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# Pelvic Discontinuity Treated With Custom Triflange Component

## A Reliable Option

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**Abstract**

*Background* Pelvic discontinuity is an increasingly common complication of THA. Treatments of this complex situation are varied, including cup-cage constructs, acetabular allografts with plating, pelvic distraction technique, and custom triflange acetabular components. It is unclear whether any of these offer substantial advantages.

*Questions/purposes* We therefore determined (1) revision and overall survival rates, (2) discontinuity healing rate, and (3) Harris hip score (HHS) after treatment of pelvic discontinuity with a custom triflange acetabular component and (4) the cost of this reconstructive operation compared to other constructs.

*Methods* We retrospectively reviewed 57 patients with pelvic discontinuity treated with revision THA using a custom triflange acetabular component. We reviewed operative reports, radiographs, and clinical data for clinical and radiographic results. We also performed a cost comparison with utilization of other techniques. Minimum followup was 24 months (average, 65 months; range, 24–215 months).

*Results* Fifty-six of 57 (98%) were free of revision for aseptic loosening at latest followup. Fifty-four (95%) were free of revision of the triflange component for any reason. Thirty-seven (65%) were free of revision for any reason. Twenty-eight (49%) were free of revision for any reason and free of any component migration and had a healed discontinuity. Forty-six (81%) had a stable triflange component with a healed pelvic discontinuity. Average HHS was 74.8. The costs of the custom triflange implants and a Trabecular Metal® cup-cage construct were equivalent: $12,500 and $11,250, respectively.

*Conclusions* In this group of patients with osteolytic pelvic discontinuity, triflange implants provided predictable mid-term fixation at a cost equivalent to other treatment methods.

*Level of Evidence* Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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## Introduction

Pelvic discontinuity is an important complication of THA, estimated at nearly 1% to 5% of all acetabular revisions, and may be increasing [2, 10]. Pelvic discontinuity results when the anterior and posterior columns of the acetabulum both become discontinuous and the cephalad hemipelvis is dissociated from the caudad portion. This complication of THA is seen in osteolysis, infection, and occasionally acute fracture.

Current options for management of osteolytic pelvic discontinuity include bulk acetabular allograft with plating [13, 16], standard cage reconstruction with ischial and ilial screw fixation [2, 13], a cup-cage construct with a porous metal acetabular component covered by a cage fixed proximally and distally [1, 10], and technique using porous metal augmentations and a porous metal acetabular component [13]. The variety of surgical options available speaks to the difficulty in treating discontinuity. While the methods differ, healing of the discontinuity and a stable acetabular construct remain the treatment goals.

A custom triflange acetabular component is another option that has been proposed to achieve both of these goals [3]. The variability and shape of the pelvis and the variety, size, and shape of acetabular defects make treatment with conventional off-the-shelf implants difficult [3, 4, 8]. The triflange cup is a custom-designed, titanium, porous- and/or hydroxyapatite-coated acetabular component with ilial, ischial, and pubic flanges. These flanges allow for intimate contact between the implant and stable host bone for initial stability, while maintaining or returning the hip center to its anatomic location. In contrast to off-the-shelf malleable reconstructive cages, which have the potential for fatigue failure in cases of discontinuity, the triflange component offers rigid fixation to promote healing of the discontinuity and biologic fixation of the implant itself.

DeBoer et al. [5] previously reported 20 hips with pelvic discontinuity treated with a triflange component at a mean of 10 years and found bridging callous in 18 of 20 hips.

To confirm the findings of DeBoer et al. [5], we determined (1) the revision rate and overall survival rate, (2) the rate of discontinuity healing, and (3) the Harris hip score (HHS) after treatment of pelvic discontinuity with a custom triflange acetabular component and (4) the cost of this reconstructive operation compared to other constructs.

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## Patients and Methods

We retrospectively identified 77 patients from four centers who had pelvic discontinuity treated with a custom Pinnacle™ Triflange Acetabular System (DePuy Orthopaedics, Inc, Warsaw, IN, USA) (Fig. 1) from 1992 to 2008. All data had been prospectively collected. During the study period, all patients with osteolytic pelvic discontinuity were treated with triflange acetabular component at the authors' institutions. The indication for the triflange acetabular components was osteolytic pelvic discontinuity in the setting of failed THA. The contraindications were (1) active infection, (2) medical comorbidities inhibiting operative intervention, and (3) bone loss that was so severe that fixation for the triflange component could not be achieved. Twenty of these 77 patients were reported in a previous article [5] at 89 to 157 months' followup. Eleven patients were lost to followup. This left 66 patients for review. Nine of these 66 patients died without radiographs performed at greater than 2 years' followup, but all had a least 2 years' clinical followup. This left 57 patients for review with complete minimum 2-year clinical and radiographic followup. The average age of the 57 patients was 61 years (range, 35–81 years). There were 51 women and six men. The average BMI was 27 (range, 21–40). All patients had had a minimum of one previous hip arthroplasty procedure. The minimum followup was 24 months (average, 76 months; range, 24–215 months). IRB approval was obtained by the authors for all institutions involved.

Preoperative bone deficiency was classified by the operating surgeon according to the method of the American Academy of Orthopaedic Surgeons (AAOS) as reported by D'Antonio et al. [4] using AP radiographs of the pelvis and AP and true-lateral radiographs of the hip. Pelvic discontinuity (AAOS Type IV) is defined as a defect across the anterior and posterior columns with total separation of the superior from the inferior acetabulum. Trochanteric escape was identified by the authors as nonunion of any nature of the greater trochanter to the femoral prosthesis or remaining femur with greater than 1 cm of displacement.

The first goal of acetabular reconstruction with the triflange cup was to achieve initial stable fixation through intimate contact between structural host bone and the rigid iliac, ischial, and public flanges augmented with multiple 6.5-mm screws. The second goal was to achieve fixation through this intimate contact of the host bone and the flanges and posterior hemispherical cup augmented with porous surfaces. The design of the triflange cup was

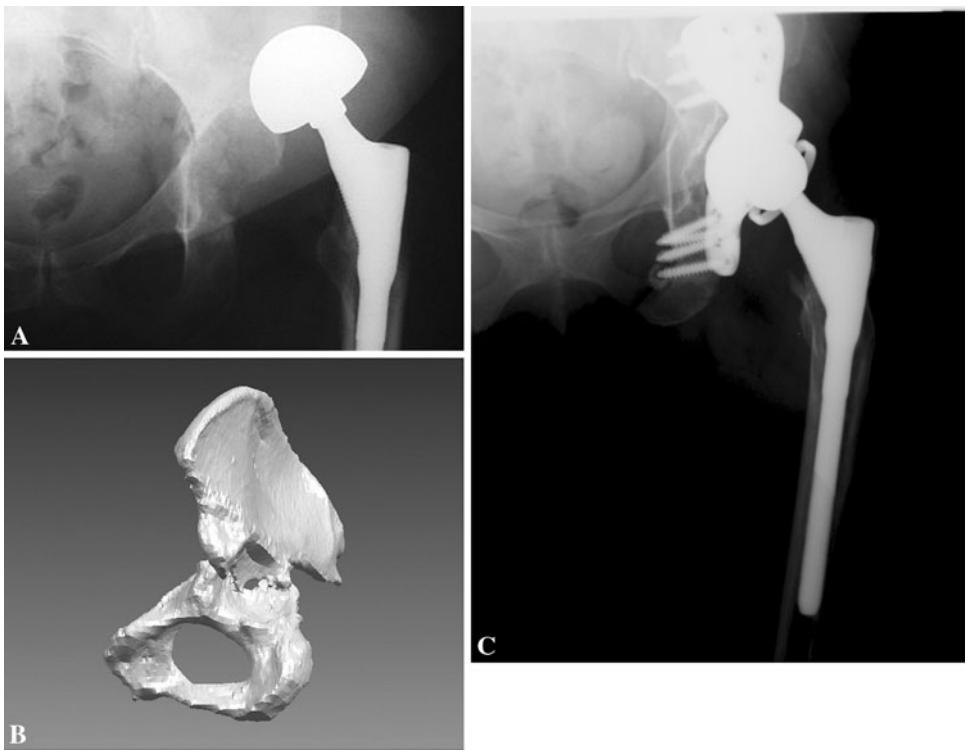


**Fig. 1A–C** (**A**) A preoperative AP pelvic radiograph demonstrates a failed acetabular component with pelvic discontinuity. (**B**) A 3D reconstruction of CT scans demonstrates the anatomy of the discontinuity. (**C**) A postoperative AP pelvic radiograph demonstrates a well-fixed triflange component with a healed discontinuity.

initiated with a CT scan of the patient's pelvis. The standard CT scan of the pelvis consisted of 3-mm cuts of the pelvis, with metal subtraction software with the uncompressed data recorded on a CD-ROM and sent to the implant manufacturer. The CT scan slide data were translated to create a computerized, three-dimensional (3D) reconstruction of the patient's hemipelvis and a one-to-one hemipelvis model was constructed.

The remaining pelvic landmarks (obturator foramen, iliac wing, pubic ramus) were then used to determine the hip center, cup orientation, and flange geometry and to identify thin, fragile bone along the remaining rim of acetabulum that was removed at the time of cup insertion. This incompetent bone was removed from the 3D model before the triflange cup was designed. Using the markings of the flanges made on the pelvic model, a clay prototype of the cup was prepared. This assisted the surgeon in determining the head center and cup orientation. The head center location was chosen based on patient-specific considerations, including leg length discrepancy, planned retention or revision of the femoral component, length of contralateral leg, and cup size. Generally, the vertical head center location was established by first determining the approximate anatomic position of the head center using the superior aspect of the obturator foramen as a reference point. The remaining bone of the anterior and posterior columns determined the head center in the coronal plane, whereas the flange geometry and cup face diameter guided the position of the head center in the sagittal plane. The cup face orientation was established by setting the abduction and anteversion angles of the cup. The abduction angle generally was targeted at 35° to 40° from horizontal and was established using the plane of the obturator foramen as a reference. The anteversion angle was established using the plane of the iliac wing and the obturator foramen as references. The three flanges were then designed to facilitate initial fixation. The first row of screw holes targeted the most inferior, structural bone of the ilium. Care was then taken to achieve fit on the two planes of the ilium delineated by the gluteal ridge. The ischial flange normally had three to seven screw holes to accommodate 6.5-mm acetabular screws and was designed to rest primarily on the posterior surface of the ischial tuberosity. The pubic flange generally was the smallest of the three and normally did not contain screw holes. Once the design of the implant was finalized, reverse-engineering techniques were used to digitize the surface of the clay prototype into a numerical format used by computer-controlled machining centers to mill the surfaces of the titanium stock. The blank of wrought titanium bar stock was prepared using a hemispheric inner geometry compatible with standard, snap-in UHMWPE acetabular liners. This blank was fixed in a five-axis mill to machine the surfaces of the device. Porous coatings were applied to the medial aspect of the flanges and the cup portion of the device to facilitate osteointegration. Clearance was built into the medial aspect of the junctions between the flanges and cup portion to compensate for any discrepancies between the CT-generated hemipelvis model and actual

patient anatomy. This ensured the device transferred loads through the broad faces of the flanges to the cortical bone of the ilium, ischium, and pubis, rather than to the deficient bone of the acetabular rim.

The hip generally was approached with a standard posterior incision. An extended trochanteric osteotomy was used in selected cases, primarily for difficult femoral stem or cement removal. The sciatic nerve was identified and traced from the greater sciatic notch to the ischium. After dislocation of the femoral head, the femoral stem was removed. In cases where the femoral component was retained, the gluteus minimum and gluteus medius were elevated and a space created between the muscle and the ilium. The femoral head was then displaced into this space. The gluteus medius and minimus were elevated off the wing of the ilium, taking care to protect the superior gluteal artery and nerve as they exited the greater sciatic notch. The hamstring tendon origin was released sharply from the ischium as far as needed to facilitate the ischial flange placement. Particular care was taken to protect the sciatic nerve during this maneuver because it lies in close proximity. Finally, a pouch was created over the pubis to accept the pubic flange. The gas-sterilized, 3D pelvic model was referenced intraoperatively, and the thin, fragile rim of bone in the periacetabular area was removed to match the bone removed on the hemipelvis model as determined preoperatively. Bony defects were supplemented with particulate allograft. Insertion of the triflange cup usually was initiated with insertion of the ilial flange, which was facilitated by translating the hip proximally with some flexion to relax the abductors. The ischial and pubic flanges were rotated into position while extending the hip. If remaining bone was found that needed to be contoured further, the triflange was removed and further burring was completed per the pelvic model. Fixation was initiated with screws in the ischial flange, where the bone is poorest and lysis is common. The ilial flange then was fixed with screws, again protecting the superior gluteal vessels, and the liner was inserted. It is important to note the deep branch of the superior gluteal artery and superior gluteal nerve traverses 4 to 6 cm superior to the acetabular rim [12]. In cases of discontinuity, the iliac screws pulled the flange down into intimate contact with the bone, which reduced the discontinuity and rotated the inferior ½ of the hemipelvis into correct orientation relative to the superior hemipelvis. Nine to 13 screws generally were inserted. The average acetabular cup size was 55 mm (range, 48–68 mm). Twelve hips had constrained liners placed at the time of index operation. Three hips had femoral heads of 40 mm or greater placed at the index operation (Fig. 1).

Postoperatively, patients were mobilized with the use of a walker in the acute hospitalization, usually on the first postoperative day. Physiotherapy consisted of ambulation with the use of a walker with partial weightbearing. Muscle strengthening exercises for the hip were held until 6 weeks postoperatively. Weightbearing was restricted for 12 weeks, allowing toe touch weightbearing with a walker or crutches. After 12 weeks, the patients were allowed to progress to weightbear as tolerated over a four 4 week period. The patients were instructed in gently daily hip strengthening after 12 weeks. Patients received supervised therapy based on the operative surgeon's discretion.

The followup of patients varied among centers, but all patients were evaluated within 12 weeks after surgery and at 1 year and then followup varied based on surgeon discretion. At each visit, clinical results were obtained by the treating physicians using the HHS [7]. All patients received an AP pelvis radiograph. Strength grading was as follows: 0 = absent voluntary contraction, 1 = feeble contractions that are unable to move a joint, 2 = movement with gravity eliminated, 3 = movement against gravity, 4 = movement against partial resistance, and 5 = full strength [6].

One of the five of us (MJT, TKF, MJC, GEH, TB) reviewed preoperative and postoperative radiographs at each of our respective institutions. The average radiographic followup was 76 months for all patients included in the study. Early and most recent postoperative films were reviewed and compared for the presence of radiolucent lines; evidence of bony remodeling and healing of pelvic discontinuity; and evidence of loosening, migration, screw breakage, or screw motion. Utilizing the criteria of Berry et al. [2], we considered the pelvic discontinuity healed if trabecular bone or callus bridged the discontinuity and we considered the discontinuity unhealed if the fracture line still was visible or if there was evidence of loosened or broken screws. Migration was assessed by comparing immediate postoperative and most recent radiographs and looking for any movement of the triflange or screws. Any movement of the implant or screws of more than 2 mm was deemed migration. Screws were scrutinized for any "pullout" or "halos" indicative of loosening. We considered components to have definite loosening if there was acetabular migration of 2 mm or more in the horizontal or vertical direction with implant rotation, screw breakage, or progressive bead shedding. There was probable loosening if there was a radiolucent line of more than 1 mm in all three zones without migration, rotation, or screw breakage [11]. We defined stable fixation as documented stable fixation of the triflange component with time to the ilium and superior acetabulum with or without healing of the discontinuity and migration of the inferior pelvis.

We compared the cost of a custom triflange implant with other commonly reported methods of treating a pelvic discontinuity, specifically a Trabecular Metal® cup combined with a antiprotrusio cage, the "cup-cage" construct (Zimmer, Inc, Warsaw, IN, USA), and the "distraction technique" that

commonly utilizes a Trabecular Metal® cup, combined often with two Trabecular Metal® wedges for supplemental fixation (Zimmer). We performed this cost comparison by asking each manufacturer the cost of the implants.

Descriptive statistics including frequency, proportion, mean, and range were calculated.

## Results

Twenty (30.3%) of the 57 hips had revision for any reason. There were three failures (5.3%) of the triflange acetabular components defined as revision or resection of the acetabular component. Two of these were resections for deep infection. One of the 57 patients (1.8%) was revised for aseptic loosening. This failure occurred at 11 years postsurgery (Fig. 2). There were seven revisions involving the femoral component with revision or resection. Three femoral revisions were for periprosthetic fracture, two for deep infection, and two for femoral component aseptic loosening. Twelve revisions were limited head and liner exchanges for either instability (10) or acute postoperative infection (two). Six of the 10 head and liner exchanges involved conversion to a constrained liner. Two patients had reoperation for superficial seromas. One patient had a nerve exploration for sciatic palsy. One patient had a reoperation for removal of wire from around the proximal femur. The average time to reoperation was 32 months (range, 1–102 months). Twenty-eight of the 57 patients (49%) were free of revision for any reason and free of migration of components and had a healed discontinuity at latest followup.

In 46 of the 57 patients (81%), we judged the triflange acetabular components as stable with a healed pelvic discontinuity. We could not assess one discontinuity owing to retained hardware. Ten patients had no obvious healing of the discontinuity at latest followup. We observed migration of at least a part of the triflange acetabular component in nine patients. Five of these migrated components were stable at latest followup and had apparently healed discontinuities. Of the remaining four patients with migration of the triflange, one was stable with ischial screw migration and the discontinuity healing could not be determined, two had initial ischial screw migration with a subsequently stable triflange component without obvious healing of the discontinuity, and one was noted to have migration and subsequently revised for aseptic loosening.

The average HHS was 74.8 at an average clinical followup of 5.4 years. Twenty-nine patients had a preoperative trochanteric escape whereas 27 patients had a postoperative trochanteric escape. The average abductor strength preoperatively (on a 1–5 scale) was 3.6. Eleven patients had abductor muscular strength testing limited to antigravity strength or less, with four patients having less than antigravity strength [6].

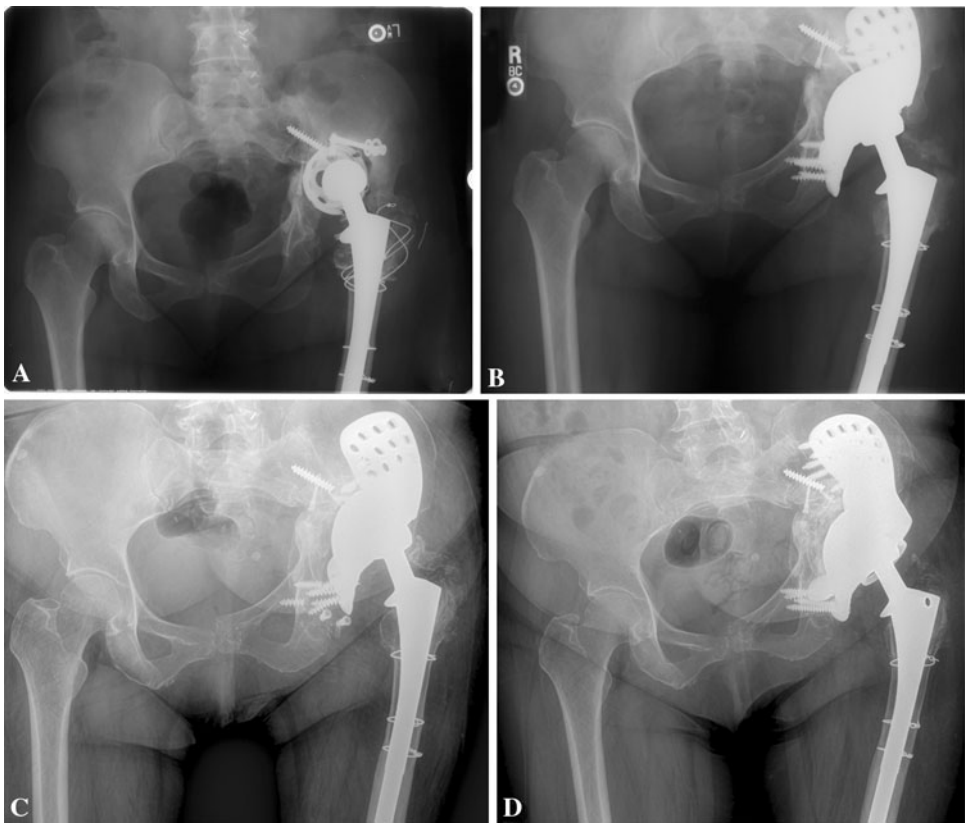


**Fig. 2A–D** (**A**) A preoperative AP pelvic radiograph demonstrates a failed acetabular component with pelvic discontinuity. (**B**) An immediate postoperative AP pelvic radiograph demonstrates a well-fixed triflange component. (**C**) The triflange component failed due to aseptic loosening at 11 years postoperatively. (**D**) The revision triflange component is well fixed at 6 months.

Twelve patients (21%) developed instability after implantation of a triflange acetabular component. Ten were revised, and two were treated nonoperatively with closed reduction and bracing. Other complications included two patients who had permanent peroneal nerve palsies treated nonoperatively with persistent foot drop.

The cost of the triflange construct, including the cup, screws, and polyethylene liner, along with the manufacturing process, was $12,500. For a comparable construct, including a tantalum cup, screws, an antiprotrusio cage, and polyethylene liner, the cost was $11,250. For a construct with a tantalum cup, screws, two Trabecular Metal® wedges, and polyethylene liner, the cost was $14,500.

## Discussion

Pelvic discontinuity is a challenging and fortunately a rare complication of THA [2–5, 8, 9, 13, 14, 16]. The variety of methods to treat this problem speaks to the difficulty of its management. The historically high failure rate [2–5, 8, 9, 13, 14, 16] of many methods of management has led to the development of the triflange component. We hoped to further confirm the results of a custom triflange acetabular component in the setting of pelvic discontinuity in a retrospective, multicenter design, with a larger patient set than previously reported. We therefore determined (1) the revision rate and overall survival rate, (2) the rate of discontinuity healing, and (3) the HHS after treatment of pelvic discontinuity with a custom triflange acetabular component and (4) the cost of this reconstructive operation compared to other constructs.

Readers should be aware of the limitations of our study. First, 11 patients were lost to followup despite an exhaustive search, and nine died before having radiographs to adequately assess for discontinuity healing. All available means were made to contact patients. Second, it is difficult to assess healing in some of these patients. The implant is bulky and it is difficult to visualize the posterior column with conventional radiographs with large amounts of metal obstructing the view. Only one hip could not have healing determined due to hardware obstructing the evaluation of the columns. Third, the retrospective nature of the study imparts observational and selection biases. There exists no prospective randomized trial comparing this technique to the other modern techniques controlling for similar defects in the setting of pelvic discontinuity, which would be quite valuable. Fourth, we did not assess intraobserver variability for assessing healing of the discontinuity or component loosening.

We found 20 (30.3%) of the 57 hips had revision for any reason. Stiehl et al. [16] reported a revision rate of 47% of 10 discontinuities treated with bulk allografts and plates (Table 1). Paprosky et al. [13] treated 12 discontinuities with structural grafts and cages. Eight of 12 (66%) failed by acetabular loosening or revision at 54 months. These authors compared their results to another group of 12 discontinuities treated with porous metal with or without augmentation. Eleven of 12 (92%) were free of revision, with one with loosening of the cup and screw breakage at limited followup of 1 to 3 years [13, 15]. Ballester Alfaro and Sueiro Fernández [1] reported treating five patients with a porous metal cup-cage construct and observed no failures at 18- to 43-month followup.

In our study, 46 of 57 (81%) triflange acetabular components were judged stable with a healed pelvic discontinuity (Fig. 1). Again, there was one (1.8%) aseptic failure. This was treated with rerevision to another triflange, with good fixation at early followup. DeBoer et al. [5] had previously reported a healing rate of 18 of 20 (90%) with this component (Table 1). Kosashvili et al. [10] reported healing in 23 of 26 (88.5%) hips treated with a

**Table 1.** Comparison of revision rates, healing, and function in treatment of chronic pelvic discontinuity

| Study | Number of hips | Technique | Revision rate | Discontinuity healing | Clinical scores | Followup (years) |
|---|---|---|---|---|---|---|
| Ballester Alfaro and Sueiro Fernández [1] | 5 | TM cup/cage | 0/5 (0%) | NR | NR | 2 |
| Berry et al. [2] | 24 | Varied | 9/27 (33%) | 17/24 (71%) | 16/27 (59%) "satisfactory" | 3 |
| DeBoer et al. [5] | 20 | Custom triflange | 0/20 (0%) | 18/20 (90%) | Average HHS 80 | 10 |
| Koshashvili et al. [10] | 26 | TM cup/cage | NR | 23/26 (89%) | Average HHS 75 | 3 |
| Sporer and Paprosky [15] | 12 | TM cup/TM augments | 1/13 (6%) | NR | Average Postel-Merle d'Aubigné 10.3 | 2.6 |
| Stiehl et al. [16] | 17 | Allograft/plates | 8/17 (47%) | 7/9 (77.8%) | NR | 6.9 |
| Current study | 57 | Custom triflange | 20/57 (30%) | 46/57 (81%) | Average HHS 75 | 5.4 |

TM = Trabecular Metal®; NR = not reported; HHS = Harris hip score.

Trabecular Metal® cup and an ilioischial cage. Berry et al. [2] reported in 1999, utilizing various techniques including antiprotrusio cages, hemispherical cups, plates, and allograft particulate graft, 17 of 24 (71%) hips had possible or definite healing of the discontinuity.

The average HHS for the 57 patients was 74.8 at an average clinical followup of 5.4 years. Utilizing the same technique, DeBoer et al. [5] reported a HHS of 80 at a mean of 10 years' followup while Kosashvili et al. [10] reported a mean HHS of 74.7 at 3 years' followup utilizing the cup-cage construct (Table 1).

The cost of the triflange construct at our institutions, including the cup, screws, and polyethylene liner, along with the manufacturing process, was $12,500, which was comparable to two other popular methods. It must be recognized the custom triflange component also comes with the cost of time of preparation (usually around 4 weeks).

The complication of dislocation is important to note in the use of the triflange component. In this group of patients, the dislocation rate was 21%. A prior series reported 25% [5]. It should be recognized, in this group of patients, 51% had preoperative trochanteric escape, which most likely predisposed these patients to instability. Other potential reasons for the high rate of instability utilizing this technique include the large dissection necessary to insert this implant, possible stretch injury to the superior gluteal nerve [12] from iliac flange placement, and the surgeon's reluctance to use a more constrained insert in the face of compromised bone stock. Potential solutions for this instability problem might be more liberal use of a flip trochanteric osteotomy to protect the superior gluteal nerve or triflange design changes such as a shorter iliac flange and a larger cup to accept 40- to 44-mm heads. Additionally, more liberal use of constrained sockets and postoperative bracing should be considered in these cases, especially in those patients with trochanteric escape.

While the preoperative recognition of pelvic discontinuity can be difficult, the advent of CT modeling technology has made preoperative planning for severe acetabular defects more precise. While a Type A discontinuity can frequently be treated by a porous metal implant with plating and bone grafting, a Type B discontinuity, which is associated with substantial bone loss, makes treatment with this type of construct unpredictable. We believe the reconstruction for pelvic discontinuity should be individualized on the basis of the severity of bone loss. Recognition of such bone loss is mandatory in dealing with these cases. When plain radiographs suggest considerable acetabular bone stock problems or the possibility of a discontinuity, the more liberal use of CT modeling technology facilitates preoperative planning, making intraoperative surprises much less common.

In conclusion, custom triflange implants for discontinuity provide predictable fixation at midterm followup and consistent discontinuity healing in the majority of cases at a cost equivalent to other treatment modalities. The inconvenience involved in the preparation of this custom implant is offset by its improved results over other treatment methods.

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