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ORIGINAL PAPER

Porous tantalum shell and augment for acetabular defect reconstruction in revision total hip arthroplasty: a mid-term follow-up study

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Abstract

Aim The use of porous tantalum trabecular metal (TM) shell and augment to reconstruct acetabular defects in revision total hip arthroplasty (THA) is a reliable technique. We evaluated the mid-term implant survival, clinical, and radiological outcomes of our first 48 revisions using this technique.

Patients and methods A total of 45 patients (48 hips) who had acetabular revision of THA between 2011 and 2017 using TM shell and augment with possible mid-term follow-up were included. Twenty-two patients were men (49%) and 23 were women (51%), mean age was 62.5 years (34 to 85) and mean follow-up was 75 months (54 to 125). Twenty-four hips (50%) had a Paprosky IIIA defect, 14 (29.2%) had a type IIIB defect, six (12.5%) had a type IIC defect, and four hips (8.3%) had a type IIB defect. None of the patients had pelvic discontinuity (PD).

Results At a mean 6.25 years follow-up, all hips remained well-fixed and implant survival of 100% with the need of re-revision as the end point. Screw fixation was used for all shells; augments and the shell-augment interface was cemented. Excellent pain relief (mean WOMAC score pain 90.5, (38.3 to 100)), and functional outcomes (mean WOMAC function 88.3 (31.9 to 100), mean OHS 89.2 (31.8 to 100)) were noted. Patient satisfaction scores were excellent.

Conclusion This study demonstrated satisfactory mid-term clinical and radiological outcomes of using TM shell and augment for reconstructing major acetabular defects without PD in revision THA.

Keywords Acetabular defect · Porous tantalum shell · Augment · THA revision

Introduction

Acetabular defect reconstruction is a complex surgical procedure that continues to present challenges in revision total hip arthroplasty (THA). Existing reconstructive techniques have included, among others, Jumbo cups [1], cemented shells with allografts [2], rings or cages [3, 4], structural allografts [5], shells at high hip centre [6], and custom tri-flanged components [7]. These methods have showed satisfactory results in selected cases; however, limitations to their use included insufficient initial stability [3, 8], risk of graft resorption [5, 9], and late breakage or loosening in the case of off-the-shelf cages [3, 4]. Custom tri-flange implants appear to be a promising alternative but these implants are costly and take time to manufacture with the need of using advanced imaging methods [7].

An alternative new technique using porous tantalum trabecular metal (TM) shell and augment has been proved to be a reliable method for major acetabular defects reconstruction

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in revision THA [10–12]. These implants have high porosity; high coefficient of friction; and elasticity that is comparable with subchondral bone [13–15]. Porous tantalum augments are good alternative to structural allografts due to their ability of providing biologic fixation, reconstructive ease, and reliable resistance against fracture or failure [11, 13].

Recent studies have been providing increasing evidence for the clinical use of TM shell and augment during acetabular revision surgery [16–20]. Eachempati et al. [16] reported implants survival of 100% at mean 3.3 years of follow-up. Long-term follow-ups have also showed good outcomes of 91% to 97% of survivorship of the implants [17–20]. We have been using TM shell and augment for acetabular defect reconstruction for over a decade now; however, we have not yet reported our experience and evaluation of using this technique. We hypothesized that the technique of using TM shell and augment would show satisfactory clinical and radiological outcomes at mid-term follow-up. The objectives of this study were to evaluate the mid-term implant survivorship, re-revision rate, and the clinical and radiological outcomes.

Methods

A search of our hospital's arthroplasty register was carried out to identify all patients who underwent acetabular revision surgery after failed total hip arthroplasty using porous tantalum TM shell and augments. Patients were excluded if their surgical dates did not allow possible mid-term follow-up; if porous tantalum components were used during primary THA; and if different revision strategies, rather than TM shell and augment, were used for acetabular defect reconstruction.

The Paprosky' classification system [10] was used to classify all the acetabular defects preoperatively and that were as follows: Twenty four hips had a Paprosky IIIA defect (50%), 14 (29.2%) had a type IIIB defect, six (12.5%) had a type IIC defect, and four hips (8.3%) had a type IIB defect. None of the patients had additional pelvic discontinuity [Table 1].

Table 1 Acetabular defects distributions based on Paprosky classification[10]

Acetabular bone defect	Cases, *n* (%)
Paprosky I	0
Paprosky IIA	0
Paprosky IIB	4 (8.3%)
Paprosky IIC	6 (12.5%)
Paprosky IIIA	24 (50%)
Paprosky IIIB	14 (29.2%)
Pelvic discontinuity	0

Surgical technique

Patients were positioned laterally and a posterolateral approach was used in all hips. Eleven hips had an extended trochanteric osteotomy (ETO). After careful removal of loose components and residual membranes, microbiological samples were taken for culture and sensitivity. The preoperative defect classification was confirmed intra-operatively. Firstly, minimal reaming was performed at the true hip center to re-establish it and achieve optimal press-fit of the reamers with less sacrificing of bone stock. A hemispherical reamer or trial shell and trial augment were then used for sizing, positioning, and defect measuring for the final constructs while maintaining maximum host bone contact and achieving adequate initial stability. Fluoroscopy assessment of the position and stability was performed intra-operatively. Particulate allografts were impacted into all the defects include filling any additional small, contained defects. After the final augment was impacted and fixed with screws, the interface between augment and shell was cemented. Then the final shell was impacted and fixed with additional screws in the correct position and orientation. New screw holes were drilled if the fixation was not satisfactory. Finally, a polyethylene liner was cemented into the porous tantalum shell for all hips.

All hips had an uncemented porous tantalum acetabular shell and augment (Trabecular Metal Acetabular Revision System (TMARS); Zimmer), with the exception of four patients with a Type 2B defect who required TM shell without augment. The mean shell diameter size was 55.8 mm (47 to 64), and the mean of screws number used for the shell and augment was 4.8 (2 to 7). All hips required only one augment and the augments thicknesses ranged from 6.5 mm to 20 mm with 10 mm (19 hips, 43%) and 15 mm (16 hip, 36%) as the most frequently used. The three most used diameters of augments were 50 mm (18 hips, 41%), 54 mm (16 hips, 36%), and 62 mm (eight hips, 18%) (Table 2). The mean duration of the surgery was 110 minutes (80 to 230).

Post-operatively, patients were advised of partial weight bearing for six weeks and weekly clinical visits evaluation to determine the time for full weight bearing. Overall implant survival was considered as the requiring for no further revision of the acetabular components.

Radiological and quality of life measures

Radiological data for all the included patients were obtained and reviewed by the authors (MO A, ZE W, and PDK). Signs of Osseointegration were assessed using the criteria of Moore et al. [21]. which involve the following: absence of radiolucent lines; presence of a superolateral buttress; presence of medial stress shielding; presence of radial trabeculae; and the presence of an infero-medial buttress. Quality of

Table 2 The components characteristics

Variable	Value
Total Trabecular metal (TM) revision shells	48
TM shell with augments	44
TM shell without augments	4
Mean shell diameter, mm (range)	55.8 (47 to 64)
Mean number of implanted screws, n (range)	4.8 (2 to 7)
Augment thickness, n (%)	
10 mm	19 (43%)
15 mm	16 (36%)
20 mm	8 (18%)
Augment diameter, n (%)	
50 mm	18 (41%)
54 mm	16 (36%)
62 mm	8 (18%)

Table 3 Cormobidities distribution

Comorbidities	Patients, *n* (%)
Hypertension	14 (31%)
Diabetes mellitus (DM)	11 (24%)
Anemia	9 (20%)
COPD	8 (17%)
Coronary heart disease	6 (13%)
Chronic kidney disease, CKD	3 (6.7%)

COPD, chronic obstructive pulmonary disease

life (QoL) measures and functional outcomes were assessed using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) [22], Oxford Hip Score (OHS) [23], and a patient satisfaction score [24]. Questionnaires of QoL were completed during patient's clinical visits or via telephone and radiographs were sent to us for assessment.

Statistical analysis

Demographic data were presented with the mean and ranges values and percentages were used to describe categorical variables. The Kaplan–Meier method was used to assess the implant survivorship and SPSS 26.0 (IBM, Chicago, IL, USA) was used to conduct all the statistical analyses.

Results

Fifty-three patients (57 hips) who underwent surgery between May 2011 (when we start to use porous tantalum acetabular components) and April 2017 were finally included. Their charts, pre-operative, and post-operative radiographs were collected and reviewed. Our institutional review board approval was obtained.

Six patients (7 hips) were lost to follow-up and two patients (2 hips) died of unrelated causes during the follow-up period without undergoing further revision surgery. Of the remaining 45 patients (48 hips), 22 were male (49%) and 23 were female (51%). Their mean age at the time of THA revision was 62.5 years (range, 34 to 85 years). Twenty-one (44%) revisions were on the right hips and twenty-seven (56%) on the left side. The mean follow-up was 75 months (range, 54 to 125 months).

The indication for the revision was aseptic loosening and osteolysis in 38 hips, and ten revisions were the second-stage of a two-stage revision for infection. The mean duration between stages was 6.7 months (3 to 10) with a minimum four weeks of intravenous antibiotics and two weeks orally. The second-stage was indicated after normal results of ESR; CRP and IL-6 were obtained for three times.

The initial diagnosis at the time of the primary THA for the 45 patients (48 hips) was avascular necrosis of the femoral head in 33 hips, posttraumatic arthritis (fractures of the acetabulum, femoral neck, femoral head) in eight hips, and osteoarthritis (secondary to developmental dysplasia of the hip) in seven hips. The most frequent comorbidities among the patients were Hypertension, Diabetes Mellitus, and Anemia [Table 3].

At a mean 6.25 years follow-up, the overall survivorship of the acetabular implants was 100% with the requirement for further revision as the end point. All hips remained well-fixed with no implant failure occurred by the end of this study. Multiple screw fixations of the shells and augments were performed in all hips and the interface between shell and augment was fixed with cement (Fig. 1). Osseointegration signs at the latest follow-up based on the criteria of Moore et al. were as follows: Four hips (8.3%) showed five signs of osseointegration, 30 hips (62.5%) showed four signs, and 14 hips (29.2%) showed three signs.

The mean WOMAC pain score was 90.5 (38.3 to 100), 33 patients had a score higher than 80, nine patients were between 70 and 80, and three patients had a score lower than 70. The mean WOMAC function score was 88.3 (31.9 to 100), 30 patients had a score higher than 80, ten patients were between 70 and 80, and five patients had a score lower than 70. The mean Oxford Hip Score (OHS) was 89.2 (31.8 to 100), 31 patients had a score higher than 80, nine patients were between 70 and 80, and five patients had a score lower than 70. The scores of patient satisfaction were also very good regarding pain relief, function, and recreational activities (Table 4). Five patients reported relatively bad function outcomes such as difficulties walking long distance and climbing stairs, and have to continue using supports. There were no complications reported in a relation with the revision surgery.

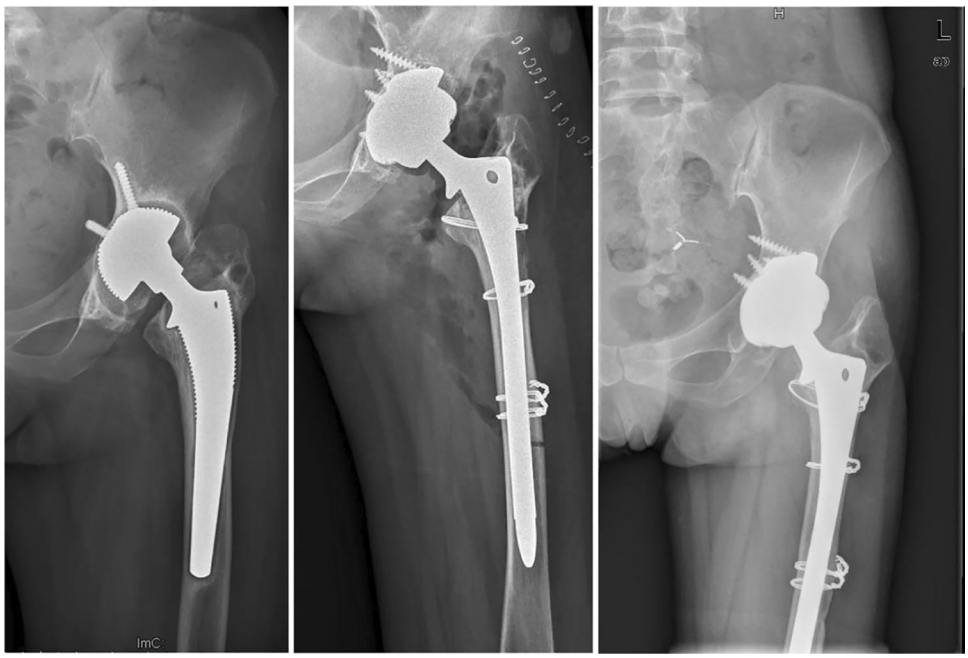

Fig. 1 The figure presents radiographs of an example case (left hip) of using TM shell and augment for Paprosky 3A defect reconstruction: Anteroposterior (AP) radiographs of preoperative (left), postoperative (middle), and at 10 years follow-up (right)

Table 4 Quality of life and functional outcomes

Minimum 54 months follow-up	Mean	Standard deviation	Range
WOMAC (function)	88.3	14.1	(31.9 to 100)
WOMAC (stiffness)	89.4	12.9	(35.4 to 100)
WOMAC (pain)	90.5	12.8	(38.3 to 100)
WOMAC (global)	89.2	14.3	(33.2 to 100)
Oxford Hip Score (OHS)	89.2	13.8	(31.8 to 100)
Satisfaction scores			
Satisfaction (pain)	90.7	8.1	(61.3 to 100)
Satisfaction (function)	89.2	8.6	(61.1 to 100)
Satisfaction (recreational)	90	8.2	(61.1 to 100)
Satisfaction (overall)	90.3	8.1	(61.2 to 100)
Mean satisfaction	90.2	8.1	(61.1 to 100)

Discussion

The technique of using porous tantalum TM shell and augment for acetabular defect reconstruction during complex revision THA has been providing increasing evidence of excellent early to long-term outcomes as reported in published series [16–20]. We have been increasingly using this technique in recent years; however, our experience has not yet been reported. Although this study was conducted at a mid-term (mean 6.25 years) follow-up time, it has also demonstrated excellent results with no report of implant failures so far. These results were consistent with those of similar studies such as the excellent results that reported by Eachempati et al. (41 hips) at a mean of 3.3 years with no implant failure noted and a survivorship of 100% [16]. Flecher et al. (51 hips) has also reported a survivorship of 100% at 5.3 years when only aseptic loosening was defined as the end point and global survivorship of 92.3% [25].

Included patients in our series had no additional pelvic discontinuity (PD) which was probably one of the reasons that no implant failures had occurred so far. Jenkins et al. (58 hips) reported implant survival of 97% at a minimum five years follow-up, with two failure cases one of which occurred in patient with pre-operative PD and five cases with pre-operative PD showed radiolucent line between TM shell and the bone and were considered at risk of further revision [18]. Lochel et al. (53 hips) also reported 92.5% implant survivorship at ten years follow-up with two failures occurred in patients with additional PD [19]. Abolghasemian et al. (34 hips) reported three aseptic loosening of the implants, two of which occurred in patients with PD at five years post-operatively [17]. Our results support the findings of Eachempati et al. [16], Lochel et al. [19], and Jenkins et al. [18] which concluded that the technique of TM shell and augment demonstrated the best results for defects without PD and Paprosky Type 3 defects without PD seem to be among the best indications for this technique.

Achieving reliable initial stability of the implants is very essential for osseointegration to improve bone ingrowth and prevent implants failure [26]. Despite this study was at a mid-term follow-up, all hips were well-fixed and radiographically stable so far. Screw fixation was performed in all shells and augments with cement fixation to the shell-augment interface. This method was strongly

recommended by Jenkins et al. [18] and supported by the findings of Lochel et al. [19]. They suggested that all shells and augments should always be fixed with multidirectional screws and the cup-augment interface should be cemented even with seemingly good initial stability. Lochel et al. [19] reported two failures of aseptic loosening due to poor initial fixation, where shells were not fixed with screws. Jenkins et al. [18] also reported one failure case where screw fixation of the shell and augment and cement fixation of shell-augment interface were not performed. Siegmeth et al. [27] reported that if the shell-augment interface is not fixed with either cement or screws, a potential micromotion might lead to debris generation. However, Beckmann et al. [26] findings showed that additional screw fixation to the cemented shell-augment interface did not result in greater primary stability.

Clinically, a considerably very good to excellent pain relief, functional outcomes, and high levels of patient satisfaction at mid-term follow-up were noted. Studies of similar settings have also demonstrated excellent clinical outcomes for this technique even at longer follow-up [16–20]. Therefore, using TM shell and augment for acetabular defect reconstruction could achieve satisfactory clinical results at mid-term follow-up. Although five patients in our series have to continue using supports and reported relatively bad function outcomes, it is acceptable considering that these patients are older, have undergone multiple surgeries, and have comorbidities.

Alternative options such as Jumbo (extra-large) cups [1], reconstruction cages [3, 4], cemented shells with allograft [2], structural allograft [5], and shells at high hip center [6] have showed satisfactory outcomes in some grades of defects but all have disadvantages. Off-the-shelf cages do not provide biological fixation with no potential of ingrowth and at risk of loosening within seven to ten years [3, 4]. A systematic review of the literature by Beckmann et al. [26] demonstrated that porous tantalum trabecular metal has a statistically significant lower rate of implant failure compared with revision cages for all types of defects including pelvic discontinuity [26]. The use of an extra-large (Jumbo) acetabular component may require reaming of the anterior column due to the anteroposterior diameter of the acetabulum being smaller than the superoinferior dimension, which can result in impingement by the iliopsoas tendon and insufficient primary stability [1]. Allograft impaction and structural allografts have a risk of graft resorption, implant migration, acetabular fracture, and disease transmission [5, 9].

This study had several limitations. The first important limitation was the inability to compare hip scores pre- and post-operatively due to the lack of documentation of pre-operative hip function assessment. The patients were presented to us experiencing pain and difficult to walk with the need for supports. A detailed evaluation of the change of hip function may have showed interesting results.

Secondly, the sample size of this study was relatively small with six patients lost to follow-up which have also limited us from presenting more data. Despite the early start of use of this technique in our hospital as a decade ago, its use was mostly increased in recent years and many cases were excluded because they did not allow possible mid-term follow-up evaluation. Therefore, a future study might include a bigger sample size with longer follow-up time.

A third limitation was that the patients in our study are young with a mean age at the time of the revision of 62.5 years (34 to 85); therefore, our findings were limited to this group of age. Another limitation was that we did not study the spine-pelvis relationship on our cases. Finally, although the length of follow-up time ranged between four and ten years (mean 6.25 years), most of the data were presented at mid-term time, and future follow-up is required to investigate the long-term outcomes.

Conclusion

This study has demonstrated excellent mid-term clinical and radiological outcomes of using porous tantalum TM shells and augments for reconstruction of major acetabular defect without additional PD in revision THA.

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Author contribution Mohammed Alqwbani (first author): Radiological and clinical assessment, data collecting, statistical analysis, and wrote the manuscript.

ZE Wang (first co-author), QR W, QH L and ZY Y: Data collection, statistical analysis, radiological, and clinical assessment.

PD Kang: Study design, radiological, clinical assessment, performed surgeries, and manuscript editing.

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Declarations

Ethics approval This study was approved by the Clinical Trials and Biomedical Ethics Committee of West China Hospital, Sichuan University.

Conflict of interest The authors declare no competing interests.

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