



# Excellent Midterm Results of Triflange Patient Matched Implants for Extensive Acetabular Bone Defect

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**Purpose:** Reconstruction of extensive acetabular bone defects is one of the most challenging problems encountered by arthroplasty surgeons. Triflange patient matched implants (PMI) offer the potential advantages of immediate, rigid fixation with a superior individualized fit. The purpose of this study was to evaluate the clinical and radiographic midterm results of PMI in extensive acetabular defect reconstruction.

**Materials and Methods:** The current prospectively designed retrospective review examined 13 consecutive patients (5 males and 8 females) with a mean age of 69 years undergoing revision hip arthroplasty with Paprosky type 3B acetabular defects reconstructed using PMI between October 2011 and December 2016. A successful result was defined as a postoperative increase in Harris hip score (HHS) of >20 points with a radiographically stable implant (assessed with hip X-rays) and no need for additional acetabular reconstruction.

**Results:** Twelve out of the 13 patients in the study were available for follow-up with mean duration of 50 months. One patient died during the study period due to an unrelated cause. The mean HHS increased from 41 to 82 points. Eleven out of 12 acetabular components were well fixed and pelvic discontinuity healed in all patients.

**Conclusion:** Custom triflange PMI is an excellent option for management of complex and extensive acetabular defects with or without pelvic discontinuity.

**Key Words:** Custom triflange patient matched implant, Extensive acetabular defects, Pelvic discontinuity

## INTRODUCTION

The management of extensive acetabular bone defect and pelvic discontinuity in revision total hip arthroplasty (THA) is one of the most challenging problems encountered by orthopaedic surgeons<sup>1)</sup>. Though the incidence of pelvic discontinuity documented in literature is low ranging between 1% and 5%<sup>1)</sup>, of the number THAs performed annually has increased. Furthermore, given a younger and more active patient population, the volume of revision THA is expected to substantially increase over the next few decades<sup>2,3)</sup>.

There are various options for management of acetabular bone defects during revision THA such as placing the

**Submitted:** June 18, 2020 **1st revision:** September 22, 2020

**Final acceptance:** October 13, 2020

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acetabular cup in high hip center<sup>4)</sup>, using a large hemispherical acetabular component<sup>5)</sup>, cup cage constructs<sup>6)</sup>, jumbo acetabular components with porous metal augments<sup>7)</sup> and allograft-prosthetic composites. Although these options substantially improve the orthopaedic surgeon's ability to reconstruct severe acetabular bone defects, they are complex and technically difficult<sup>8)</sup>.

The wide number of treatment options highlight the complexity of management of acetabular bone defects during revision THA, however, all options focus on a common goal to heal discontinuity and establish a stable acetabular construct<sup>9)</sup>. Given the variety of shape and sizes of pelvis and the variability in bone defects most conventional methods available for reconstruction are challenging to use. In response to these challenges, a custom-designed triflange acetabular component known as a triflange patient matched implant (PMI) was introduced for treatment of extensive acetabular bone defects<sup>10)</sup>. PMIs offer the potential advantages of immediate, rigid fixation with a superior fit individualized to each patient. The purpose of this prospectively designed retrospective review was to evaluate the clinical and radiographic midterm results of PMI in extensive acetabular defects in revision hip reconstruction<sup>9)</sup>.

## MATERIALS AND METHODS

A prospectively designed retrospective review was conducted between October 2011 and December 2016 to evaluate the clinical and radiological results of patients undergoing revision hip reconstruction using a PMI acetabular component. Patient demographics are reported in Table 1. Clinical results were evaluated using pre- and postoperative Harris hip scores (HHS)<sup>11)</sup>. Patients were evaluated radiologically using anteroposterior and lateral radiographs preoperatively<sup>7)</sup> for classification of the defect according to the Paprosky classification system<sup>12)</sup> and postoperatively for component position and migration, osteolysis and bone bridging across the fracture<sup>7)</sup>. A successful result was defined as a postoperative increase in HHS of >20 points at 12 months follow-up with a radiographically stable implant without signs of loosening or migration and no need for additional acetabular reconstruction<sup>9)</sup>. Co-morbidities were assessed according to the American Society of Anesthesiologists grading system<sup>13)</sup>.

### 1. Implant Design and Manufacturing

We used a porous coated Triflange acetabular PMI (Biomet Inc., Warsaw, IN, USA) for all reconstructions. The manu-

facturing of the prosthesis started with a computed tomography (CT) scan sequence with metal deletion software of the patient's pelvis and 3-dimensional (3D) reconstruction of patient's hemi-pelvis using these CT images. A design of the patient's hemi-pelvis along with acetabulum and the bone defect was fabricated on the computer using the CT images (Fig. 1). A custom model acetabular component was made using 3D printing with plastic. Component flanges were designed with optimal geometry and angulation to provide an exact fit against the existing bone and bridge defects to facilitate implant fixation. The hip center and acetabular cup orientation were determined using pelvic landmarks and anatomic planes. All factors specific to the patient were taken into consideration, including leg length discrepancy, cup size, and any existing femoral component. The cup closure angle generally was targeted at 35 to 40 degrees from horizontal and the anteversion angle was established using the plane of the iliac wing and the obturator foramen. The model hemi-pelvis and sample plastic implant were sent to the operating surgeon for review to allow the surgeon an opportunity to make any necessary changes in the implant. Once the implant design had been finalized by the surgeon, the final implant was milled out

**Table 1.** Patient Demographics

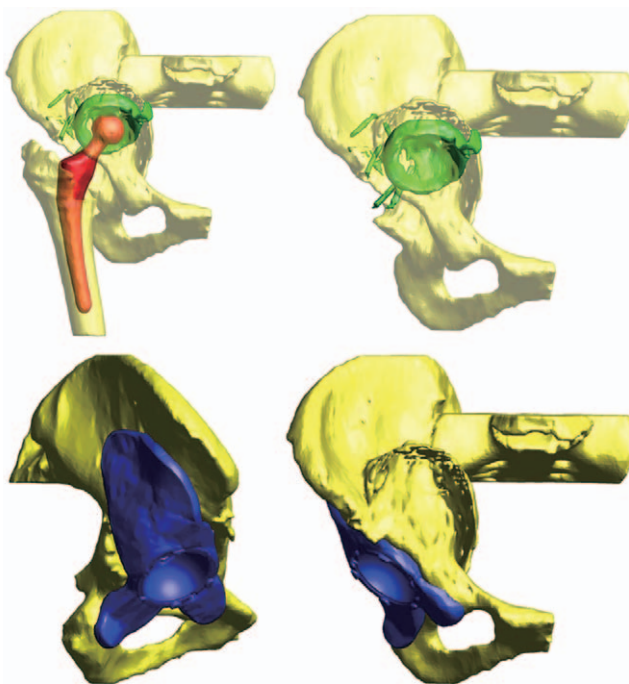
Variable	Value
No. of patients	13
Sex	
Male	5 (38.5)
Female	8 (61.5)
Operative side	
Right	7 (53.8)
Left	6 (46.2)
Age (yr)	69 (57-86)
BMI (kg/m <sup>2</sup> )	27
ASA grade	
Grade I	0 (0)
Grade II	11 (84.6)
Grade III	2 (15.4)
Grade IV	0 (0)
Grade V	0 (0)
Type of surgery	
Cup only revision	7 (53.8)
Both component revision	6 (46.2)
Pelvic discontinuity	
Present	5 (38.5)
Absent	8 (61.5)

Values are presented as number only, number (%), or mean (range).

BMI: body mass index, ASA: American Society of Anesthesiologists grading system.

of titanium. Triflange Acetabular Component offers a PPS® Porous Plasma Spray coated bone-implant interface that incorporates proven RingLoc® locking technology<sup>9,14</sup> (Fig. 2).

The time required for planning and completion of the implant is about six weeks. A plastic model of the patient’s hemi-pelvis and the implant was provided with the final implant for proper orientation and positioning in the patient during surgery.



**Fig. 1.** Digital templates of the patient matched implants [This image was provided from the manufacture [Zimmer Biomet] during the production process.].



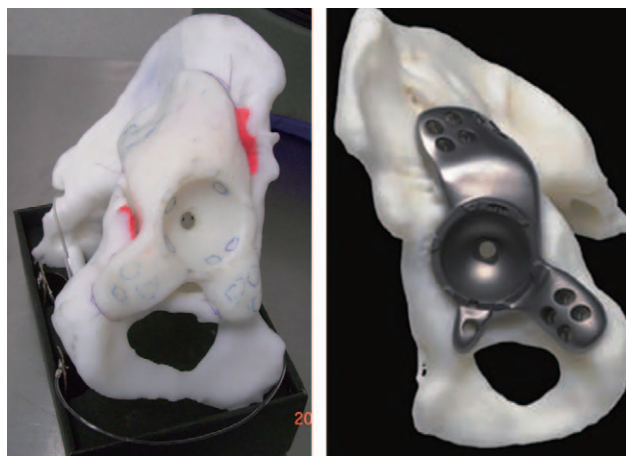
**Fig. 2.** Patient matched implant with porous coating [https://www.zimmerbiomet.com/medical-professionals/hip/product/triflange-acetabular-component.html].

## 2. Surgical Technique

All surgeries were performed by the senior author using an extensile posterior approach with necessary exposure of patient’s hemi-pelvis including ilium, ischium and pubis in order to obtain an adequate view of the bony defects and the bony surfaces required for screw fixation. Bone was curetted to remove all the soft tissue and to get good bleeding bone. Placement of the implant was confirmed using the plastic model of the hemi-pelvis and implant. Osteophytes and bony spikes were removed to facilitate the proper placement of final implant. The final PMI was seated in the same position as seen on the model and fixed in place with two cortical screws, one each in the ilium and ischium (Fig. 3). The subsequent locking screws were placed using the drill guide. No bone graft was used in this surgical technique as the perfect fit of the PMI addressed concerns regarding defects. A high-walled vitamin E polyethylene liner was used in all the patients. When required, the femoral revision was done using the ARCOS revision stem (Zimmer Biomet, Warsaw, IN, USA). Well-fixed stems were retained, and ceramic heads were used in all patients.

Postoperatively patients were allowed weight bearing as tolerated and ambulated using a walking frame under physiotherapist supervision typically from the first postoperative day and were shifted to elbow crutches when comfortable. All patients were put on a supervised physiotherapy regimen.

Patients were followed by the senior author at 6 weeks, 6 months, 1 year and as required thereafter with X-rays of the pelvis<sup>7</sup>. At each visit the patients were evaluated for pain, gait, range of hip motion, and muscle strength and HHS was



**Fig. 3.** Plastic model of hemi-pelvis with implant template and the actual implant.

recorded. Immediate postoperative and most recent X-rays were reviewed and compared for the presence of radiolucent lines, healing of pelvic discontinuity, and evidence of loosening, migration, screw breakage or migration. Pelvic discontinuity was considered healed if bridging callus or trabecular bone was visible across the site of the discontinuity. The discontinuity was considered to be unhealed if the fracture line was still visible or if there was evidence of loosening of the prosthesis or broken screws at the time of the latest follow-up. Any movement of the implant or screws of more than 2 mm was considered migration. Components were classified as loose if there was component migration

of 2 mm or more or screw breakage. Probable loosening of the implant was considered if there was a radiolucent line of more than 1 mm in all three zones without migration, rotation, or screw breakage<sup>15</sup>.

### 3. Statistical Analysis

A paired *t*-test was used for calculating the differences in the pre- and postoperative HHS with a confidence interval of 95%. A probability value of <0.05 was considered statistically significant. Statistical analysis was done using the 'open EPI' online site ([https://www.openepi.com/Menu/OE\\_Menu.htm](https://www.openepi.com/Menu/OE_Menu.htm)).

### 4. Ethics Statement

As the study is a prospectively designed retrospective review, the study was exempted from ethical committee review.

### RESULTS

Thirteen consecutive patients, 5 males and 8 females with a mean age of 69 years with Paprosky type 3B acetabular defects with or without pelvic discontinuity (Fig. 4-6, Table 1) were reconstructed using PMI (Zimmer Biomet). Twelve out of thirteen patients were available for follow-up, and one patient died during the period of study due to an unrelated cause. The last follow-up for this patient was at 18 months. The mean duration of follow-up was 50 months (range of 42 to 70 months). Five out of thirteen patients had pelvic discontinuity along with Paprosky type 3B defect. Six patients had an infected hip after revision THR with

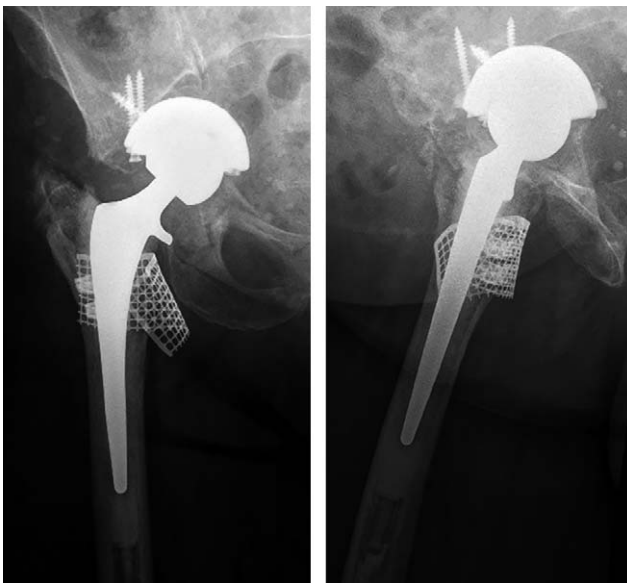


Fig. 4. Preoperative X-rays showing Type 3B acetabular defect with pelvic discontinuity.

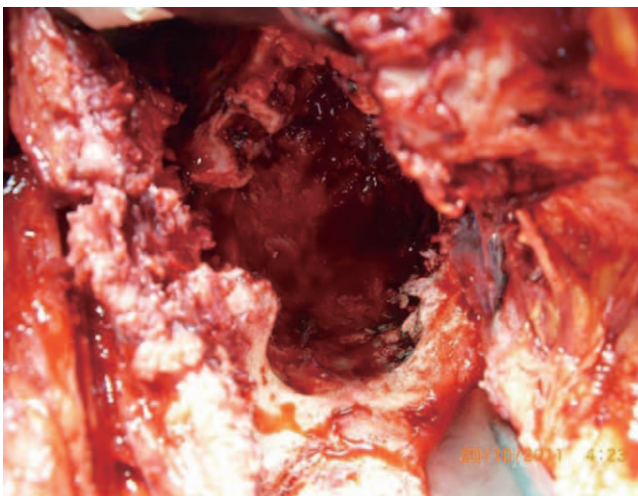
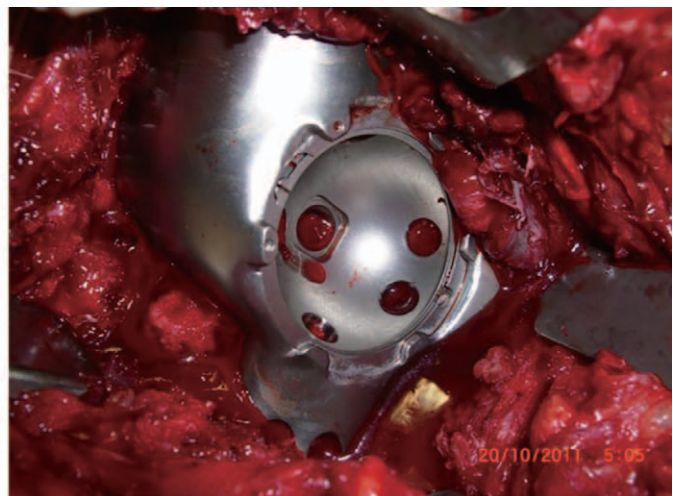


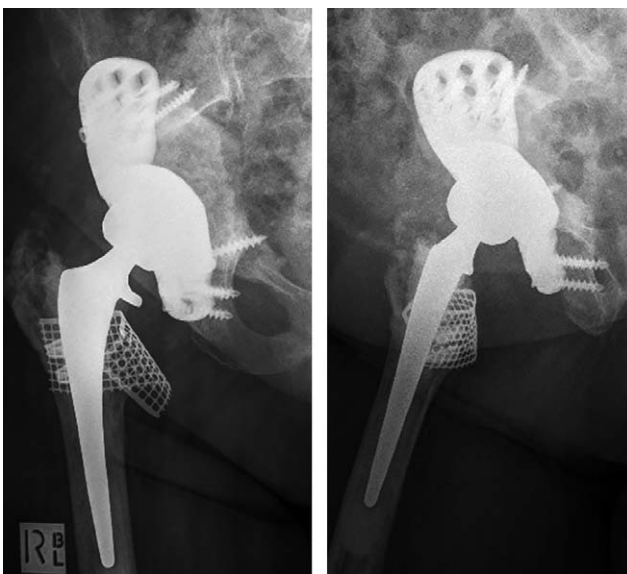
Fig. 5. Intraoperative defect and triflange implant *in situ*.



extensive bone loss, these patients were operated with two stage revision. The remaining seven patients were operated with a single stage procedure. Seven patients had cup only revision and six underwent both component revision.

The mean HHS increased from 41 points (range, 28-61 points) preoperatively to 82 points (range, 58-97 points) at final follow-up. There was a significant increase in postoperative HHS as compared to the preoperative HHS ( $P<0.005$ ), with a mean increase of 41 points, lowest improvement being 20 points, and highest improvement being 60 points which suggested marked improvement in the functional outcome of the patient. The clinical outcome according to HHS of 3 patients (25.0%) was graded as excellent; 5 patients (41.7%) as good; 3 patients (25.0%) as fair; and 1 patient (8.3%) as poor (Table 2, 3).

Eleven out of twelve acetabular components were well fixed and stable with no evidence of loosening at the latest follow-up. One patient had a persistent infection with signs of component loosening. Pelvic discontinuity healed in all five patients with evidence of bridging bone across the fracture site. One patient had hip dislocation after 66 months of the index procedure which was reduced using closed traction manipulation technique at a peripheral hospital and no further intervention was required. None of the patients needed revision or any further procedure on the hip after index surgery. Thus all 11 out of 12 patients available for follow-up had successful outcomes according to the study criteria.



**Fig. 6.** Postoperative X-rays showing stable, well fixed implant with healing of pelvic discontinuity.

## DISCUSSION

Paprosky type 3 defects are among the most complex pattern of acetabular bone defects, especially type 3B defects which are included in the current study. There is more than 60% deficiency of the acetabular host bone stock. The acetabular rim and columns are completely non-supportive with superomedial hip center migration by more than 3 cm<sup>12</sup>. Type 3B defects may be associated with pelvic discontinuity, which is defined as a complete separation of the superior and inferior hemi-pelvis. Biologic fixation with this type of bone loss is unlikely with use of a non-cemented acetabular device alone<sup>16</sup>. Thus, various options have been proposed for the management of such defects. All these techniques have their advantages and disadvantages but none has been found superior over another.

The most important goal of acetabular reconstruction is to achieve good initial implant fixation. Longevity of the implant depends on bony ingrowth which cannot be achieved without this initial implant fixation. Thus, the ideal implant for treatment of such extensive bone defect in the acetabulum should provide initial stability through a strong and rigid construct, should allow anatomic load-bearing, should restore of the hip center, and should have the potential for biologic fixation<sup>10</sup>. Due to the complexity of these cases and variability in the shape of the pelvis and the variety, size, and shape of acetabular defects, it is difficult to achieve these goals with conventional off-the-shelf implants. Custom triflange PMI not only matches the patient's anatomy but helps with perfecting the fit with precisely outlined flanges over the ilium, ischium, and pubic bone as well<sup>17</sup>. This method bridges the defect and provides stable initial bicoloumner fixation which

**Table 2.** Results

Variable	Value
Follow-up period (mo)	50 (18-70)
Duration of surgery (min)	310 (138-305)
Blood loss (mL)	1,308 (600-4,000)
Preoperative HHS	41 (28-61)
Postoperative HHS	82 (58-97)
Increase in postoperative HHS	41 (20-60)
Outcome according to HHS score	
Excellent	3/12 (25.0)
Good	5/12 (41.7)
Fair	3/12 (25.0)
Poor	1/12 (8.3)
Dislocation	1/13 (7.7)

Values are presented as mean (range) or number (%). HHS: Harris hip score.

**Table 3.** Individual Patient Demographics and Results

Subject No.	Age (yr)	Sex	BMI (kg/m <sup>2</sup> )	Side	Type of defect (Paprosky type)	Indication	ASA grade	Follow-up duration (mo)	Preoperative HHS	Postoperative HHS	Status at last follow-up
1	71	Female	22	Left	3B	Osteolysis with aseptic loosening	3	42	65	81	Well-fixed implant with no migration
2	63	Female	25	Right	3B	Septic loosening with bone loss	2	48	30	78	Well-fixed implant with no migration
3	57	Female	35	Left	3B with pelvic discontinuity	Septic loosening with bone loss	2	48	29	58	Healed pelvic discontinuity with well-fixed implant
4	57	Female	27	Right	3B with pelvic discontinuity	Aseptic loosening with bone loss	3	60	30	72	Healed pelvic discontinuity with well-fixed implant
5	74	Female	22	Left	3B	Infection, loosening, bone loss with dislocation	2	64	38	84	Well-fixed implant with no migration
6	70	Female	29	Left	3B with pelvic discontinuity	Osteolysis with aseptic loosening	2	42	21	75	Well-fixed implant with healed pelvic discontinuity
7	59	Male	28	Right	3B	Infection with bone loss	2	65	63	97	Well-fixed implant with no migration
8	81	Female	29	Right	3B	Osteolysis with aseptic loosening	2	70	32	87	Well-fixed implant with no migration
9	86	Female	25	Right	3B with pelvic discontinuity	Osteolysis with aseptic loosening	2	65	54	85	Well-fixed implant with healed pelvic discontinuity
10	70	Male	28	Right	3B	Osteolysis with aseptic loosening	2	60	67	82	Well-fixed implant with no migration
11	82	Male	29	Left	3B	Osteolysis with aseptic loosening	2	58	45	91	Well-fixed implant with no migration
12	60	Male	23	Left	3B with pelvic discontinuity	Infection with bone loss	2	48	33	93	Persistent infection with signs of loosening
13	65	Male	16	Right	3B	Septic loosening with bone loss	3	18	37	-	Dead (due to unrelated cause)

BMI: body mass index, ASA: American Society of Anesthesiologists grading system, HHS: Harris hip score.

**Table 4.** Comparison Studies

Study	Type of implant	No. of hips	Follow-up (mo)	Type of defect	HHS score (postoperative)	Dislocations	Prosthesis survival rates	Failure of components
Berasi et al. <sup>14)</sup>	Custom triflange	23	57	Paprosky type 3B	65	0	92%	2 (8%)
Berend et al. <sup>21)</sup>	Custom triflange	95	42	Paprosky 2B, 2C, 3A, 3B	75	6 (6.4%)	94.7%	5 (5.3%)
Taunton et al. <sup>9)</sup>	Custom triflange	57	65	Pelvic discontinuity	75	12 (21%)	94.7%	3 (5.3%)
DeBoer et al. <sup>22)</sup>	Custom triflange	20	123	Pelvic discontinuity	80	6 (30%)		0
Colen et al. <sup>23)</sup>	Custom triflange	6	29	AAOS type III, type IV	61	0		0
Van Kleunen et al. <sup>24)</sup>	Trabecular metal cup	97	45	Paprosky type 3A, 3B	76	7 (7.2%)	91.8%	8 (8.2%)
Kosashvili et al. <sup>25)</sup>	Cage with trabecular metal cup	26	44	Pelvic discontinuity	77	2 (7.6%)	88.5%	3 (11.5%)
Oommen et al. <sup>20)</sup>	Impaction bone grafting	30	23	Paprosky type 2C and 3A	78	1 (3.3%)	86.7%	4 (13.3%)
Our study	Custom triflange	12	50	Paprosky type 3B and pelvic discontinuity	82	1 (8%)	92%	1 (8%)

HHS: Harris hip score, AAOS: American Academy of Orthopaedic Surgeons.

helps in anatomical load distribution through the hip. The porous coating of the implant helps with bony ingrowth, providing biological fixation in long term. Thus, PMI accomplishes the major goals of reconstruction in complex acetabular bone defects<sup>9)</sup>.

Multiple surgical techniques and implants have been used to manage extensive acetabular defects including trabecular metal cups, cup cage constructs, allograft prosthesis composites, and PMI. Uncemented hemispherical cups with porous coating, porous metal, or hydroxyapatite are the most commonly used for acetabular revisions with bone loss. This method promotes biological fixation between host bone and the titanium shell and initial stability is achieved by a press-fit in addition to screws or spikes. A minimum of 50% host bone contact was traditionally recommended for using hemispherical cups but with the advent of porous coated trabecular metal cups they can be used even if the host bone contact is less than 50%<sup>18)</sup>. In more complex situations, additional fixation utilizing an ilioischial anti-protrusion cage placed over the cup (a cup-cage construct) may be employed when the initial cup fixation is inadequate. Cup-cage techniques provide a reliable solution for complex acetabular defects but are technically challenging, and forceful impaction of the ischial flange of the cage into the ischium risks producing an iatrogenic pelvic dissociation<sup>19)</sup>. Impacted bone graft is another attractive treatment option for restoring severe acetabular bone defects but the procedure is complex and the results are variable. Bone grafts can be used in conjunction with cemented all polyethylene cups, cementless implants as well as reinforcement rings and cages<sup>20)</sup>. The results of our study are compared with published results as shown in Table 4<sup>9,14,20-25)</sup>.

In the current study 11 out of 12 components were stable with no evidence of loosening or migration and pelvic discontinuity healed in all five patients (100%). Eight patients (66.7%) had excellent to good results according to HHS. Only one patient (8.3%) had a poor result. Notably the patient had multiple co-morbidities including rheumatoid arthritis and cerebrovascular accident as well as a complex revision of her opposite hip 10 years prior with allograft composite. Thus, the poor result cannot be entirely blamed on PMI revision. The average HHS in our study was 82 with an average clinical follow-up of 50 months. Instability was found to be the most common complication of this procedure with rates ranging from 0% to 30%<sup>26)</sup>. Attempts were made to minimize this by using a high wall poly liner in all our patients with a large head along with careful placement of the prosthesis so that the cup inclination and anteversion

angle were closely matched with the pelvic model. We used a 40 mm head in three hips and a 36 mm head in the remaining 10 hips. Though no dislocation occurred during the early postoperative period, there was one dislocation 66 months after the index procedure, which was managed by closed reduction.

The primary concern regarding use of PMI is the high cost of the implant. Though we have not done a cost analysis in this study, Taunton et al.<sup>9)</sup> found that the cost of the PMI construct, including the manufacturing process was \$12,500. For a comparable construct including a tantalum cup, screws, and an anti-protrusion cage the cost was \$11,250 and for a construct with a tantalum cup, screws, and two Trabecular Metal wedges the cost was \$14,500. Although the cost of PMI is high, it is comparable to the cost of other treatment options available. Other concerns regarding PMI include the feasibility of biologic ingrowth and the long-term effect of the stiff metal construct on host bone. These concerns are well addressed by DeBoer et al.<sup>22)</sup> in their study including 20 hips with massive acetabular defects and pelvic discontinuity which were treated with custom triflange implants and followed-up for 10 years. None of the components in their study had been revised for aseptic loosening, and healing of the discontinuity was radiographically evident in 18 of the 20 hips (90.0%).

We acknowledge that this is a relatively small case series and the follow-up period is also somewhat limited. However, in such a complicated and relatively rare condition it exceedingly difficult to have a significantly higher number of cases. Additionally, as it is not a comparative study we do not have statistical data that directly compares the clinical results of other techniques used in this condition. To obtain more definitive results, a larger multicentric comparative study is needed.

## CONCLUSION

PMI is a promising option for management of complex and extensive acetabular defects (Paprosky type 3B) with or without pelvic discontinuity that shows excellent midterm results. Custom fit of the PMI and extensive preoperative planning makes these complex surgeries relatively straightforward and helps in achieving a predictable outcome.

## CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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