The management of severe acetabular bone defects in revision hip arthroplasty using modular porous metal components

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We investigated the early results of modular porous metal components used in 23 acetabular reconstructions associated with major bone loss. The series included seven men and 15 women with a mean age of 67 years (38 to 81), who had undergone a mean of two previous revisions (1 to 7).

Based on Paprosky’s classification, there were 17 type 3A and six type 3B defects. Pelvic discontinuity was noted in one case. Augments were used in 21 hips to support the shell and an acetabular component-cage construct was implanted in one case. At a mean follow-up of 41 months (24 to 62), 22 components remained well fixed. Two patients required re-revision of the liners for prosthetic joint instability. Clinically, the mean Harris Hip Score improved from 43.0 pre-operatively (14 to 86) to 75.7 post-operatively (53 to 100). The mean pre-operative Merle d’Aubigné score was 8.2 (3 to 15) and improved to a mean of 13.7 (11 to 18) post-operatively.

These short-term results suggest that modular porous metal components are a viable option in the reconstruction of Paprosky type 3 acetabular defects. More data are needed to determine whether the system yields greater long-term success than more traditional methods, such as reconstruction cages and structural allografts.

The management of severe acetabular bone defects in revision total hip replacement (THR) is challenging. Porous-coated hemispherical acetabular components have been shown to yield good long-term results in patients with adequate bone stock,1-5 but in cases where the bone loss involves 30% to 50% of the host acetabulum, the results have been less impressive.5,6 Alternative techniques, such as those using acetabular reconstruction cages and structural allografts, have been poor, and has been attributed to the absence of true biological fixation and the lack of bone graft incorporation.7-11

Tantalum is a biomaterial with high volumetric porosity (70% to 80%), and a low modulus of elasticity. As such, it has the capacity to support bony ingrowth and biological fixation.12,13 It has been used in un cemented acetabular components, which have given excellent clinical results in both primary and revision cases.14-16 Tantalum augments have also been developed, and these have been used to reconstruct uncontained structural acetabular defects, just as structural corticocancellous bone allografts have been used in the past.11 The augments provide biological fixation and mechanical support for the adjacent acetabular shells. When used together, these components provide an alternative method of treatment for revision THR cases involving severe acetabular bone loss,12,17,18 even in cases of pelvic discontinuity.19

The purpose of this report is to describe the surgical technique used to implant these components and to evaluate our initial results using this system in patients with Paprosky type 3 acetabular bone defects.20

Patients and Methods
Between January 2003 and December 2006, the senior author (NB) carried out 24 acetabular reconstructions using tantalum porous metal components for 23 patients with a Paprosky type 3 bone defect. The classification of these defects was based on both pre-operative radiographs and intra-operative assessment. During this period, no patient with a Paprosky type 3 acetabular bone defect was treated in any other way. One patient died of an unrelated cause 14 months after the procedure, and was excluded from the study group as he did not fulfil the requirement of a minimum 24-month follow-up. This patient had been assessed clinically and radiologically one year post-operatively, and was functioning well, with no signs of implant migration or
loosening. This retrospective review was approved by the authors’ Institutional Review Board.

The final study group consisted of seven men and 15 women (23 hips). Of these, 16 had a Paprosky type 3A defect and seven had Paprosky type 3B defects. Of the seven Paprosky type 3B defects, one was associated with pelvic discontinuity. The mean age of the patients at the time of surgery was 67 years (38 to 81). The mean follow-up period was 41 months (24 to 62). No patient was lost to follow-up. The diagnosis at the time of initial hip replacement included degenerative osteoarthritis in 11 patients, rheumatoid arthritis in five, developmental dysplasia of the hip in four, Paget’s disease in one, and post-traumatic arthritis in one. There had been a mean of two (1 to 7) previous surgical procedures performed on the affected hip.

The primary indication for acetabular revision was aseptic loosening in 21 hips, second-stage reimplantation for infection in one, and periprosthetic fracture of the femur with pre-existing acetabular loosening in one. Of the 23 hips, 14 were revisions of cementless acetabular components, and nine of a cemented device. In total, 12 hips underwent isolated revision of the acetabular component while 11 had both the femoral and the acetabular components revised.

**Surgical technique.** The Trabecular Metal Acetabular Revision System (Zimmer, Warsaw, Indiana) was used in this study. The tantalum revision shell was used in all patients to revise the acetabular component. It consists of an elliptical hemispherical porous shell composed entirely of tantalum, except for the titanium insertion ring. The tantalum augments are shaped as part of a hemisphere. They come in various sizes to match the hemispherical acetabular component used, and can be 10 mm, 15 mm, 20 mm or 30 mm in height.

All operations were performed in a laminar flow theatre with the use of protective surgical helmets. A posterior approach was used in each case. Acetabular reconstruction began by removing the failed acetabular component and any fibrous tissue and cement. The segmental bone defect was then assessed. Conventional reamers of increasing diameter were used to shape the defect to a size constrained by the anterior and posterior acetabular walls. Trial acetabular components and modular augments were then placed within the acetabular cavity to determine the optimal augment configuration and size that would support the acetabular component.

The definitive acetabular augment was then screwed into place. Next, the acetabular component was inserted and a layer of cement placed only between the augment and the acetabular component. Further screws were then inserted through holes in the acetabular component to enhance the fixation. In 22 of the 23 cases additional screws were inserted through the rim of the acetabular component into the ischium, to further enhance fixation of the implant (Fig. 1). In order to do this, we had to make additional screw holes in the rim of the acetabular component with a high-speed burr. This was done at a side-table to avoid contamination of the operative field with metal debris.

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**Fig. 1a** Pre-operative radiograph of a 60-year-old woman with Paprosky type 3A acetabular defect. **Fig. 1b** Post-operative radiograph showing reconstruction with tantalum shell and augment. **Fig. 1c** Lateral view showing screw through rim of shell into ischium (arrow).
Morcellised cancellous bone allograft was then used to fill the fenestrations within the augment and the remaining cavitary bone defects in the acetabulum. No structural bone graft was used.

This shell-augment combination was used in 21 of the 23 hips; a shell alone was used in one hip, and an acetabular component-cage construct in another. In the latter case, there was pelvic discontinuity and a reconstruction cage was positioned inside the acetabular component to enhance its stability and fixation. The cage was secured with five screws in the ilium, and its inferior flange was embedded into the ischium.

A mean of 7.5 bone screws (5 to 10) were used for each acetabular reconstruction (Fig. 2), with a median of five screws inserted through the acetabular component (4 to 7) and a median of two screws inserted through the augments (0 to 5). The median diameter of the acetabular component was 64 mm (50 to 70) (Fig. 3). One augment was required in 19 hips and two in two hips. No augment was used in two hips. The mean augment size was 17.1 mm (10 to 30) (Fig. 4).

Once the trabecular shell and augment were secured, a highly cross-linked polyethylene liner was cemented into the revision shell. A standard liner was used in five hips, a liner with a 10° elevated rim in 15 hips and a constrained liner in three. The femoral head size was 22 mm in one hip, 28 mm in 13 hips, 32 mm in six, and 36 mm in three.

Post-operative rehabilitation included partial weight-bearing with the use of a walking aid for the first six weeks. Full weight-bearing was allowed thereafter. Patients stayed in hospital for a mean of 10.4 days (7 to 20).

Clinical and radiographic assessment. Clinical evaluation was performed pre-operatively, and at follow-up visits at six weeks, three months and annually thereafter. The clinical evaluation was recorded using the Harris Hip Score (HHS), and the Merle d’Aubigné score. Radiological evaluation was performed pre-operatively, at five days post-operatively, and at follow-up examinations at three months and annually thereafter. This consisted of a standard anteroposterior (AP) radiograph of the pelvis, and true AP and lateral radiographs of the proximal femur.

The pre-operative radiographs were examined to grade the acetabular defect according to the method of Paprosky et al. The Paprosky classification system is based on the presence or absence of an intact acetabular rim and its ability to support an acetabular component. With a type 1 defect, the acetabulum has an intact rim with no osteolysis or migration of the component. In type 2 defects, the rim of the acetabulum is distorted, but the anterior and posterior columns are intact and provide support. Radiographs also show < 2 cm of migration of the component, with minimal osteolysis of the ischium and teardrop. In type 3 defects there is severe bone loss with major destruction of the acetabular rim and supporting structure. Radiographs show superior migration of > 2 cm. These defects are further subdivided into two subcategories. In type 3A defects Kohler’s line is intact, whereas in type 3B defects Kohler’s line is no longer intact. Type 3B defects are often associated with destruction of the teardrop and extensive osteolysis of the ischium. All the patients in our study group had Paprosky type 3A or 3B defects identified pre-operatively.

Post-operatively the radiographs were examined for radiolucent lines in the three zones of the acetabulum described by DeLee and Charnley, and the acetabular component inclination angle was recorded. This was measured against a horizontal line connecting the bases of
had no pain. Post-operatively, 12 patients (13 hips) had no pain, and 10 patients needed both components revised. Operative and post-operative outcome scores were lower in the acetabular revisions with femoral revision. As expected, the pre-operative score improved to 13.7 (11 to 18). The mean Merle d’Aubigné score was 8.2 (3 to 15), and the mean pre-operative score improved to 75.7 (53 to 100). The mean pre-operative chance of 1 mm or larger radiolucent line in all three DeLee and Charnley zones, a change in the abduction angle of the acetabular component of more than 10°, or a change in the horizontal or vertical position of the acetabular component of > 5 mm.

Results

Clinical outcome. The mean pre-operative HHS was 43 points (14 to 86). Post-operatively, the mean HHS improved to 75.7 (53 to 100). The mean pre-operative Merle d’Aubigné score was 8.2 (3 to 15), and the mean post-operative score improved to 13.7 (11 to 18). The detailed results are shown in Table I. As expected, the pre-operative and post-operative outcome scores were lower in those who needed both components revised.

Pre-operatively, eight patients (nine hips) had severe pain, eight had moderate pain, four had mild pain, and two had no pain. Post-operatively, 12 patients (13 hips) had no pain, nine had slight pain and one had moderate pain. Pre-operatively, five patients did not require a walking aid, three needed a stick for long walks, and 12 needed full-time support with either a walking frame or crutches. Two patients were unable to walk pre-operatively. Post-operatively, eight could walk unaided, four needed a walking stick for long walks, and ten needed full-time support with either a walking frame or crutches. All patients were able to walk after surgery.

Pre-operatively, 15 patients had a severe limp and seven had a moderate limp. Post-operatively, six patients had no limp, ten had a moderate limp, and six had a severe limp. The mean pre-operative limb-length discrepancy was 1.9 cm of shortening (6 cm short to 1 cm long) on the affected side. Post-operatively, the mean limb-length discrepancy was 0 cm (5 cm short to 2 cm long).

Radiological outcome. Radiological loosening was noted in one of the 23 cases. This was manifested by a change in the acetabular component inclination angle of 18°. However, the patient remained pain free and did not undergo re-revision. The acetabular components in all of the other patients remained radiographically stable at the final follow-up review. The mean acetabular component inclination angle after reconstruction was 39.7° (21° to 75°). Post-operatively, the centres of the prosthetic femoral head were located at a mean vertical distance of 4.7 cm (2.8 to 6.0) above a horizontal line connecting the bases of the obturator foramina.

Radiolucent lines were noted in one of the 23 reconstructions. Radiographs of this patient showed the development of a radiolucent line in zone three years post-operatively. However, this radiolucent line remained stable and no further progression was noted at the three and four-year follow-up visits.

Complications. Nerve injuries occurred in three of 23 patients. The first patient developed a partial lesion of the sciatic nerve affecting the common peroneal division: this patient made a complete clinical recovery. The second patient developed sciatic nerve irritation from the inferior flange of a reconstruction cage used in an acetabular component-cage construct. She presented with severe buttock pain radiating to the posterior aspect of the thigh. She underwent exploration, removal of the flange and placement of an interpositional fat graft seven months after the initial revision. This resulted in partial resolution of her symptoms.

The third patient developed a complete sciatic nerve palsy 12 hours after surgery. She was taken back to the operating theatre for exploration, where the sciatic nerve was found to be under tension. The femoral component was shortened. At the most recent review three years post-operatively, she had mild neuropathic pain and a partial motor deficit.

Two of the 23 patients developed recurrent joint instability in the first post-operative year, and required re-revision. Only the acetabular liners were revised, as the shell and augments remained stable. The first was revised to a tripolar articulation and the second was revised to a constrained insert. No further instability was noted after these procedures.

One patient developed an early superficial wound infection, which was treated successfully with local wound excision and antibiotic therapy. One patient developed a deep vein thrombosis in the affected limb and was treated with warfarin for three months.

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**Table I. Mean pre- and post-operative outcome scores**

<table>
<thead>
<tr>
<th>Patient group</th>
<th>Harris Hip score</th>
<th>Merle d’Aubigné</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pre-operative</td>
<td>Post-operative</td>
</tr>
<tr>
<td>Acetabular revisions without femoral revision</td>
<td>48.8 (14 to 86)</td>
<td>80.4 (53 to 100)</td>
</tr>
<tr>
<td>Acetabular revisions with femoral revision</td>
<td>35.9 (20 to 64)</td>
<td>70.5 (61 to 86)</td>
</tr>
<tr>
<td>All acetabular revisions</td>
<td>43.0 (14 to 86)</td>
<td>75.7 (53 to 100)</td>
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There were no cases of deep infection, pulmonary embolism or death as a result of the revision procedure.

**Discussion**

Most acetabular reconstructions in revision THR can be performed with porous-coated hemispherical acetabular components when there is sufficient bone available to support the component and provide contact for bone ingrowth.1-3 With a severe acetabular defect there is often insufficient bone to support such a component, and in these cases alternative techniques and implants are needed. These include reconstruction cages, bilobed components, custom triflange components and the long oblong component.11,12

However, these options have their problems. Reconstruction cages and structural allografts are associated with high rates of loosening and re-revision in patients with < 50% host bone support.7,11 Garbuz et al.7 reported a series of 33 hips treated by this method and noted a success rate of 55% (18 of 33 hips) at a mean follow-up of 7.1 years. This included seven hips which needed revision (six for loosening of the acetabular component) and eight hips in which both the prosthesis and the allograft had failed.7

Bilobed acetabular components are designed to fill only superior segmental defects and it is difficult to obtain good bony apposition without gaps. Additional bone may have to be removed to accommodate the shape of this type of implant. Custom components, on the other hand, are expensive, time-consuming to make, and technically difficult to implant.11

These problems have prompted the development of modular components made of tantalum. Their advantages include the potential to achieve long-term biological fixation as the porosity of tantalum is conducive to bony ingrowth. Its high coefficient of friction improves the initial stability of the component. In addition, the modularity of the system, which consists of a range of revision shells and augments, makes it easier to use in a wide variety of acetabular defects and avoids the need for custom-made components.12,13

Recent short-term reports have shown promising results using these components in type 3A and 3B acetabular defects. Weeden and Schmidt18 reported a series of 43 patients with type 3A and 3B defects treated with tantalum porous metal implants. They had a 98% success rate after a mean follow-up period of 2.8 years. Flecher, Sporer and Paprosky,2,3 described a series of 23 hips with similar defects in which no loosening of the acetabular component was seen after a mean follow-up of 35 months. Our study provides additional data to support these initial findings.

The early clinical success of modular tantalum implants appears to support the view that the material properties of tantalum are conducive to initial implant stability and bony ingrowth. It is hoped that this will translate into durable, long-term fixation of these components. The disadvantages of the system, however, are the inability to restore bone stock for future revision, the potential for debris generation at the shell-implant interface, the potential for fatigue failure, and the lack of knowledge regarding the long-term effects of tantalum within the body.

In summary, our short-term results suggest that modular porous metal components are a viable option in the reconstruction of Paprosky type 3 acetabular defects. However, more data are needed to determine whether the system does indeed provide greater long-term success over more traditional methods, such as reconstruction cages and structural allografts.

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**References**


