Managing severe periacetabular bone loss during revision total hip arthroplasty (THA) is a challenging task. Multiple treatment options have been described. A custom triflanged acetabular component is a recent treatment option. The authors retrospectively reviewed 19 hips in 19 patients with massive periacetabular bone loss (Paprosky types 3A/3B and AAOS types III/IV) treated with custom triflanged acetabular components. Mean patient age at surgery was 58 years (range, 42-79 years).

At an average follow-up of 31 months (range, 16-59 months), mean Harris Hip Score had improved from 38 preoperatively to 63 postoperatively, and mean Western Ontario McMaster Osteoarthritis Index scores had improved from 43 preoperatively to 26 postoperatively. Sixty-five percent of cases were considered successful. Three (16%) patients had significant complications; 2 (11%) custom triflanged acetabular components were removed due to failure. At last follow-up, 6 (43%) of 14 patients reported that their ambulatory status was improved vs their preoperative status, 3 (21%) reported no change, and 5 (36%) reported that their ambulatory status was worse than their preoperative status.

In this study, the use of a custom triflanged acetabular component for massive periacetabular bone loss in revision THA had less favorable results than in other reports. Use of a custom triflanged acetabular component for massive periacetabular bone loss in revision THA remains a viable option, but surgeon and patient expectations should be realistic.
Managing massive periacetabular bone loss during revision total hip arthroplasty (THA) has been an ongoing challenge for orthopedic surgeons. Multiple treatment options have been proposed, including massive structural allografts, acetabular reconstruction cages, oblong acetabular components, creation of a high hip center, bipolar arthroplasty, and jumbo hemispherical acetabular cups. Currently, none of these options has been shown to predictably yield favorable results in the setting of massive periacetabular bone loss. Common complications include component loosening and migration, alteration in gait biomechanics, changes in the center of rotation of the hip joint, nerve palsies, chronic weakness, and displacement.

Research on the diagnosis and treatment of periacetabular bone loss has led to the creation of 2 commonly accepted classification systems. D'Antonio et al reported the system commonly referred to as the American Academy of Orthopaedic Surgeons (AAOS) classification, and Paprosky et al reported the system commonly referred to as the Paprosky classification. Each of these classification systems attempts to grade the extent of periacetabular bone loss to provide treatment recommendations and prognoses.

In revision acetabular reconstruction, the recent trend, especially among orthopedic surgeons in North America, has been to attempt to attain biologic fixation with a porous-coated uncemented hemispherical cup. However, in many cases, the extent or geometry of the acetabular bone loss precludes this option. As a general rule, most authors recommend at least 50% of the socket surface be in contact with host bone. However, obtaining this amount of contact with host bone is often not feasible in settings of massive acetabular bone loss. Structural allografts and reconstruction cages have not been able to adequately address this problem.

The major challenge of complex acetabular reconstruction is obtaining implant stability on host bone. A product designed to address significant acetabular bone loss, including cases of pelvic discontinuity, is the custom triflange acetabular component, a custom-designed titanium component. It is porous-coated for uncemented implantation and is often coated with hydroxyapatite. It has 3 flanges designed to rest on the ilium, ischium, and pubis. Production of the component begins with a computed tomography (CT) scan of the patient's pelvis. From these data, a computerized 3-dimensional model of the pelvis is created. A 1-to-1 model of the involved hemipelvis is then created using stereolithography or, more recently, a rapid prototyping machine. Based on this pelvic model, clay is used to design a custom acetabular cup model with its 3 individualized flanges (Figure 1). Flange size, geometry, and orientation are designed to fit securely along the patient’s remaining bone and to bridge bone defects. Cup abduction and anteverision angles are established using existing pelvic landmarks and anatomic planes as a reference. Multiple screw holes to accommodate 6.5-mm screws are placed into the iliac and ischial flanges. Often, the pubic flange does not contain screw holes. The surface of the completed clay model is then digitized, and this information is used by machining centers to mill the surfaces of the titanium stock. A custom triflange acetabular component is then created using the titanium alloy. The cup is compatible with standard snap-in acetabular liners. Porous and hydroxyapatite coatings are applied to the flanges and cup to facilitate bone ingrowth. These characteristics allow for a rigid implant designed to accommodate and bypass host bone loss patterns while allowing for biologic fixation (Figure 2).

The purpose of this study was to report the short-term results of custom triflange acetabular components used in the treatment of massive acetabular bone loss (Paprosky types 3A/3B and AAOS types III/IV) in THA. The null hypothesis was that the clinical improvement and compli-
cation rates in the custom triflange acetabular component study group would be similar to those found in the current literature.

MATERIALS AND METHODS
Between May 2001 and March 2005, two surgeons (JJS, MLS) reconstructed 23 hips in 23 patients using a custom triflange acetabular component (DePuy, Warsaw, Indiana). This represents all custom triflange acetabular components implanted during this time by these surgeons. Patient selection for this procedure was based on radiograph and CT studies demonstrating periacetabular bone loss to an extent that would preclude the use of a hemispherical uncemented cup. All patients had a preoperative CT scan that was used to create a pelvic model and a custom triflange acetabular component. To be included in the study, patients had to have undergone the custom triflange acetabular component reconstruction due to massive periacetabular bone loss and had to be available for at least 1 year of follow-up. One patient with dwarfism did not have severe bone loss and was reconstructed using a custom triflange acetabular component due to the size and geometry of the acetabulum. This patient was not included in the study. Three additional patients died of causes unrelated to surgery before a minimum of 1-year follow-up. These patients were also not included in the study. The remaining 19 patients composed the study group for this retrospective case series. This study was approved by the Institutional Review Board of the University of Cincinnati.

The study group comprised 12 women and 7 men with a mean age at surgery of 58 years (range, 42-79 years). Patients were retrospectively reviewed at a mean of 31 months (range, 16-59 months) postoperatively. The patients consented to the study, and individual charts were reviewed. Patients were asked to participate in an interview; 17 of 19 patients were interviewed. Two patients gave consent for their records to be reviewed and to participate in the study but did not come in for a formal interview. The office notes, evaluations, and most recent postoperative radiographs were used to obtain outcomes scores and patient satisfaction results. All patients were undergoing revision THA except for 1 patient who had severe bone loss from a previous acetabular fracture but had not undergone a previous THA. This patient was included in the study.

Mean number of previous reconstructions of the involved hip was 2 (range, 0-5). The most common indication for the original hip reconstruction was osteoarthritis. The most common indication for reconstruction using a custom triflange acetabular component was aseptic osteolysis with mechanical failure and pain. Other indications for a custom triflange acetabular component included previous infected THA and multiple dislocations.

All 19 patients included in this study had massive acetabular bone deficiency. Bone loss grading was performed using preoperative radiographs, pelvic models, and operative notes. Three patients were considered to have Paprosky type 3A bone loss and 16 to have type 3B. Using the AAOS classification, 16 patients were classified as having type III bone loss and 3 as having type IV. Three cases of pelvic discontinuity were noted.

All surgeries were performed through a posterior approach. Three patients had a trochanteric osteotomy, and 2 others had either trochanteric nonunion or trochanteric deficiency from previous surgeries. The femoral stem was revised in 7 patients and retained in 12. The custom triflange acetabular component is compatible with standard snap-in liners. Six patients had constrained liners, and 13 had standard nonconstrained liners. Bone grafting with allograft fill was performed in all patients. Custom triflanged components were secured to host bone using acetabular screws in the iliac and ischial flanges. In some cases, no screw holes were located in the ischial flange due to the patient’s bony geometry and the surgeon’s preference. In 13 cases, fixation to the ischium was either augmented or obtained with a cable passed around the ischial flange, securing it to the ischium. Posterior column plating for discontinuity was not performed in any patient.

Patient data were collected through chart review and patient interviews. Seventeen of 19 patients were interviewed. Pre- and postoperative Harris Hip Scores (HHS) and Western Ontario McMaster Osteoarthritis Index (WOMAC) scores were available for 13 patients. Two of these patients had undergone explantation of the custom triflange acetabular component, resulting in 11 patients with pre- and postoperative scores. Patients were also asked a series of questions relating to ambulatory ability, need for narcotic pain medication, and satisfaction with the procedure. Patient preoperative radiographs and pelvic models were examined to determine the grade of periacetabular bone loss. Postoperative radiographs were examined for component stability and evidence of radiographic migration. Radiographic migration was defined as progressive component migration coupled with symptoms of loosening. An isolated broken screw in the absence of symptoms or obvious component movement was not defined as radiographic migration. Rates of reoperation and postoperative complications were defined.

RESULTS
Harris Hip Scores and WOMAC scores were available for 11 patients. Mean HHS improved from 38 (range, 14-52) preoperatively to 63 (range, 28-92) at last follow-up. Mean WOMAC score improved from 43 (range, 24-64) preoperatively to 26 (range, 12-43) postoperatively. (A higher HHS correlates with less hip pain and increased hip function, whereas a lower WOMAC score indicates less pain and disability.) Ten (91%) of 11 patients had improved post- vs preoperative HHS at last follow-up. Ten (91%) of 11 patients also had improved postoperative WOMAC scores.
Eleven (65%) of 17 patients were considered to have a successful result. Based on a previous custom triflange acetabular component study by Holt and Dennis,16 a procedure was considered successful if the patient was independently ambulating without supplementary narcotic analgesics and the custom triflange acetabular component was stable without migration radiographically.

No significant intraoperative complications occurred related to insertion of the custom triflange acetabular component. Three (16%) of 19 patients had significant postoperative complications: mechanical failure of the implant, septic loosening and failure of the implant, and injury to the superior gluteal nerve. The 2 cases of failure were treated with explantation. The superior gluteal nerve injury was diagnosed clinically and by electromyography. The patient was treated with physical therapy, and, to date, the patient continues to have abductor weakness.

Seven (37%) additional patients had minor postoperative complications. Two (11%) patients had wound infections and 5 (26%) had postoperative dislocations. The wound infections were each diagnosed within several weeks of surgery and treated with irrigation and debridement. The custom triflange acetabular component was retained and the wound went on to heal in each case. The 5 patients who dislocated were treated with reduction while under anesthesia. Two of these patients had multiple dislocations. One underwent conversion to a constrained liner, and the other underwent exchange of the constrained liner due to failure of the locking ring. None of the patients who sustained dislocations had undergone a concomitant revision of the femoral component during initial implantation of the custom triflange acetabular component.

The overall reoperation rate for any reason was 32% (6/19). Reoperations included 1 explantation for aseptic failure, 1 explantation for septic failure, 1 revision to constrained liner, 1 exchange of constrained liner due to locking ring failure, and 2 irrigations and debridements of postoperative wound infections.

All patients were followed postoperatively with anteroposterior pelvis radiographs. At last follow-up, 6 (32%) of 19 patients demonstrated evidence of custom triflange acetabular component osteointegration with bone remodeling about the porous surface. Nine (47%) of 19 patients had no obvious osteointegration where the component was still radiographically stable; in 3 of these patients, a fractured screw was present, but no evidence of component migration was noted. In 4 (21%) of 19 patients, clear evidence existed of radiographic migration involving pulloff from the ischium. Of these, 2 required explantation of the custom triflange acetabular component, 1 due to aseptic loosening (Figure 3) and 1 due to septic loosening. In the other 2 cases, minor pulloff from the ischium existed that appeared to have stabilized at last follow-up.

Each patient was asked to compare preoperative ambulatory status with his or her current abilities. Fourteen patients responded to this question. Six (43%) patients stated that overall ambulatory status had improved, 3 (21%) felt that ambulatory status was unchanged, and 5 (36%) felt that it was worse than their preoperative status. Each patient was asked to assess overall satisfaction with the custom triflange acetabular component surgery on a scale of 1 to 5, with 1 being very dissatisfied and 5 being very satisfied. Mean satisfaction grade was 3.5 (range, 1-5). Finally, each patient was asked to consider whether he or she would again choose to have the surgery. Sixteen patients responded, with 12 (75%) stating yes and 4 (25%) stating no.

Pelvic discontinuity was present in 3 cases preoperatively. All 3 patients had improved HHS and WOMAC scores at last follow-up. No cases of radiographic migration existed among these 3 patients. Two minor complications occurred, both dislocations, and 1 patient underwent a revision to a constrained liner. Neither of the other 2 patients underwent reoperation. One patient gave a satisfaction grade of 3, and the other patients gave satisfaction grades of 5. Ambulatory status from preoperative level was improved in 2 patients and unchanged in 1. All 3 patients stated that they would choose to have the surgery again. Two patients were considered to have a successful result according to previously defined criteria. One patient was not considered to have a successful result due to being prescribed chronic narcotic pain medication.

**DISCUSSION**

The management of massive periacetabular bone loss in THA continues to be a challenging problem. Considerable controversy exists in the literature on how to manage this problem, and currently no procedure consistently and reliably produces favorable outcomes.5,12,15,16 Multiple treatment options for severe acetabular bone loss during revision THA have been described, including use of uncemented jumbo cups,11 biopolar hemiarthroplasty,17 oblong acetabular components,8,9 structural allografts,1,7,14 and reconstruction cages.1,2,7 Each of these methods has produced only modest success for massive acetabular bone loss.

The custom triflange acetabular component has the reported advantage of being able to rigidly span large combined ac-
etabular defects while having a custom fit to host bone and the expectation of biologic fixation. Three recent studies have looked at short- and intermediate-term results of the custom triflange acetabular component. Christie et al followed 67 cases for an average of 53 months. Mean HHS improved from 33 preoperatively to 82 postoperatively. No custom triflange acetabular component was removed. The most common complication was dislocation. No cases of obvious cup migration were noted. The authors concluded that the triflanged cup was a favorable option for revision THA with extensive acetabular bone loss.

Holt and Dennis reported 26 patients with Paprosky type 3B bone loss treated with custom triflange acetabular components. Three patients had preoperative pelvic discontinuity. Mean HHS improved from 39 preoperatively to 78 postoperatively. Eighty-eight percent of cases were considered clinically successful. Component failure occurred in 3 (12%) patients. All failures were secondary to aseptic component loosening and occurred predominantly by loss of ischial fixation. Preoperative pelvic discontinuity was present in 2 of the 3 cases of failure. The third case of pelvic discontinuity, which did not fail, was treated with supplementary posterior column plating. Union of the discontinuity was noted in this case, which had a successful clinical result. One of the failed cases was revised to a resection arthroplasty. The other 2 patients with failure refused additional surgery. Other complications included 2 dislocations treated with closed reduction and 2 cases of significant limp where a superior gluteal nerve injury was suspected. Recommendations included performing a greater trochanteric osteotomy to relieve tension on the superior gluteal neurovascular pedicle during custom triflange acetabular component insertion and supplemental column plating for cases of pelvic discontinuity.

Joshi et al reviewed a series of 27 patients with AAOS type III acetabular deficiency treated with a custom triflange acetabular component. Mean hip scores (Charnley’s modification of the Merle d’Aubigne and Postel scoring scale) increased from 2.3 preoperatively to 5.3 at last follow-up. Femoral revisions were performed in all 27 cases. One case of dislocation was noted. Significant complications included sciatic nerve palsy. The authors noted that the procedure was technically demanding. The results were deemed acceptable, although a high complication rate was noted. Until additional long-term results are available, it was recommended that routine use of custom triflange acetabular components be limited to patients for whom Girdlestone pseudarthrosis is the only surgical alternative.

In the current study, mean HHS and WOMAC scores improved from pre- to postoperatively. The success rate was 65%. Two (11%) cases of failure resulted in removal and revision of the custom triflange acetabular component. Both of these patients had preoperative Paprosky type 3B bone loss, and neither had a pelvic discontinuity. Five patients had dislocations. Two of these patients dislocated even though a constrained liner had been placed. All patients were reduced while under anesthesia and 2 underwent reoperation. One reoperation was for conversion to a constrained liner and the other was to revise a brokenlocking ring. Interestingly, no patient with a concomitant femoral revision sustained a dislocation. This trend was also seen in the study by Joshi et al, where femoral revision was performed in all cases and only 1 patient dislocated. The current authors believe that this is due to the inability to adjust version when using a custom triflange acetabular component in the absence of a femoral revision. This inability to modify the component intraoperatively is a disadvantage of custom triflange acetabular components.

The substantial increase in mean HHS noted in the current study was also seen in the 3 other studies examining the results of the use of custom triflange acetabular components (Table). The current study’s success rate of 65% was lower than the 88% reported by Holt and Dennis. Dislocation

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**Table**

Summary of Studies Examining the Use of Custom Triflange Acetabular Components in Revision THA

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Patients</th>
<th>Mean HHS Preop</th>
<th>Dislocation Rate, %</th>
<th>Component Revision, %</th>
<th>No. (%) of Radiographic Migration</th>
<th>Significant Postop Complications</th>
<th>Component Failure or Explantation</th>
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<td>Christie et al</td>
<td>67</td>
<td>33</td>
<td>16</td>
<td>8</td>
<td>0 (0)</td>
<td>5 (7)</td>
<td>0 (0)</td>
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<tr>
<td>Holt &amp; Dennis</td>
<td>26</td>
<td>39</td>
<td>8</td>
<td>12</td>
<td>3 (12)</td>
<td>5 (19)</td>
<td>3 (12)</td>
</tr>
<tr>
<td>Joshi et al</td>
<td>27</td>
<td>2.3</td>
<td>4</td>
<td>7</td>
<td>0 (0)</td>
<td>6 (22)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Current study</td>
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<td>38</td>
<td>26</td>
<td>21</td>
<td>4 (21)</td>
<td>3 (16)</td>
<td>2 (11)</td>
</tr>
</tbody>
</table>

Abbreviations: HHS, Harris Hip Score; Postop, postoperative; Preop, preoperative.

*Joshi et al* reported clinical results using Charnley’s modification of the Merle d’Aubigne and Postel scoring scale (range, 1-6) rather than the Harris Hip Score (range, 0-100).
and complication rates in the current study were slightly higher than in other reports. Reoperation for component revision occurred in 21% of the current patients vs 8% in the Christie et al study, 12% in the Holt and Dennis study, and 7% in the Joshi et al study. The current study’s rate of radiographic migration was 21%, significantly higher than the other custom triflange acetabular component studies. The results reported in this study are slightly less favorable than results published in the 3 other studies. Complication rates were higher and improvements were less dramatic. Although patients in this study were, on average, doing better postoperatively compared with preoperatively as demonstrated by HHS and WOMAC scores, they failed to show the extent of improvement seen in other custom triflange acetabular component studies. However, the results were not as poor as those seen in many previous studies attempting to manage massive acetabular bone loss through alternative methods. All patients in the current study had massive acetabular bone loss, and most had undergone multiple revisions. Numerous comorbid conditions, such as low back pain, chronic pain syndromes, and surgical treatment of other joint disease, existed in this patient population. In many patients, few acetabular reconstructive options remained (Figure 4). The results reported in this study are better than one would expect with resection arthroplasty.

CONCLUSION
Managing massive acetabular bone loss during revision THA is a challenging task. Complication rates are high for all reconstructive options for massive bone loss (Paprosky types 3A/3B and AAOS types III/IV). The custom triflange acetabular component also has a high rate of complications and is technically demanding to insert. However, for patients with extremely severe bone loss, the custom triflange acetabular component is a reasonable option to consider. The patient and the surgeon should both be aware that multiple past surgeries and severe acetabular bone loss are preexisting problems for which no perfect reconstruction method currently exists. Therefore, patient and surgeon expectations should be realistic.

REFERENCES