Management of the Bone Deficient Hip
Acetabular Revision Options

Michael J. Christie, MD
David K. DeBoer, MD

Reconstruction of the acetabulum in patients with significant acetabular bone deficiency remains a major challenge in modern joint replacement arthroplasty. Although there are several classification schemes to describe acetabular defects, the American Academy of Orthopaedic Surgeons (AAOS) Committee on the Hip devised a classification scheme that has become the standard for describing acetabular bone loss (Table). Type I defects are segmental deficiencies with complete loss of bone in the supporting hemisphere. These defects can be either peripheral rim defects or central defects with an absent medial wall. Type II defects are cavitary deficiencies that represent volumetric loss of bone with an intact acetabular rim. Type III defects represent a combination of segmental (type I) and cavitary (type II) bone loss. Types IV and V defects represent special circumstances in which there is either a pelvic discontinuity or hip arthrodesis. Although the AAOS system has shortcomings, it is simple and applicable to both primary and revision cases.

ACETABULAR RECONSTRUCTION
The optimal method of acetabular reconstruction depends on the severity and location of the bone loss, as well as the experience of the surgeon with the reconstruction technique. Whatever method is chosen, the success of the procedure and the longevity of the reconstruction depend on the achievement of three goals (listed in the order of importance): 1) attainment of initial stability on host bone without the reliance on graft and support, 2) restoration of joint mechanics to as near anatomic as possible, and 3) preservation or addition of bone stock.

Historically, alternatives for reconstruction in less than salvage situations include cemented components bipolars, cementless hemispherical components, small components with high hip centers, structural allografts, and oblong components. The optimal method of acetabular reconstruction under these circumstances depends on the severity of the acetabular bone loss. If the degree of superior migration is small, the acetabulum can be reconstructed using an oversized hemispherical cup by simply converting the oblong defect back into a hemisphere. However, if the defect is large, reconstruction using an oversized cup is not feasible because hemispherical reaming will cause obliteration of either the anterior or posterior columns of the acetabulum, eliminating these necessary structures required for implant stability and fixation.

METHODS OF RECONSTRUCTION
There are several methods of reconstruction available to the surgeon when the acetabular defect is significantly large, making an oversized cup unfeasible. Many authors have advocated using large structural allografts in this situation to restore acetabular bone stock, provide stability for the acetabular implant, and allow restoration of the normal hip center.

The initial results of acetabular reconstructions using large structural allografts were encouraging with excellent initial implant stability and predictable relief of symptoms. However, as these reconstructions underwent follow up for a longer period, the majority of authors report increasing failure rates between 30% and 50% after 5 to 10 years of follow up. Although the variability in the amount of acetabular bone loss and the location, size, quality, and orientation of the structural allografts have made the clinical studies difficult to compare and interpret, the etiology of the failures appears to be related to graft resorption.

The reports of long-term failures using structural allografts combined with the poor early results experienced by many surgeons led to a resurgence in the use of various antiprotrusio rings and cages to reconstruct these acetabular defects. These implants are metal rings with iliac and ischial extensions that are secured to the pelvis with multiple screws. Morselized allograft com-
monly is used with these devices to fill cavitary defects. Once the flanged component is fixed to the pelvis, a polyethylene cup is cemented in the proper orientation within the center of the cage.

A series by Zehntner and Ganz\textsuperscript{10} reports the intermediate-term outcome using the Mueller reinforcement ring (Protek AG, Bern, Switzerland) for patients with AAOS types I, II, and III acetabular defects. Kaplan-Meier survivorship analysis revealed a 79% probability of implant survival at 10 years using revision as the endpoint for failure; however, 44% of the reconstructions had pending failures with component migration of $\geq 2$ mm at 7.2 years follow up. Berry and Muller\textsuperscript{7} reported a 24% revision rate (12% aseptic loosening and 12% septic loosening) for patients undergoing acetabular revision using the Burch-Schneider cage after an average of 5 years of follow up.

Another method of acetabular reconstruction developed to avoid using structural allograft is the technique using the “high hip center” most recently described by Schutzer and Harris,\textsuperscript{11} Jasty and Freiberg,\textsuperscript{12} and Kelley.\textsuperscript{13} In this method, a standard small hemispherical cup is press-fit high on the ilium to bypass the acetabular defect and gain stability on healthy host bone. This reconstruction technique has yielded good short-term results.\textsuperscript{11}

In a series of 56 hips that underwent follow up for an average of 3.5 years, no revisions of the acetabular component were reported. This technique allows reconstruction of the acetabulum without a structural allograft. Unfortunately, the femoral component may need to be revised to restore normal limb lengths if the hip center is placed too superiorly. Under these circumstances, replacing the modular femoral head to a femoral head with greater neck length will not adequately reconstitute normal limb lengths and a calcar-replacing femoral prosthesis is required. Additionally, the trochanter must be advanced to restore normal soft-tissue tension. Thus, the revision of a well-fixed and positioned femoral component may be required to reconstruct a failed acetabulum.

Another alternative method of reconstruction was derived from our observation of the oblong-shaped defect created by the loosening and migration of the failed acetabular component which led to the design of an oblong-shaped prosthesis. This implant replaced the deficient acetabular bone stock with metal, avoiding the need for structural allograft and allowing implant stability directly on host bone. The component essentially was designed to “match” the defect. The implant is able to achieve the twin goals of intimate contact and thus initial stability on the host bone for improved stability. Restoration of the hip center back to its anatomic location is achieved as well.

Other indications include isolated rim and superior rim defects and, more recently, severe type III defects and those associated with pelvic discontinuity whereby fixation of the posterior column can be achieved via plating. We also have used the component successfully in primary situations in which the femoral head is either not sufficient for structural autografting or is absent.

Early results have been encouraging, with the initial 18 cases demonstrating predictable clinical outcomes and excellent patient satisfaction. The average follow up of this study population is 3.5 years with an average Harris hip score of 90 and a pain score of 43. Radiographically, the joint center restoration is evident; 6 of the components have exhibited radiolucencies, all of which are thus far nonprogressive. No failures have occurred as of this date, and no revisions are pending. Preliminary data analysis of cases implanted subsequent to this particular patient cohort is suggestive of similar findings and will be investigated in the future.

Reconstruction of the massively deficient acetabulum presents fewer options and is truly a “salvage procedure.” Alternatives include resection arthroplasty, major structural or total acetabular allografts, antiprotrusional rings or cages, and custom flanged components. There are certain circumstances in which porous-coated hemispherical implants have a high failure rate. In a study by Paprosky et al.\textsuperscript{2} 147 revision arthroplasties using cementless hemispherical cups with 3- to 9-year follow up were reviewed. Mechanical loosening as demonstrated by component migration of $> 3$ mm was noted in only 4% of cases. However, all of the failures occurred in patients with massive bone loss (type IIIB defect in their classification system), thus requiring large structural allografts for stability.

Similarly, McAllister and Borden\textsuperscript{14} reviewed their experience in 218 revisions using the Porous-Coated Anatomic prosthesis. They had 31 cases in which a functional rim of acetabular bone was not present and a significant structural allograft was required to stabilize the implant. Only 48% remained radiographically stable at follow up compared with 97% of cases in which a good rim press-fit was obtained. Young et al.\textsuperscript{15} summarized their experience with structural acetabular allografts after 2 to 8 years of follow up, stating that grafts with implants that have at least two-thirds host bone support were more successful than grafts that provided greater than one third of the mechanical support of the implant.

Use of major structural allografts have met with largely disappointing results, as demonstrated by Gross’s reports of a 45% rerevision rate after 7 years of follow up in a series in which $>50\%$ of the support of the component

<table>
<thead>
<tr>
<th>TABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AAOS acetabular defect classification</strong></td>
</tr>
<tr>
<td>1. Segmental</td>
</tr>
<tr>
<td>2. Peripheral</td>
</tr>
<tr>
<td>3. Central</td>
</tr>
<tr>
<td>4. Cavitary</td>
</tr>
<tr>
<td>5. Combined segmental and cavitary</td>
</tr>
<tr>
<td>6. Pelvic discontinuity</td>
</tr>
<tr>
<td>7. Arthrodesis</td>
</tr>
</tbody>
</table>
was supplied by the graft. Paprosky and Magnus\textsuperscript{11} also reported a reversion rate of 70% in their series using distal femoral allografts.

Although many authors have reported failures using bulk allografts,\textsuperscript{4,5,16,17} Chandler et al\textsuperscript{18} reported on 24 patients undergoing acetabular revisions with either structural allograft or autograft. There were only four (16%) aseptic graft failures in their cohort after an average of 12.5 years of follow up. They attributed their success to a variety of technical considerations including: the use of high-quality grafts, orienting the dead trabeculae in the line of weight-bearing forces, shaping the graft to fit the host defect accurately, aligning the fixation screws with the weight-bearing forces, cementing all cups with >50% contact with the allograft, and allowing early weight bearing to stimulate healing of the graft.

After Paprosky et al\textsuperscript{12} reported on their 6-year follow-up data using conventional allografts with a 100% failure rate for type IIIB defects, they described a new method of reconstruction using a total acetabular transplant allograft fixed to the host ilium with 6.5-mm cancellous screws. The acetabular component is cemented into the allograft in a traditional manner. Early results of this technique have been reported in 20 patients with an average of 2.5 years follow up.\textsuperscript{19} There were three failures, two due to infection and one due to graft fracture in an obese patient who was noncompliant with her weight-bearing status.

Oakeshott et al\textsuperscript{20} also have reported encouraging short-term results on a series of nine patients using whole acetabular structural allografts. The early results of this technique are similar to the early results reported with conventional grafting methods to reconstruct the acetabulum. It will be interesting to see if this total acetabular allograft will provide a mechanically stable environment long term and if the graft will help reconstitute the massive bone loss at follow-up revision surgery.

Several authors recently have reported on the use of antiprotrusio cages for acetabular revision for massive bone loss. Berry and Muller\textsuperscript{7} reviewed 42 revisions using the Burch-Schneider cage with an average follow up of 5 years. All patients were classified as AAOS type III defects (combined cavitory and segmental defects). Overall, there was a 24% failure rate, 12% due to infection and 12% due to aseptic loosening. Early patients in their series did not receive morselized bone grafting while the 20 patients treated after 1982 received bone graft. The failure rate was independent of whether or not the patients received bone graft.

Peters et al\textsuperscript{8} also reported on 28 revisions using the Burch-Schneider cage. Twenty-two patients had AAOS type III defects, five type II defects, and one type I defect. They had no clinical failures after an average of 33 months follow up, although 14% had component migration >3 mm.

Fortunately, acetabular revisions in which there is massive bone loss are not common. However, we have observed a trend toward increasing numbers in our clinical practice over the past 5 years. The best method of treatment to provide long-term stability remains unclear. A modification of the antiprotrusio design is the uncemented, fully porous-coated flanged acetabular component indicated for particularly severe pelvic bone loss. The concept is similar to that of the rings insofar as fixation of the remaining pelvis is paramount, but the custom manufacturing of the flanged component allows for much greater flexibility and “matching” to the specific anomalies or defects encountered. The components are made of titanium and are fully hydroxyapatite and porous-coated, and the custom manufacturing is based on a computed tomography-generated three-dimensional model of the patient’s pelvis. The flanged portion of the component is designed via these data and consists of contoured iliac and pubic flanges; fixation to the host ilium and ischium is obtained via 6.5-mm screws. In cases of pelvic discontinuity, the flanges of the component function as a plate to “bridge” the two halves of the pelvis.

The short-term results of the un cemented triflange cup are comparable to the results using total acetabular allografts or cemented antiprotrusio cages. Salient features of the triflange cup include: restoration of a more anatomic hip center; mechanical stability from host bone; biologic fixation with porous hydroxyapatite coating, use of a large contact area on the host ilium, ischium, and pubis to distribute joint forces over a large area to decrease the overall stress distribution on host bone; and a stable environment to allow incorporation of particulate allograft for restoration of bone stock. In contrast to the antiprotrusio cage, the flanges on the triflange cup are much thicker, resulting in a stiffer implant. Also, the polyethylene insert is secured to the implant using a standard ring locking mechanism as opposed to cement. From a historical perspective, the use of bone ingrowth prostheses with mechanical polyethylene insert locking mechanisms have had fewer intermediate- to long-term failures than standard cemented acetabular implants.

Our early experience has yielded satisfactory clinical and radiographic results, especially with regard to the particularly severe types III and IV defects that ordinarily are considered the indication for the custom flanged component. A good portion of these cases are females with a history of developmental dysplasia of the hip and have had multiple previous procedures that have resulted in massive bone loss. The initial 10 cases exhibit an improvement in pain scores to a postoperative average of 40 with correlate improvement in Harris hip scores to a postoperative average of 80. There has been no radiographic evidence of component migration, radiolu cencies, or screw breakage.

Preliminary data on a subsequent 40 patients with a maximum of 5 years of follow up demonstrate similar results. Cost has been a major concern, but when considered in the context of major allografting, acetabular roof
rings, etc, the procedure is cost competitive. The surgical time is reduced significantly since the majority of the planning and decision-making is done prior to the actual surgery.

**CONCLUSION**

It has become increasingly clear that to achieve long-term implant longevity, particularly in the structurally-deficient revision acetabulum, the primary goal of achieving stability on host bone must be achieved. The best method for revising the deficient acetabulum is not known. Only longer follow up will indicate which technique best provides long-term implant stability.

**REFERENCES**