bone loss are available in three heights (10, 20, or 30 mm), corresponding to the cup’s external diameter (Fig. 1).

Operative technique

At the preoperative workup, all patients had a bone scintigraphy examination to diagnose any femoral loosening when this did not show up radiographically and a biological workup (whole blood count, C-reactive protein, and sedimentation rate) to search for any infectious cause of the implant failure. In all cases, several samples were taken intraoperatively before antibiotic prophylaxis. The Watson-Jones anterolateral approach was used, with the patient in the dorsal decubitus position, or the posterolateral approach when the approach to the posterior column or a femorotomy seemed necessary in view of the preoperative plan. When the posterior approach was used or femorotomy was planned, a large-diameter prosthesis head was used if possible, depending on the implanted cup diameter, to limit the risk of instability. The cup was positioned after the obturator foramen was located, so as to restore the center of rotation as closely as possible. Minimal primary stability was essential with the trial cup requiring three-point bearing, preserving the posterior column as far as possible during reaming. Stability was deemed satisfactory when it allowed reduction of the trials to evaluate stability and the length of the lower limbs and was acceptable when it was not jeopardized by moderate finger pressure. Ensuring primary stability may require augments. In this case, the augment was chosen to match the external diameter of the cup and the height of the bone loss (Fig. 2). The final augment was then screwed in place, with the trial cup in place. The augment was filled with cancellous bone collected from the reamings or using morselized allograft if necessary. To create a monoblock construction, the interface between the augment and the cup was cemented and the final cup, identical in size to the trial cup, was impacted and screwed in place. Postoperatively, weightbearing was authorized with...
crutches, following the same protocol as in primary arthroplasty.

**Radiological and clinical evaluation**

The Postel Merle d’Aubigné [19] (PMA) score was used before surgery and at follow-up for the clinical assessment. Any operative or postoperative complications (infection, neurological complications, or dislocation) were recorded. The radiological analysis was done on AP pelvic x-rays and AP and lateral hip images pre- and postoperatively and at follow-up. The Paprosky et al. [20] classification was used to classify acetabular bone loss. The postoperative examination measured cup inclination (considered normal between 40° and 50°) as well as the horizontal and vertical position of the center of rotation in relation to the teardrop line according to the Hirakawa et al. [21] criteria (normal, < 35 and 25 mm, respectively). The presence of non-contact zones between the cup and bone as well as the presence of evolving radiolucent lines in the three DeLee and Charnley [22] zones.

**Figure 1** Multi-holed tantalum acetabular shell associated with an augment.

**Figure 2** Reconstruction of a hip classified 2A, patient in supine position. a: superior bone loss after implant ablation and successive reaming; b: after having chosen the trial augment, the final augment is maintained by testing the cup and then screwed in place; c: The augment is then filled with cancellous bone; d: the cup is impacted, screwed in place. The liner is then put in place.
Table 1  Relation between acetabular bone loss according to Paprosky and distribution of implants.

<table>
<thead>
<tr>
<th>Paprosky</th>
<th>Implant (%)</th>
<th>Cup</th>
<th>Augment</th>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>MH</td>
<td>AS</td>
</tr>
<tr>
<td>Stage 1</td>
<td>13 (18)</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>14 (19.5)</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>2B</td>
<td>14 (19.4)</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Stage 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3A</td>
<td>23 (31.9)</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>3B</td>
<td>8 (11.2)</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
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M: Modular cup; MH: multi-holed cup; AS: acetabular shell; BS: Burch-Schneider.

was analyzed. Stability of the acetabular component was evaluated according to Zicat et al. [23], which considers the implant to be loosened when there is a uniform radiolucent line greater than 1 mm in the three De Lee and Charnley zones [22] and to be migrated when it has changed position by more than 3 mm or 8° [24]. All these measurements were taken in relation to the known diameter of the femoral head.

The results are expressed as means and standard deviations. The chi-square and Student t-tests were used for continuous variables to search for a possible influence of clinical or radiological factors on implant loosening or migration. A p < 0.05 value was considered statistically significant.

Results

The mean PMA score increased from 8.3 points (range, 4—11) before surgery to 15.8 points (range, 9—18) after surgery (p = 0.02). According to the Paprosky classification [20], there were 13 type 1 (18%), 14 type 2A (19.5%), 14 type 2B (19.4%), 23 type 3A (31.9%), and eight type 3B (11.2%) acetabular defects, four of which showed pelvic discontinuity (Table 1). The mean cup diameter was 59 mm (range, 52—80 mm). The three- or eight-hole modular cup was used in 59 implantations (81.9%), the acetabular shell in 12 cases (16.7%) (Fig. 3), and the Burch-Schneider reinforcement device in one case (1.4%). This last case was stage 3B with pelvic discontinuity (Fig. 4). The cases of pelvic discontinuity were treated in distraction by the implant, with no osteosynthesis material or additional grafting. No structural allografting was done, but in 14 cases (19.4%) augments were used, ten in the superior position and four in the superior and inferior positions. The postoperative center of rotation position was 22 mm (range, 5—41 mm) vertically and 39 mm (range, 13—55 mm) horizontally and considered normal in 87% of the cases. The mean cup inclination was 40° (range, 20—63°) and considered normal in 84% of the cases.

Eleven hips (15.3%) showed radiolucent lines in the three DeLee and Charnley zones [22]. Eight resolved during the 1st year and three hips (two stage 3A and one stage 3B) had a radiolucent line that did not evolve, with no clinical or radiological signs of migration or loosening. No repeated loosening or migration was noted. None of the patients

Figure 3  Reconstruction of a stage 2B hip. a: preoperative pelvic X-ray. The center of rotation is raised 19 mm; b: postoperative pelvic X-ray at 25 months showing recentering of the hip using a three-holed modular cup and an augment.
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Figure 4 Reconstruction of a stage 3B hip with intraoperative discovery of pelvic discontinuity. a: preoperative X-ray showing pronounced wear of the polyethylene liner and acetabular osteolysis; b: radiograph at 18 months of follow-up of the Burch-Schneider reinforcement device in tantalum, with the lower flange impacted in the ischium.

required revision for acetabular loosening. Three hips (4.2%) were revised for recurring instability. Two retentive liners and one dual-mobility cup were therefore cemented in the properly fixed cups. One case of early infection (1.4%) was treated with lavage and adapted antibiotic therapy. No neurological complications were found.

Discussion

Loosening of an acetabular cup is accompanied by such osteolysis that it can lead to the destruction of the acetabulum. The use of an impacted, screw-fixation cementless cup has shown its efficacy and for many authors is the leading solution [1,2,3,25]. Nevertheless, primary stability is sometimes difficult to obtain, particularly in cases of substantial bone loss. During revision, the surgeon may therefore need to make a choice: either reposition the cup near the center of rotation and fill in any bone loss, sometimes requiring cemented fixation and reinforcement, or opt for biological cementless fixation sometimes requiring fixing the cup in place on the residual acetabular bone. However, whereas cavitary bone loss can be filled by an allograft associated with an impacted cementless screw fixation with satisfactory results [26,27], filling with structural allograft can compromise the biological fixation of a cementless implant when the weightbearing on the patient’s bone is less than 50% [28].

In this study, 41 hips (56.9%) were Paprosky stage 1 or 2, in which cup–bone contact is classically greater than 50%. In these cases, primary implant stability is usually obtained with an impacted screw-fixation cementless cup; the advantage of tantalum cups is not clearly defined in this context. Nevertheless, the clinical and densitometric effects related to the elastic properties of the biomaterials have been debated in the literature, showing that there is poor distribution of stresses, or stress-shielding, related to the stiffness of the metallic cups, leading to a reduction in the acetabular bone mass, which can complicate future revision over the long term [29]. Use of tantalum provides a better transfer of loads given its greater physiological elasticity (3 GPa) [30]. This is comparable to the elasticity of subchondral bone and closer to the physiological data than to the elasticity of titanium (110 GPa) or chrome–cobalt (205 GPa). Tantalum implants have also been designed to prevent stress peaks through focal contact in the bone–implant interface’s peripheral zone, as has been found with materials that are more rigid than bone [31].

In addition, 31 hips (43.1%) were Paprosky stage 3, for which weightbearing of the implant on the patient’s bone is classically less than 50%. In these conditions, the biological fixation is uncertain, and cementless cups have been reported to have loosening rates as high as 70% at 5 years [32]. If cementless fixation is to be encouraged, cup bone coverage needs to be increased by positioning the cup in place on the residual acetabular bone [5,33] or using a large-diameter implant [7,34]. These techniques seem to give good results, but expose the patient to a risk of additional bone loss or prosthetic instability, particularly when the stem is not changed. The use of bilobed cups has also been described [4,35,36]. These techniques require preoperative knowledge of the type and location of bone loss, which is often difficult. The results obtained with these cups have been published with a 24% loosening rate (9/37 hips) at a mean follow-up of 41 months [35] and have progressively been abandoned. In the present study, primary stability was always obtained, while restoring the center of rotation position (mean, 22 mm vertically and 39 mm horizontally). This was possible because in 19.4% of the cases tantalum augment was associated with morselized graft, which allowed both filling the bone defect and cementless reconstruction.

Another option is to choose the fixation cemented with a ring along with a structural allograft, which has provided apparently satisfactory results [37]. The Kerboull reinforcement device is an option with good results reported on an original series of 60 hips with a mean follow-up of 10 years and mean 13-year survival of 92.1% ± 5% [38]. The Ganz ring is an alternative and Siebenrock et al. [38] reported only 8% failures in their series of 36 hips at a mean follow-up of 11.4 years. A recent study reported excellent results using...
the Burch-Schneider ring with 89.5% survival in a series of 87 hips at a follow-up of 5–21 years [39]. The results nevertheless seem to deteriorate if there is posterior or superior bone loss [40] and studies have shown loosening rates at a mean follow-up of 5 years reaching 12–29% [8,41]. Using an allograft associated with a cemented reinforcement ring, Morand et al. [10] observed 13% aseptic loosening at a mean follow-up of 7.3 years in a series of 48 hips and Bonnomet et al. [9] described 43% ± 1.6% survival at 10 years in a series of 56 hips.

Four hips (5.6%) presented pelvic discontinuity (SOFCOT stage 4 according to Vives [42]), all diagnosed preoperatively, demonstrating how difficult it is to classify these bone lesions preoperatively [43]. These lesions were treated in distraction, with no complementary osteosynthesis and retaining the choice of cementless fixation (three acetabular shells and one Burch-Schneider reinforcement device in tantalum). The results of these four hips do not differ from those of the overall series. In a study of 13 hips implanted with tantalum cups in this indication, Sporer and Paprosky [44] found possible loosening (7.7%) at a mean follow-up of 2.6 years, whereas the same authors describe seven failures in a series of 16 cases of pelvic discontinuity (43.8%) treated with graft and a cemented reinforcement ring at a mean follow-up of 5 years [44]. In our series, no cases of loosening, migration, or revision were observed, even if the mean follow-up was only 4 years. We believe that this is related to the mechanical and biological properties of tantalum. The coefficient of friction is better with tantalum than with microporous titanium and its porosity is on the order of 80%, which is significantly better than classical coatings. Unger et al. [16] analyzed how identical implants evolved during 60 acetabular revisions with a mean follow-up of 42 months and recorded one revision for loosening (1.6%). Nehme et al. [15] described the use of this type of component in 16 revisions with a mean follow-up of 31.9 months with no migration or revision.

This technology nonetheless raises questions that require longer follow-up for an adequate answer. In this study, 19.4% of the hips required filling structural bone loss using augments filled with morselized graft. Even though the motivation behind the use of this type of component is to extend the possibilities of cementless fixation, how should these augments be considered if implant ablation is necessary, particularly in cases of infection. The nearly 80% porosity of this material implies that it is in large part filled with the patient’s cancellous bone, once integrated, and today it is difficult to know to what extent it should be considered an inert foreign body.

Restoring the bone anatomy was possible for all types of bone loss. The center of rotation position was normal in 87% of the cases and the mean inclination was normal in 84% of the cases. Given their mechanical properties (coefficient of friction, porosity), the tantalum implants allowed stable, cementless primary fixation, without compromising the center of rotation or necessarily having to use a structural allograft. A single range of cementless implants is therefore usable for any type and severity of bone loss for all types of acetabular reconstruction. Nevertheless, other studies with a mean follow-up longer than 5 years seems necessary to confirm the stability of these implants over time.

Conflict of interest statement

JN Argenson: Conferences and occasional consulting for Zimmer. WG Paprosky: Conferences and occasional consulting for Zimmer. X. Flecher, JC Grillo, and JM Aubaniac: None.

References

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