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# The Dome Technique for Managing Massive Anterosuperior Medial Acetabular Bone Loss in Revision Total Hip Arthroplasty: Short-Term Outcomes

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**Purpose**: The dome technique is a technique used in performance of revision total hip arthroplasty (THA) involving intraoperative joining of two porous metal acetabular augments to fill a massive anterosuperior medial acetabular bone defect. While excellent outcomes were achieved using this surgical technique in a series of three cases, short-term results have not been reported. We hypothesized that excellent short-term clinical and patient reported outcomes could be achieved with use of the dome technique.

**Materials and Methods**: A multicenter case series was conducted for evaluation of patients who underwent revision THA using the dome technique for management of Paprosky 3B anterosuperior medial acetabular bone loss from 2013-2019 with a minimum clinical follow-up period of two years. Twelve cases in 12 patients were identified. Baseline demographics, intraoperative variables, surgical outcomes, and patient reported outcomes were acquired.

**Results**: The implant survivorship was 91% with component failure requiring re-revision in only one patient at a mean follow-up period of 36.2 months (range, 24-72 months). Three patients (25.0%) experienced complications, including re-revision for component failure, inter-prosthetic dual-mobility dissociation, and periprosthetic joint infection. Of seven patients who completed the HOOS, JR (hip disability and osteoarthritis outcome score, joint replacement) survey, five patients showed improvement.

**Conclusion**: Excellent outcomes can be achieved using the dome technique for management of massive anterosuperior medial acetabular defects in revision THA with survivorship of 91% at a mean follow-up period of three years. Conduct of future studies will be required in order to evaluate mid- to long-term outcomes for this technique.

**Key Words**: Hip, Bone resorption, Prosthesis failure, Arthroplasty, Tantalum

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## INTRODUCTION

Massive anterosuperior medial acetabular bone loss is an uncommon but serious problem in revision total hip arthroplasty (THA). As the projected incidence of revision THA in the United States is expected to show a substantial increase in the coming years, more practical and creative solutions are needed for management of severe anterosuperior medial bone loss[1]. This particular bone defect is often associated with loss of anterosuperior column support, therefore, it can be classified as a Paprosky 3B bone defect[2]. Current solutions to this clinical scenario include bone allografts with reinforcement cages and, more recently, custom triflange implants and intra-cavitary porous metal (tantalum, Trabecular Metal®; Zimmer Biomet) augments[3-6]. Good to excellent results have been achieved with use of custom triflange implants, and many studies have reported >90% implant survival and patient reported outcomes at mid to long term[4,7-10]. In addition, consistently good results have been obtained with use of porous metal augments at both short and mid-term follow-up, with some recent studies reporting positive results at long-term follow-up[11-13]. Despite achievement of excellent clinical outcomes with use of custom triflange reconstructions, use of this technique does not allow for the real-time customization that is often required upon intraoperative discovery of the full extent of bone defects[14,15].

In order to enable intraoperative tailoring of specific acetabular implants for management of complex massive anterosuperior medial defects, some of the authors of the current study (C.M.M., N.P.S., P.M.C., W.G.P.) have reported utilization of the dome technique for systematic reconstruction of the acetabulum[16]. This technique involves joining two tantalum metal augments together, then press-fitting the augments into the medial void of the acetabulum in order to reconstruct the anterosuperior column for placement of a jumbo cup. Outcomes of three patients who underwent surgery using this technique at a mean follow-up period of 23.6 months (range, 10-37 months) have been described, and none of the three patients required further revision at the time of final follow-up[16].

The purpose of this study is to provide additional information regarding the clinical outcomes and implant survivorship of patients who underwent treatment using the dome technique by reporting on all of our patient cases with a minimum follow-up period of two years. Considering the successful outcomes of previous patients who underwent revision THA utilizing porous metal augments, including procedures performed using the dome technique, we hypothesized that patients undergoing a procedure using the dome technique would show excellent implant survival and patient reported outcomes.

## MATERIALS AND METHODS

This multicenter case series was conducted for evaluation of patients who underwent revision THA using the dome technique from 2013-2019 with a minimum clinical follow-up period of two years. This study was approved by the Institutional Review Board (IRB) of Mass General Brigham (No. 2021P002742) and conducted according to the World Medical Association Declaration of Helsinki (2013). The informed consent was exempt by the IRB.

The indication for use of the dome technique was Paprosky 3B acetabular bone defects with massive anterosuperior medial bone loss. The cases presented were contributed by five of the authors (C.M.M., N.P.S., P.M.C., H.S.B., W.G.P.). Twelve cases in 12 patients were included in our study, including two patients from the original study[16], while five patients who underwent revision THA using the dome technique but with a follow-up period of less than two years were excluded. A review of the 12 patients' charts was performed for collection of baseline demographics (age, sex, body mass index [BMI], American Society of Anesthesiologists [ASA] Physical Status Classification System score, smoking history, hip surgical history) surgical variables (patient presentations, radiographic findings, postoperative weight bearing status, and findings of infectious workup) and outcome variables (patient reported outcomes, follow-up notes, and follow-up duration). Trends in our series were described using basic statistics, including means, standard deviations, and percentages. Statistical analysis was performed using IBM SPSS Statistics for Windows (ver. 28.0; IBM).

The same surgical technique was performed by all surgeons, with minor variations in precise placement of components in order to accommodate the anatomy of each patient[16]. Each patient was placed in the lateral decubitus position and an extensile posterior approach was used. A pre-operative infectious workup was completed prior to performance of a revision procedure. The posterior capsular tissue was tagged with a No. 5 Ethibond suture and repaired at the end of the procedure. Following dislocation of the hip, the femoral head was removed, and the stems were examined for loosening and revised if indicated (n=6), and a pocket anterior/superior to the acetabular component was created for the trunnion. In all cases, the polyethylene liner was removed and

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a loosened acetabular component was identified and gently removed after complete disruption of the bone-implant interface. Following identification of the obturator foramen, defining the inferior margin of the native acetabulum, the acetabulum was debrided for removal of all remaining fibrous tissue using electrocautery and a Cobb elevator.

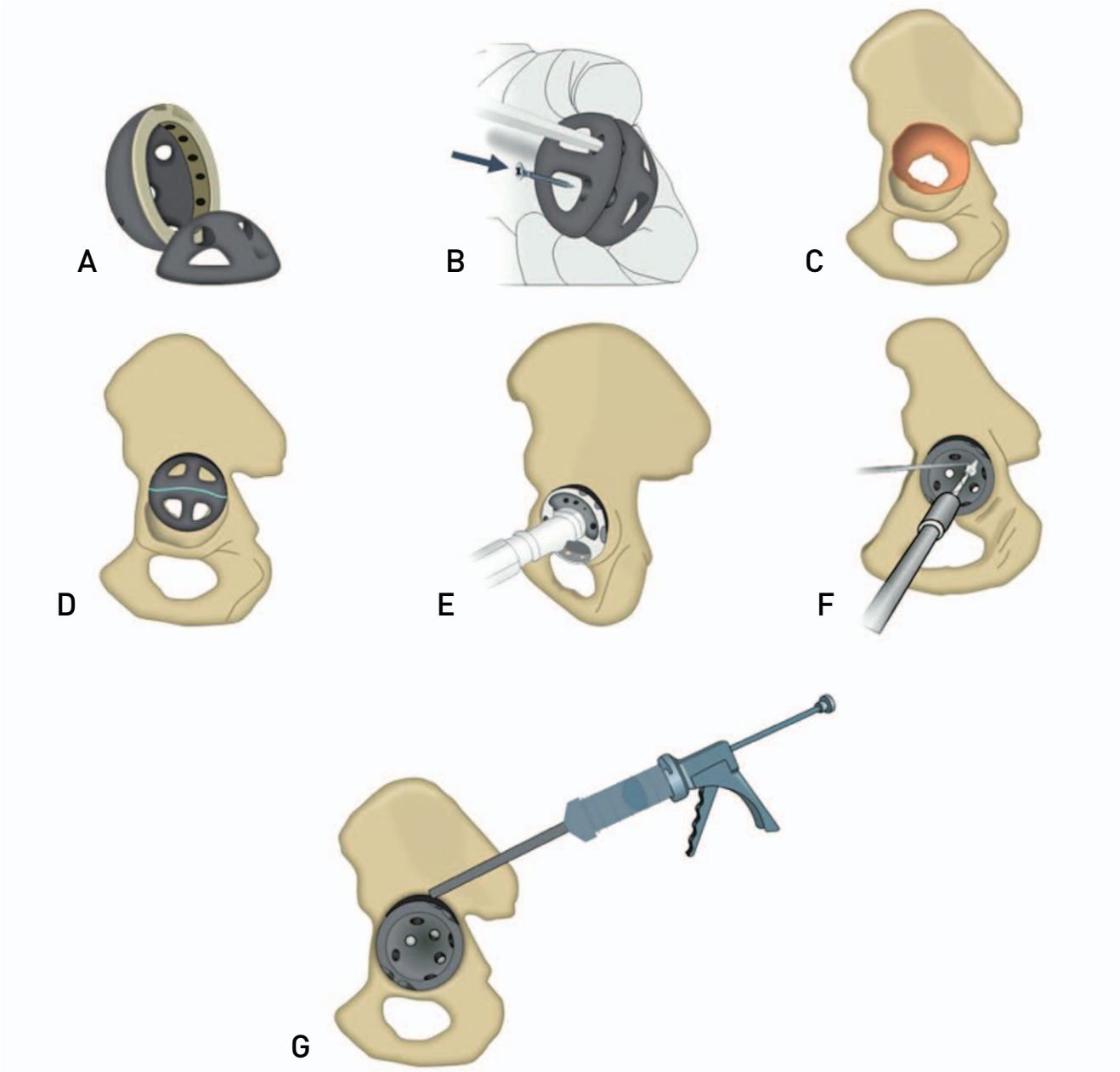


**Fig. 1.** (**A**) Example image of porous metal augments. (**B**) After trialing, appropriately sized porous metal augments are secured together with screws. (**C**) Example of a Paprosky 3B defect that could be addressed using the dome technique. (**D**) Impaction of the dome technique construct into the acetabular defect. The construct adequately spans the anterosuperior medial bony defect in order to obtain press fit to the rim surrounding the defect. (**E**) Sequential reaming is performed in reverse in order to enable appropriate sizing of the acetabulum between the newly constructed column and the intact posteroinferior column. (**F**) After reaming, the acetabular component is impacted into place with addition of screws for additional fixation. We recommend placement of both superior and inferior (ischial +/– superior pubic ramus screws) in order to avoid abduction failure. Assessment of component position and screw placement is performed prior to unitization using intra-operative fluoroscopy. (**G**) After addition of all screws, cement is placed between the cup and the augments in order to unitize the two together and to create one large, fixed construct.

Careful inspection of the anterosuperior and posteroinferior columns was then performed and the cobb was used to ascertain the presence of a pelvic discontinuity (n=6). Anterosuperior medial bone loss significant enough to be classified as a Paprosky 3B defect was identified in each case.

Trial augments were then joined together on the back table to fill the defect. Once the surgeon was satisfied with the trial reconstruction, final porous metal augments were pieced together, secured with screws, and inserted into the defect (Fig. 1). Trabecular Metal® Augments (Zimmer Biomet) were used as porous metal augments in all cases. Considering the variety of different sizes of augments that can be pieced together, sizing of the final porous metal augment unit is performed in order to enable adequate spanning of the anterosuperior medial bony defect in order to obtain press fit to the rim surrounding the defect. Because a press fit is obtained using porous metal augments, screw fixation through the augments is not required. Crushed cancellous bone graft can be added to the reconstruction at this point if necessary; however, it was not used in any case. Sequential reaming was then performed in reverse in order to enable appropriate sizing of the acetabulum between the newly constructed column and the intact posteroinferior column. After reaming, the acetabular component is impacted into place with addition of screws for additional fixation. The authors recommend placement of both superior and inferior (ischial +/– superior pubic ramus screws) in order to avoid abduction failure. Component position and screw placement were assessed prior to unitization using intra-operative fluoroscopy. After addition of all screws, cement is placed between the cup and the augments in order to unitize the two together and to create one large, fixed construct (Fig. 1). In nine cases (75.0%), a revision jumbo tantalum shell was used and impacted into place in the appropriate inclination and anteversion, with a goal of 50% contact between the acetabular shell and the residual host bone.

In eight cases (66.7%), the liner was cemented into the acetabular component, followed by a trial reduction. A dual-mobility liner was utilized in nine cases (75.0%) and a PolarCup™ (Smith & Nephew) was used as the dual-mobility liner in five (55.6%) of these cases. As appropriate, a cobalt chromium or ceramic ball head was impacted onto the trunnion, the hip was reduced, and assessment of leg lengths and stability was performed, followed by copious irrigation and closing of the wound. A list of the exact components used for each patient is shown in Table 1, and examples of two successful cases are shown in Fig. 2.

## RESULTS

Twelve cases of revision THA performed using the dome technique who met the inclusion criteria were identified in 12 patients. The mean follow-up period was 36.2 months (range, 24-72 months). The mean age of the patients at the time of surgery was 69 years (range, 53-86 years), with six females (50.0%), and a mean BMI of 26.9 kg/m$^2$ (range, 21-35 kg/m$^2$). All patients presented with severe groin pain and difficulty with weight bearing on the affected side. Of the patients with available data, five patients (41.6%) had a history of smoking. Of note, the dome technique was performed in the setting of a planned reimplant after resection arthroplasty with placement of an antibiotic spacer for management of periprosthetic joint infection (PJI) in two (16.7%) of the patients in our study. Immediately following performance of surgery using the dome technique, eight (66.7%) patients performed toe-touch weight bearing for six weeks and four (33.3%) patients performed toe-touch weight bearing for 12 weeks.

Regarding surgical outcomes, at a mean follow-up period of 36.2 months, component failure requiring re-revision occurred in only one patient. Component failure in this patient was in the setting of an acetabular fracture that occurred one week postoperatively, and was managed with explant of all acetabular components, open reduction and internal fixation, and reimplantation of a jumbo tantalum shell (Fig. 3). Radiographic signs of stable osseointegration of the dome technique components as described by Moore et al.[17] was observed in all other patients. Two other patients experienced complications prior to the most recent follow-up. One patient suffered a post-operative *Staphylococcus epidermidis* PJI which was managed with debridement, exchange of the dual-mobility head and inner liner, antibiotics, and implant retention. The other patient suffered a postoperative hip dislocation with inter-prosthetic dissociation of the dual-mobility component requiring exchange of the head and inner liner of the dual-mobility component.

All patients had returned to ambulating at their most recent follow-up visit, despite three complications, including one case of component failure. Regarding patient reported outcomes, both preoperative and postoperative PROMs (patient reported outcome measures) were available for seven patients (58.3%). Of the five patients who completed the HOOS, JR (hip disability and osteoarthritis outcome score, joint replacement), three patients showed dramatic improvement (37 to 100, 41 to 100, and 31 to 82), no change in score was observed for one patient (who required open reduction with

**Table 1.** Patient Demographics and Outcomes

| Patient No. | Age (yr) | Sex | BMI (kg/m$^2$) | ASA class | Previous hip surgery, years prior | Components placed at dome technique surgery | Pre-op and Post-op PROMs | Follow-up notes | Follow-up duration (mo) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 75 | F | 24 | 2 | Revision THA 4 years prior | 58 mm Zimmer G7 acetabular cup with uncemented dual-mobility liner | • Pre-op – SF-12 Mental: 52.97, SF-12 Physical: 42.03, PCS pain scale: 9<br>• 1-year Post-op – SF-12 Mental: 50.88, SF-12 Physical: 49.27, PCS pain scale: 3 | Doing well at 3 years follow-up | 42.3 |
| 2 | 64 | M | 30 | 3 | Primary THA 29 years prior | 68 mm Zimmer Trabecular Metal acetabular cup, 53 mm cemented Smith and Nephew PolarCup with uncemented dual-mobility liner. Wagner SL revision femoral component. | N/A | Doing well at 2 years follow-up | 24 |
| 3 | 67 | M | 26 | 3 | Resection arthroplasty and antibiotic spacer placed 2 years prior | 60 mm Zimmer G7 cup, uncemented dual-mobility liner, Zimmer Salvage System Proximal Femur Replacement | N/A | Doing well at 2 years follow-up | 25 |
| 4 | 69 | M | 27 | N/A | Revision THA 3 years prior | 62 mm Zimmer Trabecular Metal Cup, 62 mm/47 mm cemented PolarCup dual-mobility liner, Depuy AML femoral revision stem | • Pre-op – HOOS, JR: 37<br>• 1-year Post-op – HOOS, JR: 100 | Doing well at 2 years follow-up | 28 |
| 5 | 64 | F | 25 | N/A | Revision THA 10 years prior | 60 mm Zimmer Trabecular Metal Cup, cemented anatomic dual-mobility liner, Stryker Omniflex Femoral Stem | • Pre-op – HOOS, JR: 41<br>• 1-year Post-op – HOOS, JR: 100 | Doing well at 2 years follow-up | 38 |
| 6 | 83 | M | 30 | N/A | Had antibiotic loaded spacer placed 4 months prior for PJI | 64 mm Zimmer Trabecular Metal Cup, Cemented 40 mm Lipped Liner, Biomet Arcos Femoral component | • Pre-op – HOOS, JR: 31<br>• 1-year Post-op – HOOS, JR: 82 | Doing well at 3 years follow-up | 34 |
| 7 | 86 | F | 21 | 2 | Primary THA 2 years prior | 58 mm Smith and Nephew Porous Shell, cemented 50 mm/47 mm PolarCup liner, Srtyker PCA femoral stem | N/A | Doing well with occasional groin aches controlled with OTC pain medications. | 36 |

(Continued to the next page)

**Table 1.** Continued

| Pati-ent No. | Age (yr) | Sex | BMI (kg/m²) | ASA class | Previous hip surgery, years prior | Components placed at dome technique surgery | Pre-op and Post-op PROMs | Follow-up notes | Follow-up duration (mo) |
|---|---|---|---|---|---|---|---|---|---|
| 8 | 74 | M | 35 | 2 | Primary THA 4 months prior | 60 mm Zimmer TM Shell, 47 mm Smith and Nephew PolarCup, cemented 47 mm ×28 mm Smith and Nephew dual-mobility liner 47 mm ×28 mm | • Pre-op – HOOS, JR: 69.6<br>• 1-year Post-op – HOOS, JR: 66.1 | Had *Staphylococcus epidermidis* PJI of the same hip at 30 months Post-op, managed with DAIR | 48 |
| 9 | 70 | F | 27 | 2 | revision THA for acute discontinuity and pseudotumor 2 years prior | 64 mm Zimmer TM Shell, 49 mm Smith and Nephew PolarCup, cemented 49 mm ×28 mm Smith and Nephew Polar XLPE Insert 49/28 | • Pre-op – HOOS, JR: 66.1<br>• 1-year Post-op – HOOS, JR: 66.1 | Hip dislocation with interprosthetic dissociation of dual-mobility component 6 months Post-op requiring open reduction with dual-mobility inner liner exchange. Otherwise, no further complications | 26 |
| 10 | 63 | F | 24 | 2 | Hemiarthro-plasty 30 years prior | 54 mm Stryker titanium acetabular Component, uncemented 40 mm X3 liner, Zimmer dual mobility 40 mm ×26 mm head | N/A | ORIF of acetabulum fracture 1 week Post-op, which required explant of dome acetabular augments and a new jumbo porous metal cup to be placed. At 6 years follow-up patient is ambulating with minimal hip pain or muscle weakness. | 72 |
| 11 | 53 | F | N/A | N/A | Prior THA 6 years prior | Revision jumbo tantalum shell, cemented highly crosslinked standard polyethylene liner | N/A | Doing well at 3 years follow-up | 37 |

(Continued to the next page)

**Table 1.** Continued

| Patient No. | Age (yr) | Sex | BMI (kg/m²) | ASA class | Previous hip surgery, years prior | Components placed at dome technique surgery | Pre-op and Post-op PROMs | Follow-up notes | Follow-up duration (mo) |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 69 | M | N/A | N/A | two-stage revision for PJI 9 years prior | Revision jumbo tantalum shell, cemented highly crosslinked standard polyethylene liner | • Pre-op – SF-12 physical component summary score: 34.1<br>• 2-year Post-op – SF-12 physical component summary score: 53.5. | Doing well at 2 years follow-up | 24 |

Patient #1-#9 and #11 and #12 had signs of well-fixed porous metal implants at most recent follow-up.
F: female, M: male, BMI: body mass index, N/A: not available, ASA: American Society of Anesthesiologists, THA: total hip arthroplasty, PJI: periprosthetic joint infection, Pre-op: preoperative, Post-op: postoperative, PROMs: patient reported outcome measures, PCS: pain catastrophizing scale, HOOS, JR: hip disability and osteoarthritis outcome score, joint replacement, OTC: over-the-counter, DAIR: debridement, antibiotics, and implant retention, ORIF: open-reduction internal fixation.

head and inner dual-mobility liner exchange for hip dislocation), and one patient who suffered PJI (69.6 to 66.1) showed a decline in score.

## DISCUSSION

This retrospective case series including 12 patients with massive anterosuperior medial acetabular defects who underwent treatment using the dome technique demonstrates excellent (~91%) implant survivorship at a mean follow-up period of 36.2 months, with one patient requiring re-revision of the construct in the setting of an acetabular fracture. While three patients (25.0%) suffered complications that required surgical management, adequate ambulation was observed for all patients at their most recent follow-up. Similar complication rates were reported in cases involving use of singular porous metal wedge implants in management of Paprosky 3A/3B defects[18,19]. In addition, while we are only able to report short-term outcomes, other studies reporting mid to long-term outcomes from use of porous metal augments in acetabular revision have not reported on evaluation of cases involving implants that are pieced together and press fitted into the acetabulum, as we have done with the dome technique[11]. Nevertheless, our results are promising given that few treatment modalities for anterosuperior medial bone loss have been described; in addition, a study on acetabular augments of similar composition (tantalum, Trabecular Metal®) including long-term follow-up with an estimated mean survivorship of 8.99 years has been reported[11]. Of note, only two other case reports have described the use of multiple porous metal acetabulum augments for management of Paprosky 3B defects, however, these two individual cases involved use of two different techniques (separate from the dome technique) and a follow-up period of less than two years[20,21].

There are many options for management of massive acetabular bone loss during revision THA. While the focus of our study involves examination of a novel method of joining porous metal augments together, other options for management of Paprosky 3A/3B defects include antiprotrusio cages, porous metal augments with shells, hemispherical implants with hooks and flanges, custom triflange reconstruction, or bone impaction grafting with metal mesh[22]. Of note, bone impaction grafting with metal mesh or cages has poor utility in management of Paprosky 3B defects, particularly in the setting of pelvic discontinuity, as studies that included >10 years follow-up have demonstrated the potential for occurrence of bone resorption, leading to failure of the con-

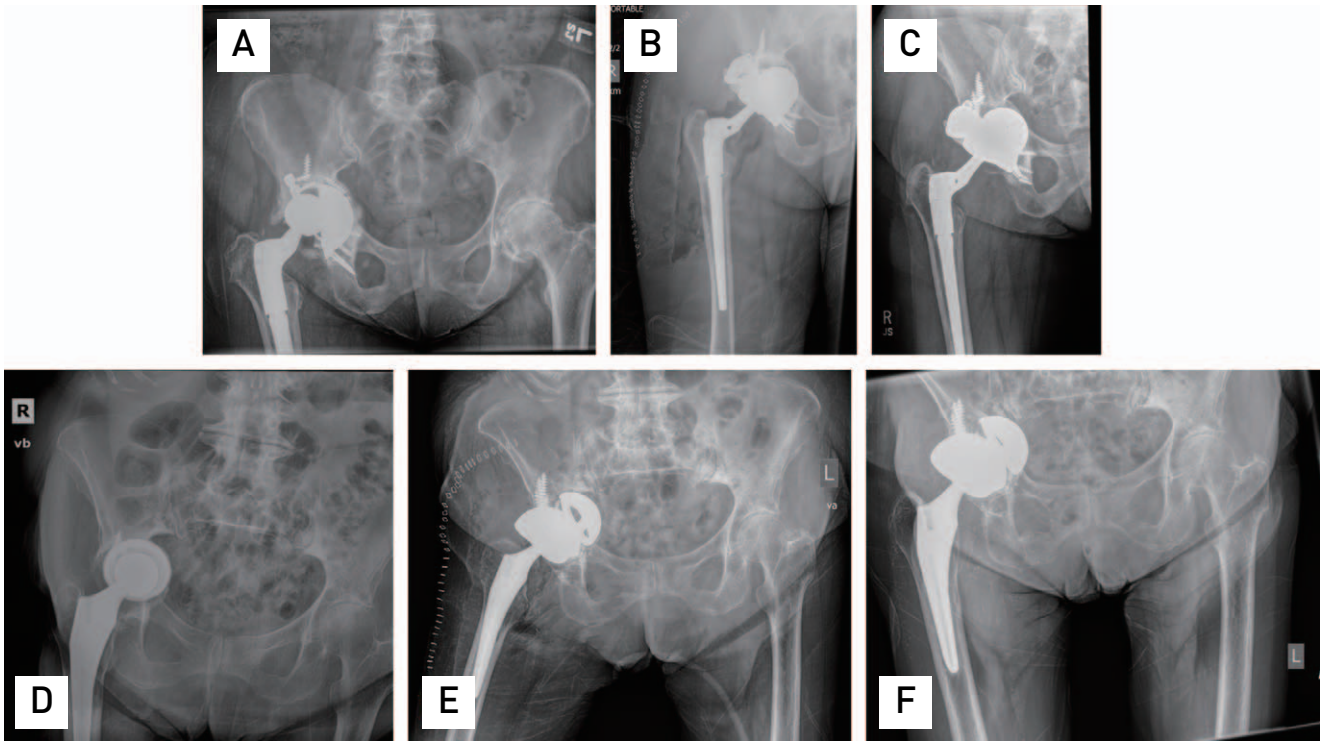


**Fig. 2.** (**A**) Preoperative anteroposterior (AP) pelvis X-ray of example case 1; a patient who underwent previous revision total hip arthroplasty for management of acute discontinuity and pseudotumour with new X-rays demonstrating failure of the acetabular component with vertical inclination, screw breakage, and massive anterosuperior medial bone loss. A chronic pelvic discontinuity was identified on computed tomorgraphy. (**B**) Postoperative AP right hip X-ray of example case 1 demonstrating successful management using the dome technique. An additional area of posterosuperior acetabular bone loss was identified and a 15×50 augment was placed for supplemental fixation. (**C**) AP right hip X-ray of example case 1 demonstrating successful management using the dome technique at the last follow-up (26 months). (**D**) Preoperative AP pelvis X-ray of example case 2 demonstrating massive anterosuperior medial bone loss in a case of failed primary total hip hemiarthroplasty. (**E**) Postoperative AP pelvis X-ray of example case 2 demonstrating successful management using the dome technique. (**F**) AP pelvis X-ray of example case 2 demonstrating successful management using the dome technique at the last follow-up (36 months).

struct[23]. Studies of porous metal augments with/without shells have reported construct survival ranging from 90-100% at approximately three years follow-up[3,24,25]. Similarly, antiprotrusio cages have shown construct survival greater than 90-95% at >3 years follow-up[22,26].

Using the dome technique, large anterosuperior medial bone defects can be addressed during intraoperative joining of wedge-shaped tantalum augments using screws. These augments range in size from 50-70 mm in diameter by 10-30 mm in thickness, thus reconstruction of a wide variety of anterosuperior medial defects can be performed as the defects are fully elucidated during performance of the revision procedure. This intra-operative customization remains a benefit associated with use of the dome technique compared to other options for management of bony defects, such as custom triflange reconstructions, which are created weeks prior to performance of surgery and require three-dimensional reconstruction of advanced imaging[10]. Additional benefits of utilizing porous metal augments as we did using the dome technique include the capacity to accept dual-mobility liners in an effort to reduce dislocation rates, and avoidance of risks associated with allografting, such as infection transmission and resorption of bone[5,27]. Conversely, lack of capacity for restoration of bone stock, which could have implications in regard to any subsequent revisions, and possible occurrence of tantalum metallosis secondary to micromotion are potential disadvantages of porous metal augments. We believe that tantalum metallosis can likely be avoided when using the dome technique, which enables secure utilization of the porous metal construct with screws along with an additional cement interface between the augments and cup[5,14].

This study should be interpreted in the context of its limitations. First, as a retrospective case series that included a

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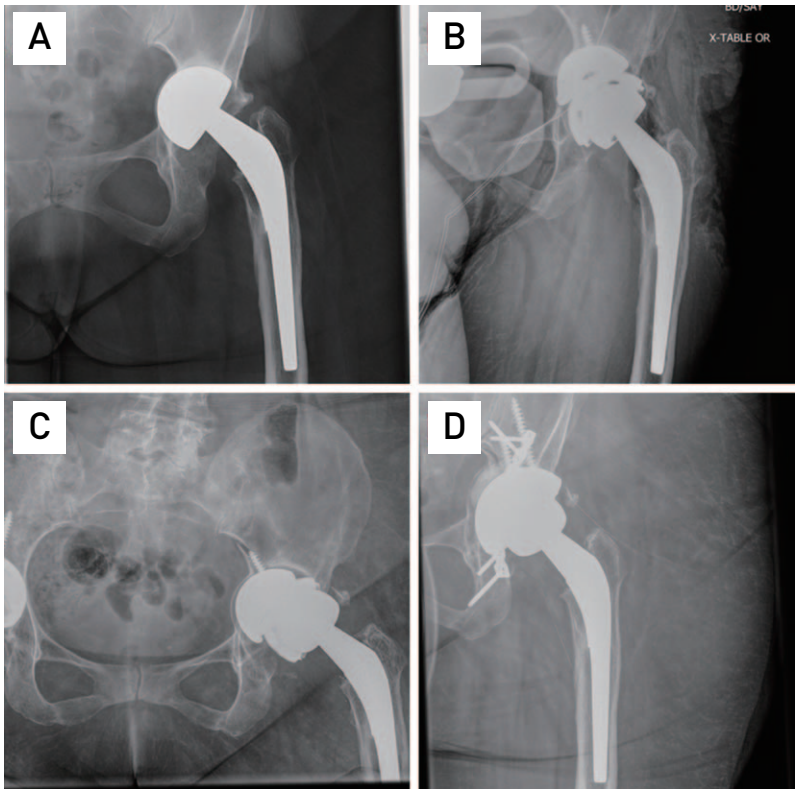


Fig. 3. (A) Preoperative anteroposterior (AP) pelvis X-ray of example case 3 demonstrating massive anterosuperior medial bone loss in a case of failed bipolar hemiarthroplasty. (B) Postoperative AP pelvis X-ray of example case 3 demonstrating management usingthe dome technique. (C) AP pelvis X-ray taken after a fall demonstrating a transverse acetabulum fracture through the dome technique construct. (D) AP pelvis X-ray taken after re-revision of the hip arthroplasty. An open-reduction internal fixation of the acetabulum was performed with placement of a porous metal acetabulum shell and a bipolar femoral head.

relatively small sample size, certain biases including selection and referral bias should be considered. Regarding our acquisition of patient data, preoperative and postoperative PROMs were not available for analysis for all patients, which would otherwise provide insight regarding patients who may be functioning at a low level despite adequate implant stability and satisfactory osseointegration. In addition, because we reported on cases with a minimum follow-up period of two years (and a mean follow-up period of 36.2 months) conduct of additional studies will be required in the future for evaluation of mid- and long-term outcomes using this technique.

## CONCLUSION

At a mean of 36 months, revision THA showed excellent outcomes with 91% survivorship using the dome technique for management of massive anterosuperior medial acetabular defects. Conduct of future studies will be required for evaluation of mid- to long-term outcomes for patients undergoing revision THA utilizing this technique.

## FUNDING

No funding to declare.

## CONFLICT OF INTEREST

T.J.H. and C.M.B. have no conflicts to disclose. C.M.M. is a speaker and paid consultant for Smith & Nephew and receives research support from Zimmer Biomet. H.S.B. receives royalties from and is a paid consultant for Exactech and Smith & Nephew, has stock options in Exactech, receives research support from Zimmer Biomet, and receives royalties from Wolters Kluwer. N.P.S. is a board or committee member of AAOS and the Eastern Orthopaedic Association, has publishing royalties with Elsevier, and is a paid consultant for Medacta, Microport, Smith & Nephew, and Zimmer. P.M.C. is a board or committee member of AAOS and the American Association of Hip and Knee Surgeons,

is a paid consultant for DePuy, A Johnson & Johnson Company, Stryker, Hip Innovation Technology, and Zimmer, is a paid presenter or speaker for Smith & Nephew, and has stock or stock options in Parvizi Surgical Innovation. W.G.P. is a paid consultant for CeramTec and ConvaTec, has IP royalties from Innomed, is a paid consultant and has stock options in Intellijoint, is on the editorial board of Journal of Arthroplasty, is a paid consultant for Next Science, receives publishing royalties, financial or material support from Wolters Kluwer Health - Lippincott Williams & Wilkins; and receives IP royalties and is a paid consultant for Zimmer.

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