Acetabular Revision Surgery With Tantalum Trabecular Metal Acetabular Cup for Failed Acetabular Cage Reconstruction With Bone Allografts: a Retrospective Study With Mid- to Long-term Follow-up

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Abstract

Background

The acetabular cage reconstruction with bone allografts is one of the successful strategies to deal with the massive acetabular bone loss. However, the nonbiological fixation nature of cages can compromise long-term success. The tantalum trabecular metal acetabular cup (TM cup) has been used in acetabular revision surgery because of its increased initial stability and good bone ingrowth features. This study was to determine if the bone stock of acetabulum is enough to support the hemispheric TM cup after failed cage reconstruction with bone allografts.

Methods

We retrospectively reviewed our patients who received acetabular revision surgery with TM cups after failed cages reconstruction with bone allografts from 2006 to 2017. There were twelve patients (5 males and 7 females) including in this study at the mean age of 61.5 years (38 to 81) at re-revision surgery. The mean follow-up after re-revision surgery was 8.6 years (2.6 to 13.3). The endpoint was defined as the aseptic loosening of TM cup and reoperation for any causes. The change of bone stock of acetabulum between index revision and re-revision was assessed according to Gross classification for acetabular bone loss.

Results

One patient died after eight years of follow-up with the cause not related to hip surgery. Two patients received two-stage revision arthroplasty due to PJI after 3.2- and 9.4-years follow-up. The bone stock of acetabulum was significantly improving between index revision and re-revision surgery ($p < 0.0001$). The Kaplan-Meier survivorship was 100% when aseptic loosening as the endpoint, and 90% and 75% at five- and ten-year when reoperation for any causes as the endpoint.

Even the cage reconstruction with bone allografts will fail eventually, the bone stock of acetabulum will improve after union and incorporation between host bone and allografts. The restored bone stocks will facilitate further revision surgery with hemispheric TM cup. The biological fixation between host bone tantalum trabecular metal will provide longstanding stability of the TM cup.

Conclusions

The results of our study offered a viable option for patients with failed cage reconstruction with bone allografts.

Background

Total hip arthroplasty (THA) is one of the most successful orthopedic interventions of its generation, but because of its popularity, an increasing number of patients undergoing total hip arthroplasty require

revision surgery. The main reasons for implant failure in 71% of cases are aseptic loosening and associated osteolysis.¹ Acetabular bone loss after THA can be a serious problem in revision surgery as bone deficiencies may limit reconstructive options, increase difficulty of operation, and necessitate autogenous or allogenic bone grafting.

Treatment options for different types of acetabular bone defects have been well-established. Most patients can have reconstruction with uncemented cups with screws with or without morselized bone grafts. Severe acetabular bone defects might require structural grafts, a cup with or without augments, a cage, or a cup-cage, depending on the type of bone defect.

Cage reconstruction is used in massive bone defects in which an uncemented porous cup cannot gain stable fixation or biologic fixation is unlikely, and in cases of pelvic discontinuity.² However, cages have high failure rates in mid- to long-term follow-up due to a lack of biologic fixation.^{3,4} Although the cages themselves will fail eventually, the allografts will be protected by the cages, and thus grafts will restore bone stock of the acetabulum.⁴⁻⁶ We aimed to determine if after the cage is loosened, if the acetabulum bone stock is sufficient to support hemispheric cups and achieve longstanding biological fixation.

The Trabecular Metal (TM, Zimmer Biomet, Warsaw, Indiana) is made of highly porous tantalum and facilitates bone ingrowth and initial stability because of its low modulus of elasticity and high frictional characteristics.⁷⁻⁹ The TM cups have been demonstrated to lead to successful clinical outcomes and survivorship in revision hip surgery.¹⁰ In our previous study, we used structural allografts with the TM cup to treat Paprosky type III defects in revision THA with good clinical outcomes.¹¹

Because of the bioactive nature and bone ingrowth properties of the TM,¹⁰ we suspect that TM cups are suitable for patients who need acetabular revision surgery due to loose cages. The purpose of this study was to report the mid- to long-term results of using trabecular metal-coated hemispherical cups (TM cup) to salvage failed cages in acetabular revision surgery.

Methods

We retrospectively reviewed the rTHA register database of our institution, and identified 2831 patients receiving rTHA in our institution from 2006 to 2017. We included patients who received acetabular revision surgery with the TM cups due to aseptic loosening of cages. The first revision surgery using cage reconstruction with bone allografts was termed “index revision,” and the following revision surgery using the TM cup due to aseptic loosening of the cage was termed “re-revision.”

Patients

Twelve of these patients (twelve hips), including five males and seven females, were included in this study. The mean age of the patients at index revision was 56.1 ± 14.7 years and 61.5 ± 14.6 years at re-revision. Patient demographics are summarized in Table 1.

The acetabular bone defects at the time of index revision and re-revision were classified based on pre-operative radiographs and intraoperative findings according to the Paprosky classification¹² and the Gross classification for acetabular bone loss.¹³ Briefly, Paprosky type I defects are classified by minimal bone loss, intact dome, presented posterior wall and teardrop, and uninvolved medial wall. Type II defects are classified by distorted acetabular hemisphere, destructed dome and/or medial wall, and preserved anterior and posterior columns. Type III defects are classified by severe bone loss, destroyed acetabular rim and supporting structures.¹² The Gross classification was defined as type I: no significant loss of bone stock; type II: contained loss of bone stock (cavitary); type III: uncontained loss of bone stock involving less than 50% of the acetabulum (posterior column $\pm$ anterior column); type IV: Uncontained loss of bone stock involving more than 50% of the acetabulum (segmental loss affecting both columns); and type V: pelvic discontinuity with uncontained loss of bone stock.¹³

Surgical procedure

In all patients, an anterolateral approach in lateral decubitus position was chosen in index revision and re-revision surgery. Bone allografts were obtained from the bone bank of our institution. The bone bank protocol, which consisted of donor selection, harvesting, and processing of allograft followed the recommendations of the Musculoskeletal Council of the American Association of Tissue Banks. During index revision surgery, the bone defects of the acetabulum were filled with structural and morselized fresh frozen bone allografts after removal of the previous implant, debridement, and reaming to bleeding host bone. When the reasonable hip center was restored by bone grafting, the cage was placed within the acetabulum and affixed by screws. After the cage was secured, a PE liner was fixed to the cage in the appropriate orientation using bone cement. In re-revision surgery, after removal of the failed cage and debridement, the acetabulum was reamed to bleeding host bone (Figure 1A). The acetabular bone defects were assessed and the structural and/or morselized bone grafts were applied to the segmental or cavity bone defects. Then, a TM cup was press-fitted to the acetabulum.

Outcome assessment

The Gross classification was used to quantify the restoration of bone stock between index revision and re-revision surgery. The modified Harris hip score¹⁴ was used to assess clinical status. All patients were followed routinely (6 weeks, 3 months, 6 months, 1 year post-op, and annually thereafter). We retrospectively reviewed medical records and radiographs, including anteroposterior (AP) pelvis view and lateral hip view. Osseointegration of the TM cups after re-revision surgery was assessed according to the classification by Moore et al.,¹⁵ which includes five radiographic signs: (1) absence of radiolucent lines; (2) presence of a superolateral buttress; (3) medial stress-shielding; (4) radial trabeculae; and (5) an inferomedial buttress. Loosening of TM cups was defined as migration > 3 mm in horizontal or vertical, change in the angle of inclination $> 5^\circ$, and less than 2 signs of osteointegration.¹⁵

Statistical analysis

All statistical analyses were performed with MedCalc Statistical Software version 19.2.5 (MedCalc Software Ltd, Ostend, Belgium; <https://www.medcalc.org>; 2020). Kaplan–Meier survival analysis was used to estimate the survivorship of the TM cup in re-revision surgery by two endpoints: (1) aseptic loosening and (2) reoperation for any cause. Restoration of acetabular bone loss was assessed using Student's paired t-test. A p-value of < 0.05 was considered statistically significant.

Results

One patient died after eight years of follow-up for reasons unrelated to hip surgery, but the TM cup was stable at her last follow-up. Two patients suffered from hematogenous periprosthetic joint infection (PJI) 3.2 years and 9.4 years following re-revision surgery. These two patients were received two-stage revision arthroplasty for PJI at that time. The TM cups were stable during first stage surgery for PJI. The mean interval of index revision and re-revision of these twelve patients was 5.4 ± 3.4 years. At the time of index revision, there were five cases of Paprosky type IIIA defects, six type IIIB defects, and one pelvic discontinuity. At re-revision, there was one Paprosky type I, four type IIA, four type IIB, two type IIC, and one type IIIA defect. Overall, bone defects were downgraded in re-revision surgery. Bone defects at index revision and re-revision surgery, according to the Gross classification are shown in Table 2. The bone stock of the acetabulum was significant restoration at the time of re-revision surgery ($p < 0.001$) according to the Gross classification (Figure 2). The mean follow-up time after re-revision surgery was 8.6 ± 4 years (Figure 3). With aseptic loosening defined as an endpoint, the Kaplan–Meier survivorship was 100%. When reoperation for any cause was set as the endpoint, the Kaplan–Meier survivorship at five- and ten-years was 90% and 75%, respectively (Figure 4). There were no complications such as dislocations, sciatic nerve palsy, or surgical site infection after index revision or re-revision surgery. The mean modified Harries hip score was 85.6 ± 4.1 at the latest follow-up after re-revision surgery.

Discussion

Acetabular revision surgery with extensive acetabular bone defects is challenging and technically demanding. Massive bony deficiencies can arise from osteolysis after polyethylene wear, destroying the bone by loosening of an acetabular component, repeated revision of the acetabulum, or extended debridement for PJI. When dealing with massive acetabular bone loss, such as Paprosky type III acetabular defect, structural allografts not only restore bone stock, but also support new acetabular components.¹⁶ Garbuz et al. reported a high failure rate of acetabular revisions if structural allografts supported $> 50\%$ of the cup at a mean follow-up of 7 years, and more than half of failed cases showed both prosthesis and allograft failure.⁵ A number of previous studies have reported that reconstruction of massive acetabular bone defects using the cage with allografts could provide good initial stability.^{17,18} However, the inability of biologic fixation at the cage-bone interface can compromise the chances of long-term success.^{3,4} The cage will fail eventually because of its nonbiological fixation.

Allogenic bone grafts are biocompatible scaffolds. Revascularization, resorption, and appositional bone growth will occur slowly.¹⁶ During acetabular revision surgery, the cage can protect the bone grafts, and the bone stock will restore over time through the union and incorporation between host bone and bone grafts.³ In our study, bone base bleeding was noted after removal of the loosened cages and reaming of the acetabulum in re-revision surgery. It indicated the host bone had incorporated with the allografts, which was implanted during index revision surgery. This bleeding living bone, remodeling from allografts, thus renovated the bone stock of the acetabulum.

The new bone stock can downgrade the bone defects of the acetabulum and provide the capableness of facilitating the re-revisions. Abolghasemian et al. reported that 48% of patients with Gross type III or higher acetabular bone defect at the time of index revision were downgraded to Gross type I or II defect at re-revision;¹⁹ moreover, 60% of hips could use hemispherical cups in re-revision surgery. In our study, all acetabular bone defects were restored through re-revision surgery, according to the Gross classification. The reconstitution of acetabulum bone stock provided an opportunity to use cementless hemispherical components in re-revision surgery.

As shown in figure 1B, although the allografts had united with the host bone, it was not all revascularized (no bleeding area, marked as *), and allograft had been absorbed. A revascularized allograft predisposes weakening and loosening of the structure.²⁰ Although there was Gross type I or II acetabular bone defects in re-revision surgery, the bleeding host bone may not be strong enough to support a conventional uncemented cup.¹⁰

The TM is made of tantalum, a highly porous biomaterial (porosity 70%–80%), in 3D architecture. One study using an animal model reported bone ingrowth within two weeks, and substantial ingrowth occurred within four weeks.⁷ Other studies have report that the TM cup is suitable for acetabular revision surgery with massive bone loss, even when there is less than 50% of acetabulum host bone.^{10,11,21} Kosashvili et al. reported 15 patients receiving non-buttressed TM cup reconstruction for failed acetabular cages with a mean follow-up time of 48.3 months (range, 24–72 months). Of these 15 patients, 12 did not have cup loosening at the end of the follow-up period.²² In the current study, we observed no radiological failures due to aseptic loosening after re-revision surgery at a mean follow-up time of 8.7 years follow-up, and only two hips failed due to infection after 3.2 and 9.4 years follow-up. The TM cup provides higher mechanical stability and a more favorable environment for bone incorporation with the metal cup.^{23,24} For these reasons, we use the TM cup in re-revision surgery after the failed cage reconstruction with bone allografts in our clinical practice with good results.

There are some limitations to our study which need to be addressed. First, the number of patients this study was relatively small, despite the high-volume of referrals to our institution. Also, we were not able to compare this technique to other revision techniques as this was a retrospective study, and this was not a randomized study thus there may have been selection bias. We used TM cups to salvage failed cages based on evaluation of pre-operative radiographs and assessing acetabular bone defects and the quality

of bleeding living bone intra-operation. However, taken together, our study suggests that TM cup reconstruction is a viable option for re-revision surgery after failed cage reconstruction with bone allografts.

Conclusions

This study suggests that using cages combining with allografts in acetabular revision surgery with massive bone loss can restore acetabular bone stock. Although the cages will eventually fail, the reconstituted bone stock can help with future revisions. The TM cup is a reliable option and relatively easier procedure for re-revision surgery after the failed cage reconstruction with bone allografts. The benefit of TM cups for biological fixation can provide a long-lasting construction after re-revision surgery.

List Of Abbreviations

Tantalum trabecular metal acetabular cup (TM cup), Total hip arthroplasty (THA)

Declarations

-Ethics approval and consent to participate:

The ethics committee of the Chang Gung Memorial Hospital (CGMH), Kweishian, Taoyuan, Taiwan approved the study design on Sep 9th, 2016 (CGMH IRB No: 201601034B0) and waived the requirement for obtaining informed consent and patient records.

-Consent for publication:

The authors confirmed that all methods were carried out in accordance with relevant guidelines and regulations. Consent for publication is not applicable to our study

-Availability of data and materials:

The authors confirm that the data supporting the findings of this study are available within its supplementary file.

-Competing interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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-Authors' contributions:

Hsin-Nung Shih conceived of the presented idea. Chen-Heng Hsu, Chun-Chieh Chen developed the theory and performed the computations. Chun-Chieh Chen verified the analytical methods and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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-Consent for Publication:

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Tables

Table 1. Patient demographics

Variable	All hips (n=12)
Sex, n	
Male	5
Female	7
Mean age at index revision surgery, years (SD)	56.1 (14.7)
Mean age at re-revision surgery, years (SD)	61.5 (14.6)
Mean interval between index revision and re-revision, years (SD)	5.4 (3.4)
Mean follow-up after re-revision, years (SD)	8.6 (4)
Reason for index revision surgery, n	
Loose acetabular component	9
Second-stage re-implantation for infection	3
Paprosky classification for index revision, n	
IIIA	5
IIIB	6
Pelvic discontinuity	1
Paprosky classification for re-revision, n	
I	1
IIA	4
IIB	4
IIC	2
IIIA	1

Table 2. Gross classification of acetabular bone loss at index and re-revision surgery

	Defect (n)				
Surgery	Type I	Type II	Type III	Type IV	Type V
Index revision			1	10	1
Re-revision	4	3	5		

Figures

Figure 1

A) The host bone of acetabulum was bleeding after reaming in re-revision surgery, indicating revascularization of allografts. B) The allografts, which were implanted in index revision, had non-vascularized areas (marked with *) during re-revision surgery.

Figure 2

Acetabulum bone loss significantly decreased between index revision and re-revision according to Gross classification ($p < 0.001$).

Figure 3

A) Paprosky type IIIA acetabular bone defect after operation for periprosthetic joint infection. B) Reconstruction with the cage and bone allografts. C) The cage failed eight years after index revision. There was radiolucent line between the cage and host bone (arrow), and union of the host bone and allografts (*). D) The TM cup remained stable after nine years of follow-up after re-revision surgery.

Figure 4

The Kaplan–Meier survivorship was 100% with aseptic loosening as the endpoint, and 90% and 75% at five- and ten-years respectively with the reoperation for any causes as the endpoint.

Supplementary Files

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