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*ORIGINAL STUDY*

# Clinical and radiological evaluation of modular trabecular metal acetabular cups
## *Short-term results in 64 hips*

Jean-Pierre SIMON, Johan BELLEMANS

*From the University Hospital Pellenberg, Leuven, Belgium*

**Bone ingrowth and long-term survival of cementless acetabular implants, both in primary and revision hip arthroplasty, are determined by initial implant stability and by the osteoconductive properties of the metal shell. The outcome of a trabecular metal tantalum modular uncemented cup was evaluated in 64 hips in 62 patients. Eleven cups were used in complex primary total hip replacements, 53 cups were implanted in revision hip arthroplasties. The follow-up ranged from 12 months to 48 months. Clinically the Charnley modified Merle-d'Aubigné Postel score improved from 9 to 16 in the primary arthroplasty group and from 10 to16 in the revision group. Serial radiographs demonstrated excellent stability and bone apposition ; in the revision cases, graft incorporation was noted in all but one cup. The number of periacetabular gaps detected on initial postoperative radiographs in the revision cases decreased from 15 to 4 and none of the remainder deteriorated with time. Complications included 2 haematomas, 1 dislocation and 1 cup failure in a Paprosky IIIb defect because of cup undersizing. The early results with the trabecular metal modular cementless cup appear promising in both complex primary and revision hip arthroplasty, even in the presence of considerable bone loss that requires additional bone grafting.**

**Keywords** : acetabular cup ; bone ingrowth ; revision ; tantalum ; trabecular metal ; total hip arthroplasty.

## INTRODUCTION

Cementless cup fixation in complex primary total hip arthroplasty (THA) and in acetabular revisions for septic and aseptic loosening or for recurrent dislocation poses a number of problems to the surgeon. These comprise achieving intra-and postoperative joint stability, getting sufficient cup coverage, achieving stable fixation of the cementless implant into an often poorly vascularised sclerotic bone bed, and repairing osseous defects. Prerequisites for durable cementless cup fixation, both in primary and revision hip arthroplasty are intimate contact of the implant with viable native bone, mechanical stability (motion < 40-50 μm) and proper osteoconductive properties of the metal shell.

Trabecular Metal™ (TM™, Zimmer Inc, Warsaw, IN, USA) is an 80% porous material manufactured from elemental tantalum. *In vivo*

■ Jean-Pierre Simon, MD, PhD, Professor of Orthopaedics.
■ Johan Bellemans, MD, PhD, Professor of Orthopaedics.
Correspondence : J.-P. Simon, MD, University Hospital Pellenberg, Weligerveld 1, 3212 Pellenberg, Belgium.
E-mail : Jean-Pierre.Simon@uz.kuleuven.ac.be


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tantalum has excellent biocompatibility, at least in bulk form, making the material attractive for many medical applications. It was approved for use in acetabular cups by the Food and Drug Administration in 1997. The 3-dimensional structure consists of a network of dodecahedron pores with an average diameter of 550 µm creating a metallic strut configuration (*1,4,14*). The elastic modulus of tantalum (3 GPa) is very much closer to that of cancellous bone (0.8 GPa) and subchondral bone (1.5 GPa) than is the elastic modulus of titanium (110 GPa) (*4,14*). These characteristics favour bone ingrowth and bone remodeling adapted to physiological load distribution. In animal studies bone ingrowth has been demonstrated within 8 weeks of surgery (*2*). One of the most attractive properties of trabecular metal is its high coefficient of friction (µ) against cancellous bone ($\mu = 0.88$) which is much higher than that of a porous titanium fiber coating (*1*). The combination of these properties makes the material particularly suitable in situations where it is difficult to obtain full contact with viable host bone and in cases where stability is compromised by deficient and or sclerotic bone stock. Good results have been reported following implantation of monoblock trabecular metal cups in both primary and revision total hip arthroplasty (*6,9,10,15,18,21,23,24,25*). The purpose of this report is to present the early clinical and radiological outcome following the implantation of a modular trabecular metal tantalum cup in complex primary THA and in revision hip arthroplasty.

## PATIENTS AND METHODS

We reviewed the clinical results and radiographs of 64 cementless modular TM cups in 62 patients. Tables I and II show an overview of patient demographics and implant details. Eleven patients had a primary THA. In 10 of these patients there was a distinct deformation of the acetabulum. In 5 hips the distortion was due to a congenital dysplasia requiring acetabular reconstruction in order to obtain adequate cup coverage. Three patients had prior surgery because of an acetabular fracture and in two patients there was a deformation of the acetabulum, most probably due to an extreme slipped epiphysis of the proximal femur. Finally one cup was inserted into markedly sclerotic bone in a patient with Paget's disease.

Table I. — Patient demographics and characteristics in primary THAs (CMD = Charnley-Merle d'Aubigné score)

| | |
|---|---|
| Number patients | 11 |
| Number THAs | 11 |
| Male | 4 |
| Female | 7 |
| Age at time of surgery | |
| Mean (SD) | 63.8 (20.6) |
| Range | 21-88 |
| Diagnosis | |
| CDH | 5 |
| Slipped Epiphysis | 2 |
| Post traumatic | 3 |
| Paget | 1 |
| CMD Preoperative | |
| Mean (SD) | 9.3 (1.8) |
| Range | 6-12 |
| CMD Postoperative | |
| Mean (SD) | 16.1 (1.2) |
| Range | 14-18 |
| Duration of Follow-up (months) | |
| Mean (SD) | 25.5 (7.9) |
| Range (months) | 12-24 |

Fifty-three trabecular metal cups were used in 51 patients during revision arthroplasty. The indications for revision were recurrent dislocations in 6 patients, in whom the TM cup was combined with a constrained liner. These patients with chronic dislocating hips all had well ingrown cementless cups that had to be removed using the Explant Acetabular Cup Removal System™ (Zimmer Inc, Warsaw, IN, USA). This instrument allows for removal of a well fixed cementless cup with a minimum of bone loss. As a consequence these acetabula did not have major bone defects and were essentially comparable to primary acetabula (Paprosky type I) (*19*). The reason for selecting the TM cup was the fact that the constrained liner inserted during the revision operation immediately puts high shear stresses on the implant-bone interface in the acetabulum. Owing to its extremely rough surface, the TM cup exhibits remarkable stability from the moment it is inserted, and it can withstand these high shear stresses. In two patients the cup was implanted following an infection. In one of them, this was done as a single-stage operation, in the other patient as a two-stage procedure after removal of the primary prosthesis three months earlier. In the remaining 43 patients, 45 cups were revised for aseptic loosening. In 10 hips there was revision of both the femoral and acetabular components. Trabecular metal augments or massive allografts were

Table II. — Patient demographics and characteristics in revision arthroplasties (CMD : Charnley-Merle d'Aubigné score)

| | |
|---|---|
| Number patients | 51 |
| Number revisions | 53 |
| Male | 19 |
| Female | 32 |
| Age at time of surgery ( years) | |
| Mean (SD) | 67.4 (12.8) |
| Range | 39-92 |
| Years to revision | |
| Mean (SD) | 12.3 (4.6) |
| Range | 3-21 |
| Reason for revision | |
| Recurrent dislocation | 6 |
| Septic loosening | 2 |
| Aseptic loosening | 45 |
| Number of revisions | |
| First | 39 |
| Second | 12 |
| Third | 1 |
| Fourth | 1 |
| Paprosky grades preoperative | |
| Grade I | 15 |
| Grade IIa | 15 |
| Grade IIb | 14 |
| Grade IIc | 5 |
| Grade IIIa | 4 |
| CMD Preoperative | |
| Mean (SD) | 10.3 (2.4) |
| Range | 6-14 |
| CMD Postoperative | |
| Mean (SD) | 16.1 (1.5) |
| Range | 14-18 |
| Duration of Follow-up (months) | |
| Mean (SD) | 28.3 (10.1) |
| Range | 12-48 |

not used in any instance. Defects in the medial acetabular wall or defects in the acetabular dome due to former cement holes or osteolysis were bone grafted with a mixture of larger ($5 \times 8$ mm) and smaller ($2 \times 4$ mm) bone chips. The large chips were hand made using large nibblers, the smaller ones were made with a bone mill from deep frozen (- 70° C) femoral heads from the bone bank. The chips were impacted into the defects and further dispersed by reverse reaming. Redundant allograft bone was removed in order to achieve at least 50% to 60% host bone contact with the implant, a requisite for cementless fixation in revision arthroplasty. We used additional fixation with 30 to 60 mm dome-oriented cancellous titanium screws in all revision cases to obtain maximal stability. In 15 cases a 25 millimeter cancellous screw was also fixed in the ischium, where good purchase can usually be achieved without any major risk for the sciatic nerve. In all revisions, with the exception of the constrained liners, a highly cross-linked and heat-stabilized direct compression molded, 10° or 20° elevated, polyethylene liner (Longevity™, Zimmer Inc, Warsaw, IN, USA) was used. Constrained liners were manufactured from conventional UHMW polyethylene. A 32-mm metal femoral head was used in all patients. All arthroplasties were done via a posterolateral approach. Two technical points are worth mentioning. During introduction of the TM cup, difficulties may be encountered because of friction against the lateral and posterior acetabular rim, and even against the surrounding soft tissues, due to its extremely rough surface. It is often necessary to initially force the cup towards the medial acetabular wall by several blows with a mallet using a blunt instrument placed on the outer, lateral edge of the cup while the latter is stabilized with the cup introducer. Only then, when the cup is well centered over the acetabular opening can it be further advanced cranially into the acetabulum by forceful blows onto the cup holder/introducer. If the shell is not sufficiently centered over the acetabular opening, further damage or a fracture may be produced to an already defective acetabular wall. Another technical tip we recommend in revision surgery when using the TM cup is to select a cup one size larger than the well-seated trial component. This clearly makes insertion of the TM cup even more difficult, but oversizing the TM cup versus the trial cup has two advantages : it guarantees optimal contact with a large part of the peripheral rim of the acetabulum and increases its stability. Because of the hemi-ellipsoid geometry of the TM cup, it is not necessary to obtain dome contact. However, peripheral contact of at least 50 to 60% is mandatory. In addition in many revision cases the loose cup has migrated cranially as a result of osteolysis, which results in shortening of the limb. If the stem does not need to be exchanged it is difficult to restore adequate length, which is a prerequisite to stabilize the joint. By oversizing the TM cup versus its trial component, the definite cup cannot be seated as deep as the trial component and hence its final position is somewhat distalised. Being hemi-ellipsoid, however, its peripheral hoop gets excellent purchase onto the acetabular rim, even when the latter is partially defective. When the TM cup is inserted in this oversized manner, up to 1.5 to 2 centimeters length may be gained. Hence the stability of the joint can be assured and shortening of the limb may be partially or fully corrected.

## RESULTS

### Clinical results

None of the patients were lost to follow-up. Patients were clinically evaluated before and after the procedure using the Charnley modification of the Merle-d'Aubigné-Postel scoring system (CMD) (*3,16*). Following the operation the patients were assessed at 6 weeks and at 3, 6 and 12 months. Minimal follow-up was 12 months, the longest follow up was 48 months (mean 28.3 - SD 10.1). The latest CMD score was compared to the preoperative CMD status for every patient. In the primary THA group the CMD score improved from 9.2 (SD 1.8) to 16.1 (SD 1.2) and in the revision group from 10.3 (SD 2.4) to 16.1 (SD 1.5). Postoperatively in the revision group one patient required the use of a crutch and two required a cane including a lady with a past periprosthetic fracture. Three patients had mild pain, one had moderate pain. Only one patient who had his loose cemented acetabular component replaced by a TM cup in combination with a cemented revision of the femoral component was unsatisfied with the result because of persisting mid thigh pain. There were no signs of infection and no signs of loosening, and no explanation could be given for his complaints.

### Radiographic assessment

Radiographs were obtained for all patients preoperatively and postoperatively at one week, 6 weeks and at 3, 6 and 12 months and yearly thereafter for patients exceeding one year follow up. These included an AP Pelvis, an AP view centered on the pubic symphysis and a lateral view of the involved hip. Radiographs taken at 6 weeks were used as a baseline reference for evaluation of subsequent radiographs (*11*). On the preoperative radiographs of patients needing a cup revision for loosening, the osteolytic lesions and defects were graded according to Paprosky's classification (*19*). There were 9 grade I, 15 grade IIa, 14 grade IIb, 5 grade IIc and 4 grade IIIa acetabula. All patients requiring revision for chronic dislocation were graded Paprosky I. Strict criteria needed to be fulfilled to consider the cup stable after 12 months. On serial radiographs the cup position had to remain unchanged compared to the index position at 6 weeks without any signs of migration or tilting (*8*). No screw fracture and no osteolysis were accepted around any of the fixating screws. In addition the radiograps were evaluated according to the criteria proposed by Moore *et al* to determine radiographic signs of osseointegration (*17*). Radiolucent lines around the acetabular component were identified and designated as being in one of the 3 zones, as described by DeLee and Charnley (*5*). We did not register any new radiolucent lines that were not initially present on the index radiographs. In addition gaps that could be observed on the 6 weeks radiograph were assessed on the 12 months or later images. In the revision cups the number of periacetabular gaps decreased from 15 to 4 and none of the remainder deteriorated with time. The evolution of gaps is presented in table III. There was one cup that failed at 5 months and migrated into the pelvis. This occurred in a type IIIb defective acetabulum. None of the other TM cups has so far demonstrated any signs of loosening or migration and not a single screw has broken. Two representative radiographs are given in figures 1 and 2.

### Complications

Patients were monitored for complications related to their arthroplasties including infection, nerve injury, deep vein thrombosis, pulmonary embolism, dislocation and cup migration or loosening.

Table III. — Gaps in zones I, II and III ; Number and percentage immediately postoperative and at most recent follow-up for revision cases

| Number of initial postoperative gaps | | Number of gaps at latest follow-up | |
|---|---|---|---|
| Zone I | 6 | Zone I | 1 |
| Zone II | 8 | Zone II | 2 |
| Zone III | 1 | Zone III | 1 |
| Total / Rev. | 15/53 | Total / Rev. | 4/53 |
| Percent | 28.3 | Percent | 7.5 |

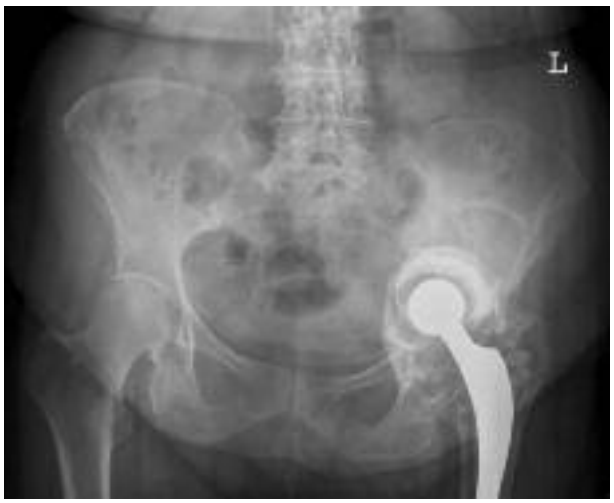


***Fig. 1a.*** — Paprosky IIIa acetabular defect after previous cup revision.

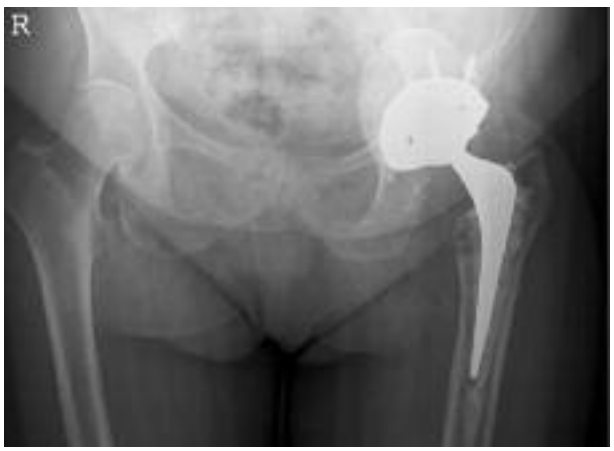


***Fig. 1b.*** — Postoperative radiograph 14 months following cancellous grafting in combination with a TM cup.

Four complications occurred in the revision group, none in the primary THA series. Two patients developed a postoperative haematoma. One haematoma needed drainage under general anaesthesia 8 days following the revision ; the further course in this patient was uneventful. In one patient with a type IIIb defect the cup turned upside down in the acetabulum 3 months following the initial revision after she fell from the stairs. Presumably there was no or insufficient ingrowth at the moment of the fall. In retrospect the diameter of the cup was clearly undersized in relation to the acetabular cavity, the cup was mainly supported by allograft chips and probably had insufficient grip on the peripheral rim. The cup subsequently migrated into the pelvis. Although a repeat revision was advised for reasons of possible iliac vessels erosion, the patient denied further surgery.

One lady had recurrent dislocations following a revision arthroplasty for a Vancouver type B2 fracture with a long cementless stem (Revitan™ Zimmer Inc, Warsaw, Ind, USA). She was revised with a TM cup with a constrained liner, combined with a strut allograft of the femur to reattach the abductor mechanism. Three weeks later she dislocated the 32 mm femoral head out of the constrained liner during a forward bending movement. Despite the dislocation the TM shell did not show any change in position on the radiographs. During the subsequent revision, 3 weeks following the index revision, it was noted that the locking ring had remained around the liner, and the liner was retained in the cup by the cup-liner locking mechanism. Intraoperatively the TM shell still appeared solidly fixed. The liner was exchanged for a new one and the hip was reduced. The patient was then instructed to wear a brace for 3 months. No further dislocations occurred during the two years follow-up. There were no infections and no recurrence of infection in the two patients who had their revision for a previous deep infection. There were no cases of deep vein thrombosis, pulmonary embolism or fractures.

## DISCUSSION

Tantalum is a high-performance metal with exceptional properties including strength, ductility, toughness, corrosion resistance, thermal conductivity and a high melting point. The metal is widely used in electronic devices for its corrosion resistance and in many technical applications requiring high strength such as the aeronautical appliances, turbines and in the weapon industry. In bulk form, tantalum has an excellent *in vivo* biocompatibility, making the material attractive for many medical applications including surgical instruments, dental implants, implantable electrodes, nerve repair,

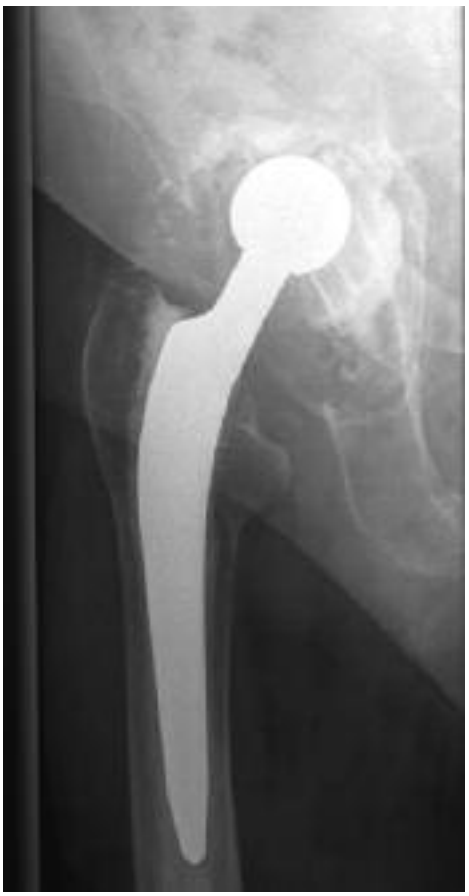

***Fig. 2a.*** — Preoperative Paprosky Type IIc acetabular defect

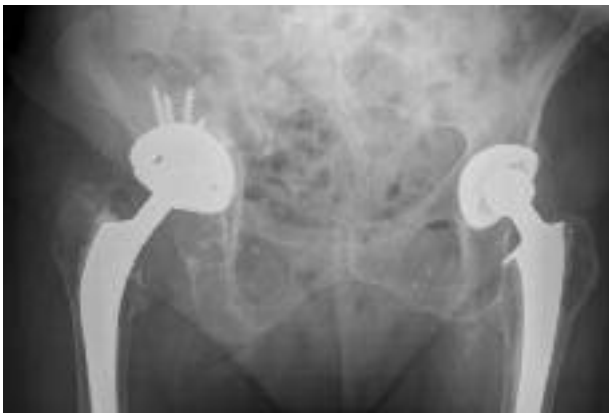

***Fig. 2b.*** — Postoperative radiograph 6 weeks following cancellous grafting in combination with a TM cup.

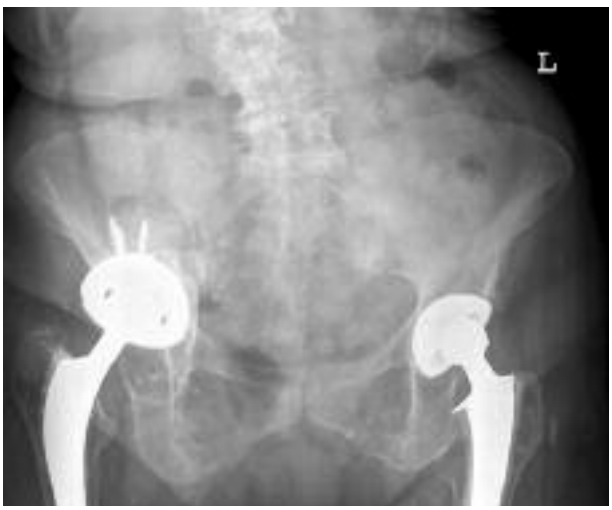


***Fig. 2c.*** — Radiograph 32 months after the revision. The TM cup remains stable.

cranioplasty plates and a variety of orthopedic applications requiring bone ingrowth (*4,12,14*). Histological analyses have shown quick penetration and rapid rates of mechanical attachment of both fibrous and osseous tissues (*1*). The 3-dimensional structure and excellent biocompatibility of trabecular- metal tantalum allows for rapid bone ingrowth and restoration of bone stock. Important factors to achieve bone ingrowth and long-term survival of cementless implants are a stable bone implant interface and favourable osteoconductive properties of the metal. The unique material properties of porous tantalum are ideal for complex primary THAs and for acetabular revisions, particularly when substantial bone loss or poor bone quality is present. Good results have been reported by Sporer and Paprosky and by Siegmeth *et al* in type II, IIIa and type IIIb defects using trabecular metal augments (*22,24*). Trabecular metal has also opened new treatment options, and favourable results have been reported in revision total knee arthroplasty using TM augments and cones (*13,20*). Currently TM acetabular components exist in three versions : a monoblock acetabular component, a monoblock acetabular component with peripheral screw fixation and a modular acetabular component coated with an open cell tantalum framework. The latter allows for additional dome and ischial screw fixation and accepts a highly cross-linked and thermally

stabilized polethylene liner. The cup moreover combines with modular 10°, 20° and constrained liners offering the surgeon a wide choice to address most of the instability problems that may be encountered during revision surgery. The sole potential disadvantage of the cup is the fact that combination with screws poses a risk of fretting between screws and shell if immediate or later stability is not properly achieved.

The three components have a similar elliptical shape with a flattened dome and share the advantage of the convex high-friction trabecular surface that comes into contact with bone. Owing to its high porosity (80%) and optimal 3-dimensional structure mimicking cancellous bone, with an average pore size of 550 µm, the material is an excellent substrate for bone ingrowth. The three versions of the TM cups can be combined with porous tantalum augments, if necessary when used in the presence of structural bone defects *(7,22,24)*. In this study we have reported the early clinical and radiological results in a consecutive series of 64 TM cups, 11 in complex primary THA and 53 in revision arthroplasty in 62 patients. Despite the relatively short follow-up period, this modular component appears to provide a promising choice, with the added advantage that it accepts a variety of polyethylene liners. Porous tantalum showed excellent bone ingrowth, and no change in position was noted except for one cup that failed and migrated, in a type IIIb defect, almost certainly due to cup undersizing. The healing and incorporation of allograft bone nearby the porous tantalum is remarkable. Clinical results were good and radiological assessment showed excellent gap filling, bone apposition and incorporation of bone grafts. Similar results have been reported in other studies using TM cups. Longer-term follow-up of our cases however remains mandatory to provide further insight into the long-term performance of this material.

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