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Custom-made triflanged implants in reconstruction of severe acetabular bone loss with pelvic discontinuity after total hip arthroplasty consecutive cohort study

TWO TO 11 YEARS OF FOLLOW-UP

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Aims

Pelvic discontinuity is a rare but increasingly common complication of total hip arthroplasty (THA). This single-centre study evaluated the performance of custom-made triflange acetabular components in acetabular reconstruction with pelvic discontinuity by determining: 1) revision and overall implant survival rates; 2) discontinuity healing rate; and 3) Harris Hip Score (HHS).

Methods

Retrospectively collected data of 38 patients (39 hips) with pelvic discontinuity treated with revision THA using a custom-made triflange acetabular component were analyzed. Minimum follow-up was two years (mean 5.1 years (2 to 11)).

Results

There were eight subsequent surgical interventions. Two failures (5%) of the triflange acetabular components were both revised because of deep infection. There were seven (18%) patients with dislocation, and five (13%) of these were treated with a constraint liner. One patient had a debridement, antibiotics, and implant retention (DAIR) procedure. In 34 (92%) hips the custom-made triflange component was considered stable, with a healed pelvic discontinuity with no aseptic loosening at midterm follow-up. Mean HHS was 80.5 (48 to 96).

Conclusion

The performance of the custom triflange implant in this study is encouraging, with high rates of discontinuity healing and osteointegration of the acetabular implant with no aseptic loosening at midterm follow-up. However, complications are not uncommon, particularly instability which we successfully addressed with constrained liners.

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Keywords: Pelvic discontinuity, Custom acetabular triflange, Midterm follow-up, Revision total hip arthroplasty, Survivorship

Introduction

Pelvic discontinuity is one of the most challenging aspects of acetabular revision surgery.[1] Pelvic discontinuity is described as a distinct but uncommon condition, occurring in association with total hip arthroplasty (THA), characterized by separation of the superior pelvis from the inferior aspect by bone loss or a fracture line through the acetabulum.[2] The aetiology of acetabular

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bone loss may result from periprosthetic joint infection, osteolysis, periprosthetic fracture, metastatic lesions, and iatrogenic bone loss that occur during component removal in revision THA.[3]

An increasing number of younger patients undergoing a primary THA procedure, prolonged life expectancies, and extended indication areas are causing an increase in complexity and volume of revision surgery,[4] including management of pelvic discontinuities.

One promising treatment option for dealing with large acetabular bone loss at revision THA is a custom triflange acetabular component, which has been repeatedly suggested as a good solution even when a pelvic discontinuity is present.[5-7] A proposed advantage is the ability to customize and individualize the implant to the defect in each individual case restoring the anatomical dimension, choosing the optimal centre of rotation, and optimizing host-bone contact area and osseointegration. Further, the triflange acetabular component is able to create initial implant stability due to optimized CT guided dome screw placement and additional flange screw insertion.

Very few have reported the outcome of custom triflange acetabular components used in cases with pelvic discontinuity. This is, to our knowledge, the largest single-centre study to date reviewing the outcome of custom triflange acetabular components in the setting of pelvic discontinuity. This study evaluated: 1) revision and overall implant survival rates; 2) discontinuity healing rate; and 3) Harris Hip Score (HHS)[8] after treatment of pelvic discontinuity with a custom triflange acetabular component.

Methods

We retrospectively identified 43 patients with 44 hips from a tertiary referral centre for hip revision surgery treated with a custom Triflange Acetabular System (Patient-Matched Implants; Zimmer Biomet, USA) from 29 June 2010 to 10 October 2021. Medical records were reviewed for pertinent data extracted from an electronic patient journal system. Patient demographics, re-revision, American Society of Anesthesiologists (ASA) grade,[9] revision causes, revision number, primary prosthesis status, preoperative data, radiological classification of bone loss, date of surgery, blood loss, perioperative data, postoperative complications, date of arthroplasty if failure of the prosthesis, the reason for failure, and death were noted. The indication for a triflange acetabular component was pelvic discontinuity in the setting of failed THA caused by a chronic large bone loss. During the study period, every patient with this condition received a custom acetabular component. Prior to the custom-made era we used plate osteosynthesis with structural allograft and protrusion cages, but experienced problems with fatigue fracture of the cage and lack of discontinuity healing.

Acute traumatic fracture of the pelvis with discontinuity was not included in this study because such injuries have a different aetiology/pathophysiology and different treatment options. A preoperative bone deficiency was classified by the operating surgeon (NSW) and a radiologist (NSK) according to the Gross classification[10] using a CT scan and anteroposterior (AP) and true lateral radiographs of the hip. Pelvic discontinuity was defined as a defect across the anterior and posterior columns with total separation of the superior from the inferior acetabulum.

No patients were lost to follow-up, but five of these 43 patients (44 hips) with a unilateral triflange acetabular component died (without having experienced any hip revision surgery) before two years of radiological follow-up. This left 38 patients (39 hips) for review with a complete minimum two-year clinical and radiological follow-up. The mean age at the time of index surgery was 69 years (45 to 85). There were 24 female and 14 male patients included. The mean BMI was 26 kg/m^2 (5 to 40). Before index revision, 35 hips were revised due to aseptic loosening, and four due to septic loosening. The mean number of previous revisions was two (1 to 7). The first 27 patients received a standard 10° liner with a 32 mm head, although because of high rates of dislocation the last ten patients received a constrained liner with a 36 mm head.

The minimum follow-up was two years (mean five years (two to 11)). Mean perioperative blood loss during index revision was 1,241 ml (235 to 3,100) and mean surgery time was 139 minutes (94 to 202).

All study participants provided written informed consent about personal and medical data collection prior to study enrolment (all had at least 48 hours before the decision for participation), and informed written consent was completed in accordance with the Helsinki declaration.[11] The study was approved by the local Data Protection Agency (case number P-2021-258). Patient Safety Authority granted access to patient files for those patients whom we were unable to contact (case number R-21015388).

Implants and surgery. The design of the triflange cup was initiated with a specific preoperative CT protocol of the patient's pelvis for bone defect analyses and reconstruction planning. The remaining pelvic landmarks (obturator foramen, iliac wing, pubic ramus) were then used to determine the centre of rotation, cup orientation, and flange geometry.

We had the following requirements for the design of the implant: 1) the implant must bypass the discontinuity, creating stable conditions for ingrowth of the implant above and below the discontinuity; 2) host bone implant distance must not be more than 1 mm, especially in the superior part of the acetabulum where the load is highest – all flange screws were locking screws to

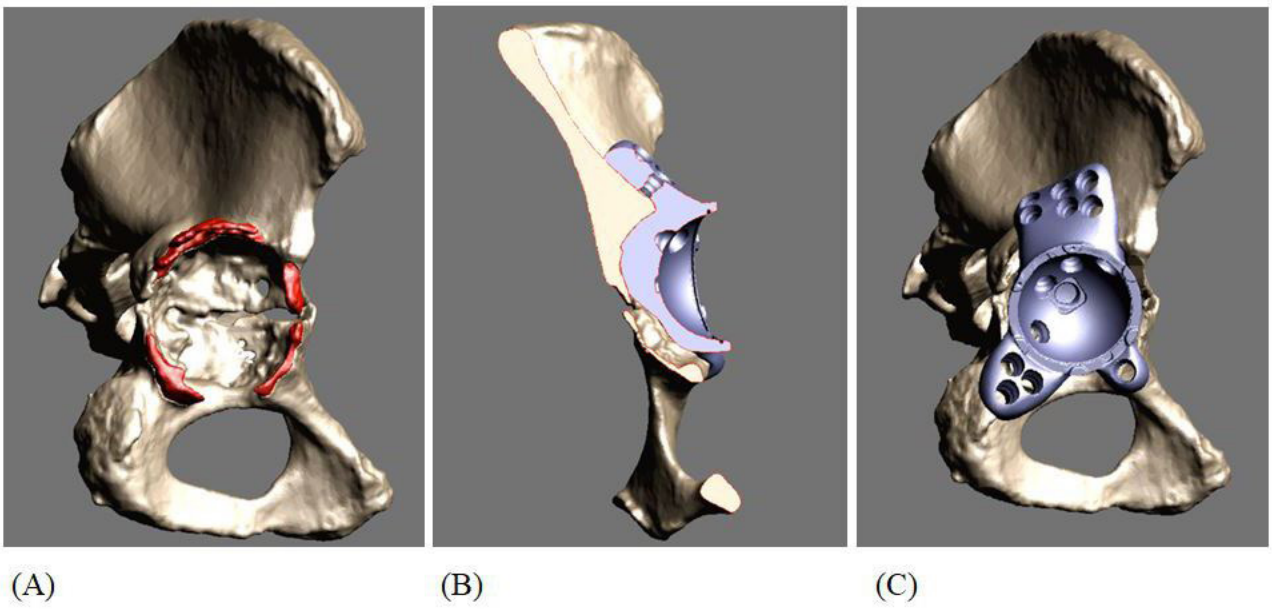


Fig. 1

a) 3D reconstruction of a hemipelvis created from a CT image. b) 3D reconstruction of a hemipelvis visualizing the host bone implant distance. c) 3D reconstruction of a hemipelvis with a proposed implant design.

optimize stability; and 3) the iliac flange is to be orientated posteriorly where the iliac bone is abundant and where there is less risk of perioperative interfering with the femoral stem.

With the above-mentioned requirements, the implant often forms a non-hemispherical shape against the acetabulum creating optimal bone contact. (Figures 1a to 1c)

Based on close cooperation between the surgeons (NSW, JS) and an engineer, a porous titanium triflange component, with flanges on ilium, ischium, and pubis, was designed as a monoblock, with screw fixation to be inserted into the best host bone quality (Figures 2a to 2e).

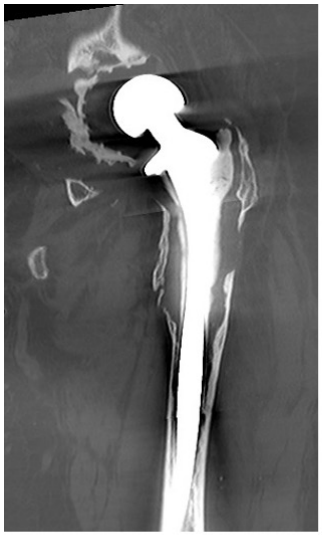
All operations were performed by one of two senior hip surgeons (NSW, JS). A posterolateral approach was used in all patients as it allows good exposure of the acetabulum, ilium, and the posterior column including the ischium bone that works as a contact area for the implant. After morcellized allograft was reversed reamed in the acetabulum, the first step was to position the porous coated acetabular triflange with insertion of a minimum of three dome screws to facilitate compression and maximal host bone contact. Initial fixation was achieved, and the rigid iliac, ischial, and pubic flanges were augmented with multiple 6.5 mm locking screws, creating a stable acetabular construct which permitted healing of the discontinuity with biological fixation of the acetabular component through osseointegration. Systemic antibiotics were routinely used perioperatively (vancomycin 1 g × 2 and cefuroxime 1.5 g × 3) until results of intraoperative culture were known.

Postoperatively, patients were mobilized with the use of crutches, usually on the first postoperative day. Physiotherapy consisted of ambulation with partial weight-bearing for six weeks. Muscle-strengthening exercises for the hip were held until a minimum of 12 weeks depending on patient performance. The patients were instructed in gently daily hip strengthening after 12 weeks.

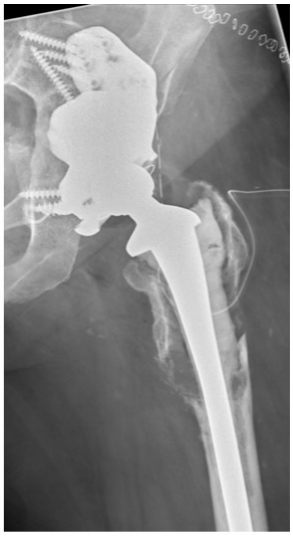
Clinical and radiological assessment. The follow-up of patients took place at a tertiary referral centre for hip revision surgery. All patients were routinely evaluated within 12 weeks after surgery and at one year. Further, patients in this study were invited to a recent follow-up, where all patients received AP radiographs of the pelvis and true lateral radiographs of the hip, if no recent radiographs already existed. Patients were clinically evaluated by HHS.[12]

The preoperative radiological assessment was performed from a CT scan evaluated by one radiologist (NSK) and the surgeon (NSW). The mean radiological follow-up was 3.9 years (2 to 9). The preoperative, immediate postoperative, and most recent radiographs were reviewed when evaluating evidence of bony remodelling and healing of pelvic discontinuity, and evidence of loosening, migration, screw breakage, or screw motion. Using the criteria of Berry et al,[1] we considered the pelvic discontinuity healed if bridging callus or trabecular bone was visible across the site of the discontinuity. We considered the discontinuity unhealed if the fracture line was still visible.

Stable fixation of the implant was defined as cases where there was no discernable migration of the implant and no evidence of loose or broken screws. An unstable

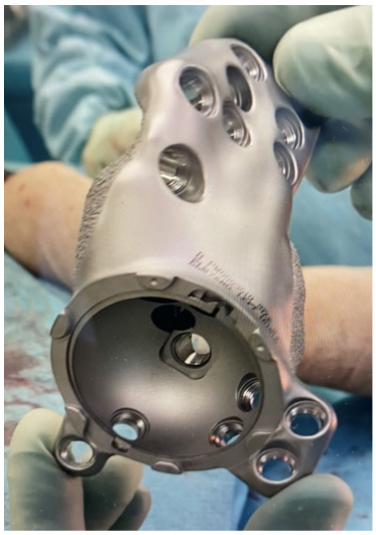


(A): Preoperative CT scan

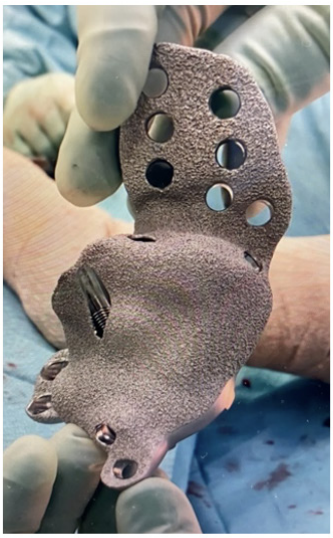


(B): Postoperative radiograph

(C): Bone model



(D): Anterior view of the implant



(E): Posterior view of the implant

Fig. 2

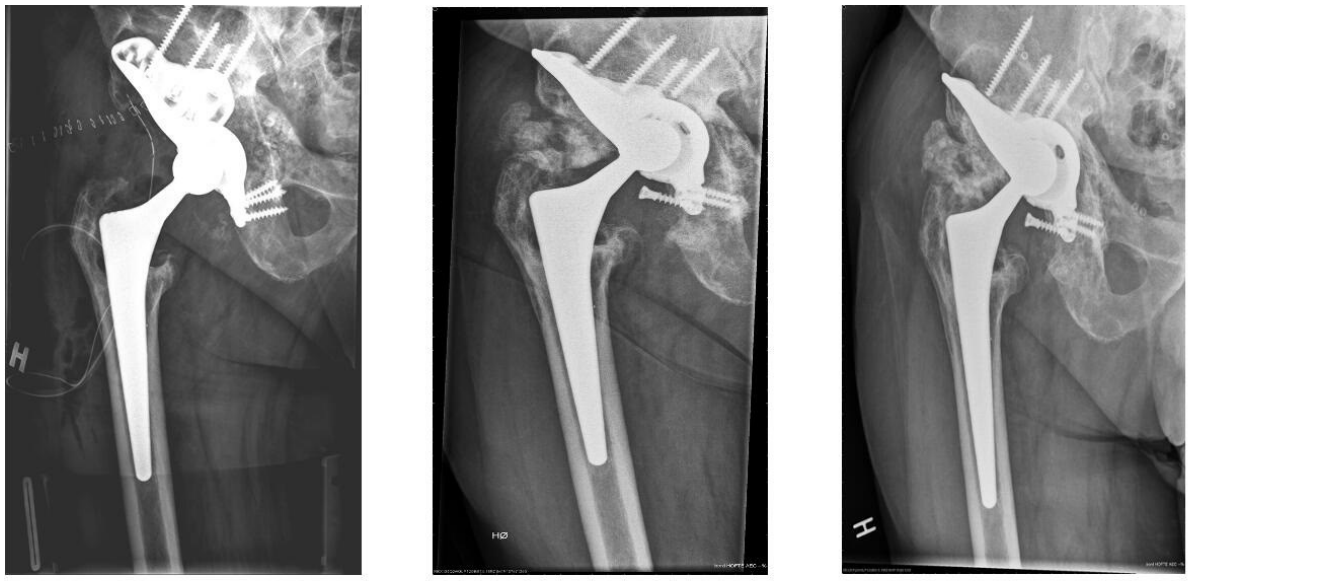
a) Preoperative CT scan with pelvic discontinuity of a 72-year-old female, coronal view. b) One day postoperative radiograph, anteroposterior view. c) Bone model. d) and e) Porous titanium triflange component forms a non-hemispherical shape against the acetabulum, creating optimal bone contact. All flange screws are locking screws to optimize stability.

fixation of the implant was defined as when there was noted to be radiological migration, evidence of broken screws, or a continuous radiolucent line surrounding the implant.

Statistical analysis. Statistical analyses were performed in RStudio version 1.2.1335 (RStudio, PBC, USA) and SPSS version 25 (IBM, USA). The level of statistical significance was set at $p < 0.05$, and confidence intervals (CIs) were reported at 95%. Unless otherwise specified, all reported values are presented as means and ranges. Survival analysis was performed with the endpoint defined as a revision of the custom-made triflange acetabular component for any reason. The Kaplan–Meier survival analysis was used to calculate the possibility of implant survival of the custom-made triflange acetabular component, and 95% CIs for the cumulative five-year and ten-year survival were calculated. All patients (n = 43) were followed until their most recent follow-up, revision of the custom-made triflange acetabular, or death.

Results

Of the 39 hips with a minimum two-year clinical and radiological follow-up, there were eight (21%) subsequent surgical interventions related to the acetabular component.



(A) Preoperative radiograph (B) 10 months postoperatively (C) 2 years postoperatively follow-up

Fig. 3

a) Preoperative radiograph of a 74-year-old male, anteroposterior view. b) Postoperative at ten months. c) Postoperative follow-up at two years.

There were two failures (5%) of the triflange acetabular components defined as removal of the acetabular component, and both acetabular components were removed because of deep infection. One revised in a two-stage procedure three years after index surgery with loosening of the implant and unhealed discontinuity. After a period of three months with temporary Girdlestone status, a new custom-made triflange component was implanted. The patient was included in this study also with implant number 2, and at two-year follow-up the patient had good clinical outcome and healing of the discontinuity. The other failure was revised with removal of the triflange two years after index surgery, and the patient was left with a permanent Girdlestone status. The implant was found loose and the discontinuity unhealed.

One patient had a debridement, antibiotics, and implant retention (DAIR) procedure three years after index procedure, and after that was treated with lifelong antibiotics. The implant was considered stable and the discontinuity healed.

The radiological examination showed that one patient had no obvious healing of the discontinuity at the latest follow-up, but the patient was asymptomatic with HHS = 81. In the two patients with failures of the triflange acetabular components, due to infection, the pelvic discontinuity was considered unhealed.

Migration of the custom triflange implant was detected in two patients (5%). One acetabular component had breakage of screws and migration at one-year follow-up. The patient was asymptomatic and was followed clinically and radiologically, with a CT scan produced one year later that showed a fully integrated implant with a healed pelvic discontinuity (Figure 3c). At six years' follow-up, the patient had no sign of migration or loosening of the implant.

The component that migrated was subsequently revised for septic loosening. In 34 of the 39 hips (92%), we considered the custom triflange component stable with a healed pelvic discontinuity (Figure 4).

There were seven (18%) patients with dislocation, and five (13%) of these were treated with a constraint liner because of recurrent dislocation, while the remaining two experienced no re-dislocation and were not revised.

In this cohort there were no nerve injuries or major vascular injuries. Mean perioperative blood loss during index revision was 1,241 ml (235 to 3,100).

The probability of the cumulative five-year and ten-year implant survival was equal, and estimation by Kaplan–Meier survival analysis based on all 43 patients was 93.8% (95% CI 89.4% to 99.2%), while the last revision was performed after 3.4 years. (Figure 5).

The mean HHS was 80.5 (48 to 96). Overall there were 25 patients with excellent or good HHS scores, 11 patients with a fair score, and three patients with poor scores.

Discussion

Pelvic discontinuity poses a major challenge in revision surgery. There are several treatment options to address this complex problem including the use of a jumbo cup, plating and uncemented cup, acetabular cage, acetabular allograft reconstruction with a cage, and cemented liner and a cup-cage construct. Jumbo cups have been

Fig. 4

a) Preoperative CT scan, coronal view of a 64-year-old female. b) Preoperative radiograph, anteroposterior (AP) view. c) Postoperative radiograph at 12 weeks, AP view. d) Postoperative radiograph at 6.3 years with healing of pelvic discontinuity, AP view.

very successful in treating small defects.[13,14] Reconstruction of large defects, particularly with discontinuity, has shown less consistent results.[15–17]

An acetabular cage alone can be used for fixation in the ischium and the iliac wing and bridges the discontinuity. Unfavourable results (50% to 60% failure rates) have been reported due to mechanical loosening, fatigue fracture of the cage, or broken flanges.[18,19] This may in part be attributable to the lack of biological fixation. In a retrospective study of large uncontained acetabular bone defects measuring 30% to 50%, Lee et al[20] reviewed 74 patients treated with acetabular allografts and cemented cups and found that implant survivorship at 15 and 20 years was 67% and 61%, respectively. In a series by Martin et al,[21] 50 hips (44%) were treated with posterior column plate and an uncemented cup. Five-year revision-free survivorship of the implant was 80%, and healing of the pelvic discontinuity was evident in 74% of the patients.

Satisfactory results have been reported with the use of a porous metal cup-cage construct. Rogers et al[22]

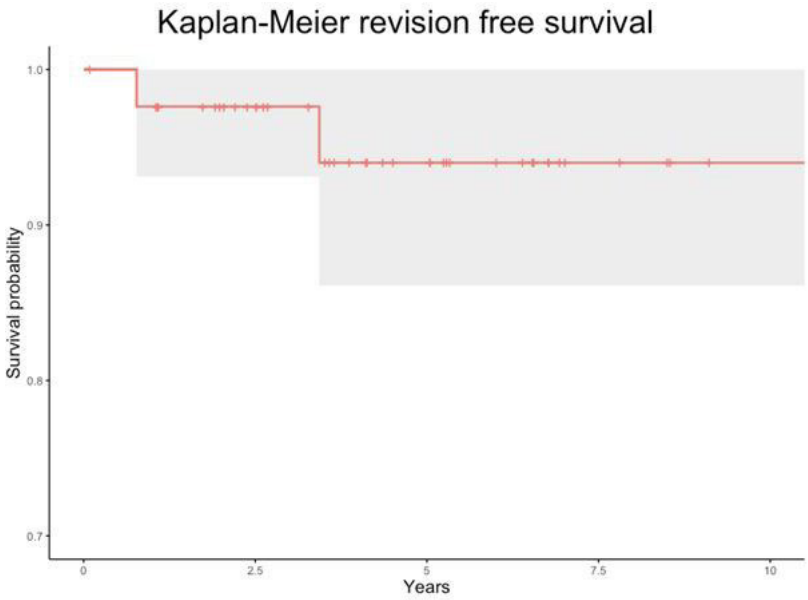


Fig. 5

Kaplan–Meier implant survival analysis. The 95% confidence intervals (CIs) are shown in the shaded grey area (five- and ten-year implant survival = 93.8% (95% CI 89.4% to 99.2%)).

reported an eight-year survivorship of 86.3% with 42 cup-cage reconstructions in chronic pelvic discontinuity. Amenabar et al[23] published midterm results on cup-cage constructs used in 45 patients (mean follow-up 6.4 years). At the most recent follow-up, four of 45 cup-cage constructs had been revised for any cause (9% failure rate).

When dealing with pelvic discontinuity, a porous metal cup-cage construct or custom acetabular components must be considered. A systematic review evaluating the various types of acetabular reconstructions in management of chronical pelvic discontinuity was published by Malahias et al.[6] Both pelvic distraction technique combined with highly porous shells and custom-made triflanges resulted in less than 5% failure rates.

A potential advantage of the custom triflange acetabular components includes the possibility of obtaining rigid fixation on remaining host bone (ilium, ischium, and pubic). In addition, the porous-coated surface on the flanges and cup allows biological ingrowth on host bone for long-term stability. Its custom design enhances the precision of fit and can optimize the implant-bone contact in the acetabulum.

Biomechanically, custom triflange components are much stronger than traditional non-custom antiprotrusio devices.[24,25] On the other hand, the main disadvantages of custom implants are the requirement for advanced imaging, manufacturing time, expense, and the inability to modify the implant intraoperatively.[26]

There are some limitations to the present study. First, five patients died before the two-year radiological follow-up, which made them unavailable for assessment of discontinuity healing. Second, it was difficult to assess healing in some of these patients. The implant is often bulky against the acetabulum, and it was difficult to visualize the posterior column with conventional radiographs with large amounts of metal obstructing the view. Third, the retrospective nature of the study imparts observational and selection biases. Fourth, we did not have a control group to compare results. This is a recurrent issue when reviewing the literature describing the use of a custom-made triflange (Table I). The main reason is probably the rare incidence/appearance of this condition (pelvic discontinuity). A comprehensive review of alternative treatment options and results are shown in this Discussion section.

A strength of this study is that due to its single-centre nature, only two surgeons (NSW, JS) were needed to perform all the procedures. The study presents the largest number of cases with pelvic discontinuity and custom-made triflange in a single-centre setup.

The preoperative bone deficiency was classified using a CT scan, which is considered the most precise method for the diagnosis of pelvic discontinuity. Furthermore, no patients were lost to follow-up.

In the present study we found that eight (21%) of the 39 hips had revision for any reason, with a minimum two-year follow-up (mean 5.1 years) and two failures of the triflange component (5%). This is slightly lower compared with previous studies of custom triflange acetabular components. DeBoer et al[5] reported in a study with ten years' follow-up that 6/18 patients (33%)

Table I. Published studies using custom-made triflange acetabular component.

Study/county	No. of hips	M/F, n	Mean age, yrs	Defect	Mean FU, yrs	Outcomes	Clinical outcome, mean
DeBoer et al/USA[5]	20 revision hips	3/15	56	All pelvic discontinuity	10	6 revisions for any reason (30%). No removal of triflange components.	HHS: 80
Taunton et al/USA (included patients reported by DeBoer)[7]	57 revision hips	6/51	61	All pelvic discontinuity	6.3	20 revisions for any reason (35%); 3 failures of triflange components (5.3%).	HHS: 74.8
Scharff-Baauw et al/ Netherlands[27]	50 revision hips	41/8	68	AAOS III 33 hips. Pelvic discontinuity 16 hips	2	8 complications (16%); no removal of triflange components.	None reported
Holt and Dennis/USA[24]	26 revision hips	8/18	69	AAOS III 23 hips. Pelvic discontinuity 3 hips	4.5	3 failures of triflange components (12%); two of the failures had pelvic discontinuity (2/3). 2 patients with complications (8%) (dislocation).	HHS: 78
Christie et al/USA[25]	59 revision hips/8 primary hips	20/56	59	AAOS III 35 hips. Pelvic discontinuity 32 hips	4.4	12 patients (15.6%) with dislocation and 6 reoperations for dislocation (7.8%); no removal of triflange components.	HHS: 82.1
Gladnick et al/USA[28]	73 revision hips	52/21	59	Paprosky type IIIB	7.5	15 revisions for any reason (20.5%). 3 failures of triflange components (4.1%).	WOMAC[29]: 71.35
Berasi et al/USA[30]	24 revision hips	16/8	67	Paprosky type IIIB	4.7	4 revisions for any reason (17%); 2 failures of triflange components resulting from infection (8%).	HHS: 65
Barlow et al/USA[31]	63 revision hips	Not reported	62	Paprosky type IIIB	4.3	17 revisions for any reason (27.0%). 7 failures of triflange components (13.5%).	WOMAC: 71.35
Current study	39 revision hips	24/14	69	All pelvic discontinuity	5.1	8 (21.6%) revisions for any reason (%). 2 failures of triflange components resulting from infection (8%).	HHS: 80.5

AAOS, American Academy of Orthopaedic Surgeons; FU, follow-up; HHS, Harris Hip Score; M/F, male/female; WOMAC, Western Ontario and McMaster Universities osteoarthritis index.

treated for pelvic discontinuity with a custom-made triflange component underwent a revision procedure, five of those for instability (all treated with revision to either a constrained or a dual-mobility liner). Taunton et al[7] reported a revision rate of 20/57 (35%) with a minimum two-year follow-up (mean of 6.3 years), and a 5.3% failure rate (3/57).

In another retrospective report of 63 custom triflange reconstructions in Paprosky type IIIB defects with a minimum of two years' follow-up (mean of 4.7 years), Barlow et al[31] reported 17 revisions for any reason (27%) and a 13.5% failure rate.

In our study, we found a healed pelvic discontinuity in 36 of 39 (92%) hips with the custom acetabular components. Taunton et al[7] had previously reported a healing rate of 46 of 57 (81%) hips with this component type. Christie et al[25] reported healing in 30 of 32 hips (93%) in a series of 32 pelvic discontinuities treated with custom triflange components. Kosashvili et al[32] reported healing in 23 of 26 (88.5%) hips treated with a porous metal cup-cage construct.

We believe that the high rate of discontinuity healing found in our study is due to the design of the custom triflange implants keeping the host bone implant distance no more than 1 mm, in addition to initial dome screw fixation that compresses the implant against host bone. Further, locking screws in the flanges make the implant extremely stable and resistant to pullout forces. These features are also believed to enhance osseointegration.

Despite being a difficult reconstructive challenge, our study shows relatively promising clinical outcomes. The mean postoperative HHS for the 39 patients was 80.5. Taunton et al[7] reported a score of 74.8 at a mean of 5.4 years' follow-up. Holt and Dennis[24] reported in a series of 26 triflange reconstructions a mean HHS of 78 points. Christie et al[25] also reported a promising outcome with a mean HHS of 82.

The few case-series published in the literature are summarized in Table I. Most of these studies included patients with varying severities of bone loss, but reported generally similar outcomes with overall high rates of complications and component failures. To date, we have not revised any triflange cups for aseptic loosening.

The complication of dislocation is important to note in the use of the triflange component. In this group of patients, the dislocation rate was 19%. Prior series reported 21%[7] and 15.6%.[25]

Potential reasons for the high rate of instability include the gluteal nerve denervation that can occur when the abductors are elevated off the outer table during placement of the iliac flange.

Furthermore, recurrent revision surgery compromises the attachments of the abductor musculature with increasing instability.

After experiencing a relatively high dislocation rate (7/29) (24%) in patients treated before 2017, the surgeons choose to use a constrained liner in all patients receiving a custom triflange component after 2017. The use of a constrained liner could potentially further destabilize the construct and increase the risk of pull-out. However, we are yet to experience any of these complications, as there have been no dislocations since and no pull-outs. A constrained liner seems to be a good solution to the high rate of dislocation found when using custom triflange component. Another solution to this problem could be the use of dual-mobility implants, such as in the series of Scharff-Baauw et al[27] who reported a low dislocation rate (1/49); therefore dual-mobility implants are to be considered.

In conclusion, when dealing with pelvic discontinuity in THA revision surgery the custom triflange implants are a reliable and safe solution to a complex reconstructive situation. However, complications are not uncommon, in particular instability which we successfully addressed with constrained liners. The performance of the custom triflange implant in this study is encouraging, with high rates of discontinuity healing and osseointegration of the acetabular implant and with no aseptic loosening at midterm follow-up.

Take home message

- When dealing with pelvic discontinuity in total hip arthroplasty (THA) revision surgery, the custom triflange implants are a reliable and safe solution with high rates of discontinuity healing and osseointegration.
- Complications are not uncommon, particularly instability, which we have successfully addressed with constrained liners.

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