A Review Paper

Acetabular Component Revision in Total Hip Arthroplasty. Part II: Management of Major Bone Loss and Pelvic Discontinuity

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Abstract

Use of structural bone graft and/or reconstruction cage devices in acetabular revisions with major bone loss has the advantages of providing a stable construct at the anatomical hip center of rotation and, theoretically, reconstituting bone stock. When the structural graft supports more than 50% of the acetabular component, a reconstruction cage device spanning ilium to ischium should be used to protect the graft and provide structural stability. Recent introduction of trabecular metal cups and augments and custom triflanged acetabular components has increased the potential for biological fixation and long-term stability of revision constructs. Longer follow-up of these reconstructions is needed. Revisions with pelvic discontinuity and major bone loss have a high failure rate and require techniques either to reduce and plate the discontinuity or to distract the discontinuity to achieve long-term stability.

For the majority of acetabular reconstructions in which implant–host bone contact is at least 50%, a porous-coated, hemispheric shell secured with multiple screws is the implant of choice. For minor cavitary defects, morselized graft combined with a press-fit hemispheric cup is a good reconstruction method. When loss of superior bone is more significant, an uncemented cup may be placed at a high hip center. The main disadvantages of this technique include potential impingement, potential dislocation, and failure to restore normal hip biomechanics and bone stock. Jumbo cups can restore the hip center of rotation to a more anatomical location but have a higher incidence of dislocation compared with conventional cups, do not restore bone stock, and may require excessive reaming of the posterior column, which potentially compromises implant stability. Oblong cups take advantage of the oval cavity noted with most failed acetabular components and have good intermediate-term follow-up. However, they should be avoided in cases of preoperative superior migration of more than 2 cm and medial wall defects.

With major bone loss (Paprosky type 3) and/or pelvic discontinuity, the success rates of these techniques are significantly decreased. With major bone loss, less than 50% of the implant is in contact with host bone. With pelvic discontinuity, the posterior column is disrupted. These bone deficiencies require alternative reconstruction techniques, including posterior column plating and use of reconstruction cages and structural allograft, custom triflanged acetabular components, and trabecular metal (TM) revision cups and augments. With structural grafting techniques, success depends on the implant–host bone contact area. When this area is less than 50%, the construct has a high risk of failure and requires reconstruction cages to support the graft. Acetabular revisions with pelvic discontinuity have a high failure rate and require techniques either to reduce and fix the pelvic disruption or to span the defect in distraction to achieve long-term stability.

Structural Grafting

Large acetabular defects (Paprosky type 3) may require structural bone grafting to reconstruct bone stock and provide rim and column support for the acetabular component. Several technical considerations are required for the success of this operation.

It has been noted that the failure rate is high when structural grafts support large areas (>50%) of the acetabular component.[1-4] Piriou and colleagues[5] reported on use of hemipelvic acetabular allografts to reconstitute massive bone defects during acetabular revision. Reconstruction cages were not used. At a mean follow-up of 5 years, 7 of 20 cemented acetabular components failed, 5 because of aseptic loosening and 2 because of deep infection. Pollock and Whiteside[4] reported a 59% loosening and migration rate and a 30% revision rate in their series of

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23 massive acetabular allografts used for acetabular revision. Hooten and colleagues[2] reported on 31 revisions in which a bulk acetabular allograft and cementless cup were used to reconstruct the acetabulum. Twelve cups (44%) showed radiographic evidence of instability at a mean of 46 months, and 5 of these were revised. Garbuz and colleagues[1] reported on 33 acetabular revisions reconstructed with massive acetabular allograft (it supported >50% of the cup in each case). At a mean follow-up of 7 years, 15 hips needed a repeat revision (45% failure rate) because of failure of the prosthesis (7 hips) or failure of both prosthesis and allograft (8 hips).

Results are better when the structural allograft supports less than 50% of the acetabular component.[6-11] Morsi and colleagues[7] reported an 86% success rate with use of bulk allograft to reconstruct acetabular defects during revision arthroplasty at a mean follow-up of 7 years. In all cases, more than 50% support of the cup was obtained from host bone. Woodgate and colleagues[8] reported on 51 acetabular revisions reconstructed with structural allograft in which more than 50% cup support was derived from host bone. At 10-year follow-up, implant survival and allograft reconstruction survival were 80% and 94%, respectively.

Sporer and colleagues[9] and O'Rourke and colleagues[10] described a technique of using either distal femoral or proximal tibial allograft and cementless cups to reconstruct the acetabulum. This technique involves contouring the graft in the shape of a 7 and fixing the superior limb to the ilium with cancellous screws. These grafts are selected for structural support because orientation of the trabecular bone provides better mechanical support for the implant compared with a femoral head allograft. The screws are oriented obliquely in the direction of loading to provide compression of the graft against the ilium. Furthermore, the extra-acetabular screws do not interfere with reaming. The acetabular cavity is then reamed to accept a press-fit cup secured with multiple screws. Sporer and colleagues[9] reported on use of the technique in 23 acetabular reconstructions performed for Paprosky type 3A defects (nonsupportive superior dome, superolateral migration of the acetabular component more than 3 cm above the obturator line). At a mean follow-up of 10 years, 5 of the 23 reconstructions were revised for aseptic loosening. With radiographic signs of loosening as the endpoint, 10-year construct survival was 74%.[9]

In a study of 40 acetabular reconstructions with structural graft, Young and colleagues[12] identified several additional factors contributing to failure of structural bone grafts. These factors included fit and fixation of bone graft to host (no gaps between graft and host), fit and fixation of cup to host (no motion of screws or graft), and union of bone graft to host. Confluence of the anterior and posterior columns of the acetabulum was essential for implant stability. Young and colleagues recommended using, in the absence of this confluence, large single grafts such as distal femur or cadaver acetabulum. The failure rate was higher with use of multiple grafts and freeze-dried femoral heads.[12]

Different preparations of allograft may be used to reconstruct acetabular bone deficiencies. Freeze-drying allografts reduces graft immunogenicity and enhances graft incorporation. However, with freeze-dried grafts (vs fresh-frozen allografts), remodeling and revascularization are delayed. Furthermore, freeze-drying can reduce the mechanical properties of the graft and diminish its capacity for structural support.[13,14] There is little in the literature on the irradiation of structural allografts used in revision arthroplasty. In the oncology literature, irradiation has been shown to increase the risk for allograft fracture.[15]

Although contained or central defects can be reconstructed with morselized cancellous allograft or autograft, more significant bone loss of either the anterior or posterior columns or the acetabular dome may necessitate use of structural cortical allografts.[13,16,17] As already mentioned, failure rates for these constructs approach 50% when more than 50% of the implant is supported by allograft bone. In these cases, cage support is required.[1,2,4,5]

Reconstruction Cages

In reconstructions in which structural grafts support large areas of the acetabular component and a reconstruction cage is not used, failure rates higher than 60% have been reported.[1-4,7] A major concern with acetabular reconstruction with bulk structural allograft is graft resorption leading to component migration.[5] In defects that require massive structural allograft (Paprosky type 3B defects), reconstruction cages or reinforcement rings spanning ilium to ischium can support the graft. These devices have flanges for the ilium and the ischium. Fixation to the pelvis can be done with a hook that fits under the teardrop or with a flange that fits on or into the ischium.[17-19] The cage or ring allows for reconstruction at the correct anatomical level. A polyethylene cup is cemented into the cage in the appropriate inclination and version independent of the cage (Figures 1A–1C). This construct allows for an even transfer of weight-bearing stress from the cage to the ilium, allowing the graft to remodel and incorporate into host bone.[17-19] Most cage devices are nonporous and thus do not provide biological fixation. Cages can eventually loosen or break.[17,20]

Reconstruction cages have also been used with morselized allograft for massive acetabular deficiencies. The indications for when to use bulk allograft and when to use morselized allograft with a reconstruction cage are unclear. The theoretical advantages of bulk allograft are restoration of large areas of acetabular bone stock and immediate structural support. The disadvantages of structural allograft are slow revascularization and prolonged presence of necrotic bone tissue with possible graft weakening over time.[13,17,21] Cancellous allografts incorporate more quickly and may reconstitute bone voids in the acetabulum but do not on their own provide structural stability.[13,14]

In a series of acetabular revisions reconstructed with massive acetabular allograft, in which the graft supported more than 50% of the cup, 7 of the 8 patients whose reconstructions had been done with use of a reinforcement cage had a successful result at a mean follow-up of

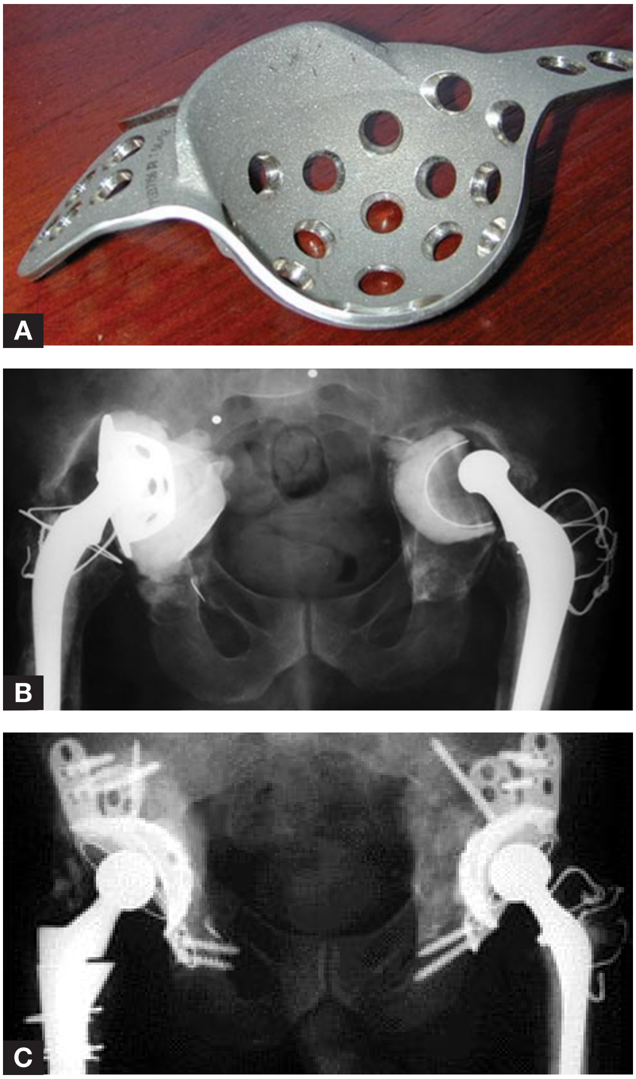

Figure 1. (A) Acetabular reconstruction cage with flanges for fixation onto ilium and ischium. (B) Failure of bilateral acetabular components and (C) bilateral acetabular reconstruction with reconstruction cage and polyethylene cup cemented into cage.

7.5 years.[1] Gross[11] reported on 33 acetabular revisions in which segmental defects involving more than 50% of the acetabulum were treated with massive allografts supported with reconstruction cages extending from the ilium to the ischium. At a mean follow-up of 7 years, the success rate was 76%. Saleh and colleagues[22] reported on 13 acetabular revisions performed with massive structural acetabular allografts and a Bürch-Schneider reconstruction cage. At a mean follow-up of 10.5 years, 77% of the constructs were in place. Three reconstructions failed, 1 for graft resorption and 2 for recurrent dislocation.

Kerboull and colleagues[23] reported on 60 acetabular revisions reconstructed with bulk structural allograft and the Kerboull acetabular reinforcement construct, a hemispheric cross-shaped device with 4 arms, an inferior hook that engages the teardrop, and a superior plate that is fixed to the ilium. This construct provides mechanical support to the graft but does not unload it, as the armature is open. With loosening of the acetabular component as the endpoint, the 13-year survival rate was 92%.

As mentioned, reconstruction cages spanning ilium to ischium have been used without structural graft to revise massive acetabular deficiencies.[17,18,24-29] Berry and Müller[18] reported on 42 acetabular revisions with massive acetabular bone loss revised with the Bürch-Schneider reconstruction cage. Morselized bone was packed into bone defects. At a mean follow-up of 5 years, 76% of cases showed no evidence of acetabular component loosening; of the failures (24%), 12% were caused by sepsis and 12% by aseptic loosening. Success rates for use of this cage with morselized bone to reconstruct massive acetabular defects has ranged from 90% to 100% at intermediate-term follow-up.[25,29] Winter and colleagues[29] reported no failures among the 38 acetabular reconstructions performed with the Bürch-Schneider cage and morselized allograft at a mean follow-up of 7 years. Wachtl and colleagues[28] reported on 38 similar reconstructions. With revision for any reason as the endpoint, 21-year survival was 92%.

Design modifications were introduced into the Contour cage (Smith & Nephew, Memphis, Tenn) to improve construct fixation. This construct contains iliac and ischial flanges, which allow for screw fixation, and a grit-blasted undersurface, which allows for bone ongrowth.[30] Bostrom and colleagues[30] reported on 31 acetabular revisions performed with this device. Structural allograft was used in 1 case and morselized allograft and demineralized bone matrix in the other 30 cases. At a mean follow-up of 2 years, 7% were revised for loosening and 16% were radiographically loose. Furthermore, only 45% had a good or excellent result, mostly because 54% had a persistent limp,[30] which suggests that the Contour cage has not improved rates of construct fixation when compared with results reported for other nonporous antiprotrusio devices.

Over the past 10 years, use of structural allograft and reconstruction cages to reconstruct major bone loss has decreased. With the advent of newer implant designs, indications for these older techniques have become severely limited. In cases of more than 50% host bone contact, a hemispheric porous-coated component with multiple screws is the current implant of choice; in cases of less host bone contact, current revision hip arthroplasty surgeons are gradually moving away from conventional cages and structural allograft to TM implants, porous augments, and triflanged acetabular components.[21,31-36]

Rates of complications after acetabular revisions using structural grafts and cage devices are high. Current-generation cages lack the potential for bone ingrowth and therefore ultimately loosen or break.[17,20] The introduction of porous-coated implants may increase the longevity of these constructs.[33-35,37]

Trabecular Metal and Cup Cage Constructs

Massive, contained acetabular deficiencies may also be managed with TM cups made of tantalum. Gross[21] and Sporer

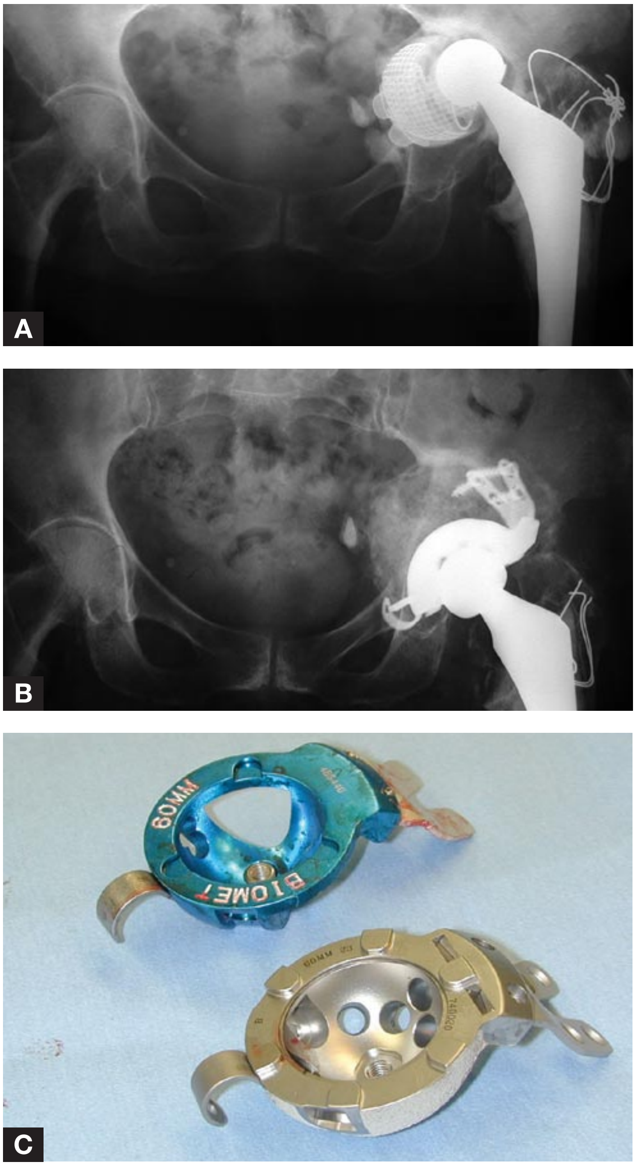

Figure 2. (A) Failed, migrated acetabular component. (B) Revision to modular antiprotrusio component (MAPC; Biomet, Warsaw, Ind). (C) MAPC.

and colleagues[36] suggested that, because tantalum provides a favorable environment for bone graft remodeling and biological ingrowth, TM cups may be used in cases of Paprosky 3A and 3B bone loss. With the addition of morselized bone, TM cups affixed to the ilium with screws can be used to fill contained defects where less than 50% contact is made with host bleeding bone.[21] When the cup is inserted in stable fashion and placed at the correct anatomical level, use of a structural allograft is unnecessary.[21]

Gross[21] suggested that, when less than 30% contact can be made with host bleeding bone, use of a cup cage construct may be considered. Instead of using structural allograft and cage to reconstruct the acetabular bone loss, surgeons can use a TM cup and cage. After insertion of morselized bone graft, the TM cup is impacted into the void and fixed with as many screws as possible. A cage is placed beneath the TM cup and affixed into the ilium and the ischium in standard fashion. As the TM cup makes limited or no contact with host bleeding bone, and remodeling or ingrowth takes several months to occur, the cup is protected by the cage. The theory is that, once ingrowth occurs into the TM cup, stress will be taken off the cage so that the early and intermediate-term failures seen with cages will be avoided.

Porous Metal Augments and Stems

Most reconstruction cage devices are 1-piece and nonporous. They require cementation of a polyethylene liner into the cage, which limits the ability to obtain biological fixation by bone ingrowth, to perform a trial reduction, and to test different liner types to optimize hip stability. Recently, a modular antiprotrusion component (MAPC) was introduced for acetabular reconstruction with major bone loss. The MAPC is a porous-coated shell with modular attachments, including iliac flange, obturator hook, and ischial blade. Several dome screw holes are present for cup fixation. The device allows for bone ingrowth and therefore, in theory, "more permanent" fixation (Figures 2A–2C).[35] In a series of 63 acetabular revisions using the MAPC, Peters and colleagues[35] found 87% still in place after a mean of 29 months. Almost half of these reconstructions were for Paprosky type 3A or type 3B defects. Seven components were revised, 4 for infection and 3 for loosening, and 8 components dislocated. Although longer term follow-up is necessary, early MAPC results are comparable to early results with conventional 1-piece, nonporous cages but include the theoretical advantages already described.

Modular porous TM (tantalum) augments were recently developed to achieve biological fixation and provide coverage and mechanical support for an uncemented hemispheric acetabular component. These cups and augments are manufactured in multiple sizes and shapes to accommodate various bony defects (Figures 3A, 3B). Trial acetabular components are combined with trial modular augments to arrive at the best reconstruction for the acetabulum. The real acetabular augment is fixed to the host through screw holes in the augments. The uncemented acetabular component is then inserted with a layer of cement between the cup and augment to unite the porous tantalum augment to the cup. Additional screws secure the cup to the pelvis, and cavitary deficiencies and augment fenestrations are filled with morselized graft (Figures 3C–3E).[34] Nehme and colleagues[34] reported on a series of 16 acetabular revisions reconstructed with this technique. Eleven of these revisions involved Paprosky type 3A or 3B defects. At a mean follow-up of 32 months, there was no evidence of loosening or migration in any of the constructs.

Another recent addition to porous-coated cage-type reconstruction devices with potential for biological fixation is the custom triflanged acetabular component (CTAC).[31-33] After a thin-cut computed tomography scan of the pelvis is obtained, metal subtraction software is used to create a 3-dimensional hemipelvis model that is

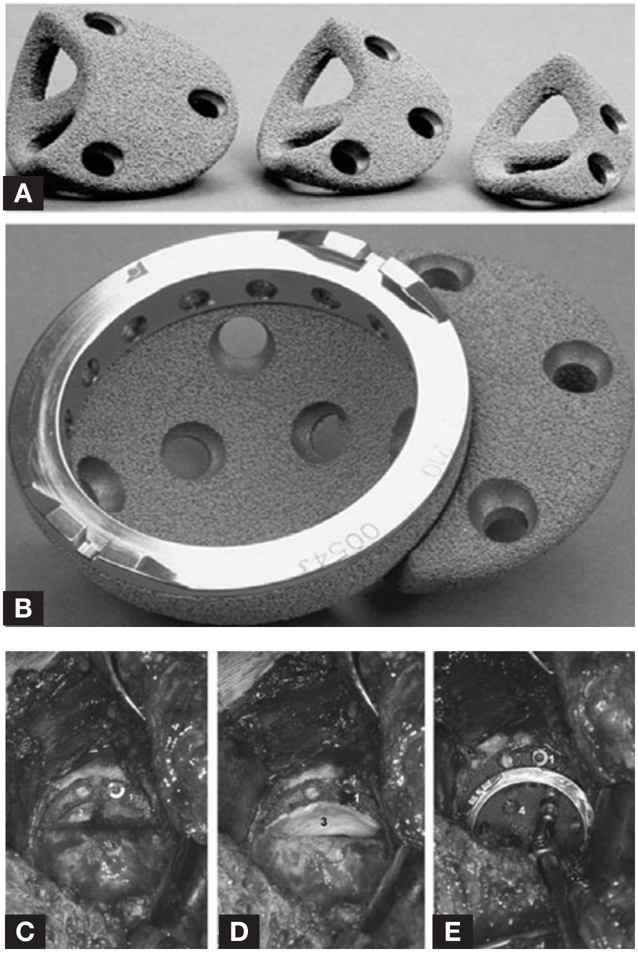

Figure 3. (A) Trabecular metal modular augments and (B) uncemented revision shell (made of porous tantalum) for acetabular reconstruction. These cups and augments are manufactured in multiple sizes and shapes to accommodate various bony defects. (C) Ten-millimeter acetabular augment being implanted in superior acetabular defect. Number 1 indicates augment; number 2 indicates morselized bone graft filling fenestration defects of modular augment. (D) Layer of cement (number 3) applied to surface of augment will unite porous tantalum augment and cup. (E) Hemispherical acetabular component (number 4) is then implanted with layer of cement between cup and augment (number 1). Cup is additionally fixed to host bone through screw holes in augments. Reproduced with permission from Nehme A, Lewallen DG, Hanssen AD. Modular porous metal augments for treatment of severe acetabular bone loss during revision hip arthroplasty. *Clin Orthop.* 2004;(429):201-208.

then used to measure bone loss and to design the CTAC. The CTAC has a central dome, which fits into the central acetabular defect, and 3 flanges, which allow for fixation on ilium, ischium, and pubis (Figures 4A–4C). A polyethylene liner is placed into the central dome using a modular locking mechanism.[31-33,37]

Christie and colleagues[31] reported on use of CTAC in reconstruction of massive acetabular defects in 78 patients. Fifty percent of their cases had a combined (segmental plus cavitary) deficiency, and 50% had a pelvic discontinuity. By 2-year follow-up, there had been no revisions, and all but 2 discontinuities (both asymptomatic) had healed. Recurrent dislocation requiring reoperation had occurred in 6 patients (7.7%). Deboer and colleagues[32] reported on use of CTAC in reconstructing massive acetabular defects with pelvic discontinuity in 20 patients. By a mean follow-up of 10 years, none of these cases had been revised, and 5 (25%) had sustained 1 or more postoperative dislocations. Dennis[33] and Holt and Dennis[37] reported on 26 acetabular revisions with massive bone loss reconstructed with CTAC. Twenty-three (88.5%) of these revisions were stable at a mean follow-up of 2 years. Of the 3 failures, 2 were in patients with a pelvic discontinuity, and 1 was in a patient with severe osteopenia. The device functions as a T-plate does and fits precisely because of its custom design. The CTAC has the potential for biological long-term fixation from bone ingrowth into the porous coating. In addition, incorporation of a modular liner allows for optimization of hip stability. Disadvantages are increased cost and surgery delay pending implant design and manufacturing.[33]

A porous-coated, stemmed acetabular component has been used to reconstruct severe acetabular defects. This technique is based on the fact that the bone between the ilium and the ischium around the greater sciatic notch is usually spared in severe deficiency and that the stem gains its initial stability here. The greater sciatic notch is exposed subperiosteally, and a guide wire is passed into its center from the anatomical center of the acetabulum using a jig. Progressive cannulated reaming over this guide wire creates a tunnel that will accept a stemmed component.[38] Badhe and Howard[38] reported on 31 acetabular reconstructions using this technique. With radiographic loosening as the endpoint, survival at a mean follow-up of 10.7 years was 92%. Pelvic discontinuity is an absolute contraindication for this operation.

Pelvic Discontinuity

Pelvic discontinuity is defined as complete separation of the superior pelvis from the inferior pelvis through the acetabulum by either bone loss or a transverse acetabular fracture. Radiographic findings include a visible fracture line through the anterior and posterior columns and medial translation and/or rotation of the inferior hemipelvis with respect to the superior hemipelvis.[39] These reconstructions are rare (<1% of acetabular revisions) but very difficult, and failure rates are high when the pelvic disruption is not addressed.[12,39] Pelvic discontinuity often occurs with type 3 defects but is also found with lesser degrees of bone loss. Degree of associated bone loss dictates how to address the pelvic discontinuity.

Berry and colleagues[39] reported on 31 acetabular revisions with a pelvic discontinuity reconstructed with a variety of techniques. At a minimum follow-up of 2 years, results were best in patients who did not have severe segmental acetabular bone loss. These cases were successfully reconstructed with stabilization of the discontinuity with posterior column plating and acetabular reconstruction with a porous-coated cup inserted without cement.

Results are poor in patients with severe segmental or combined segmental or cavitary loss and in patients previ-

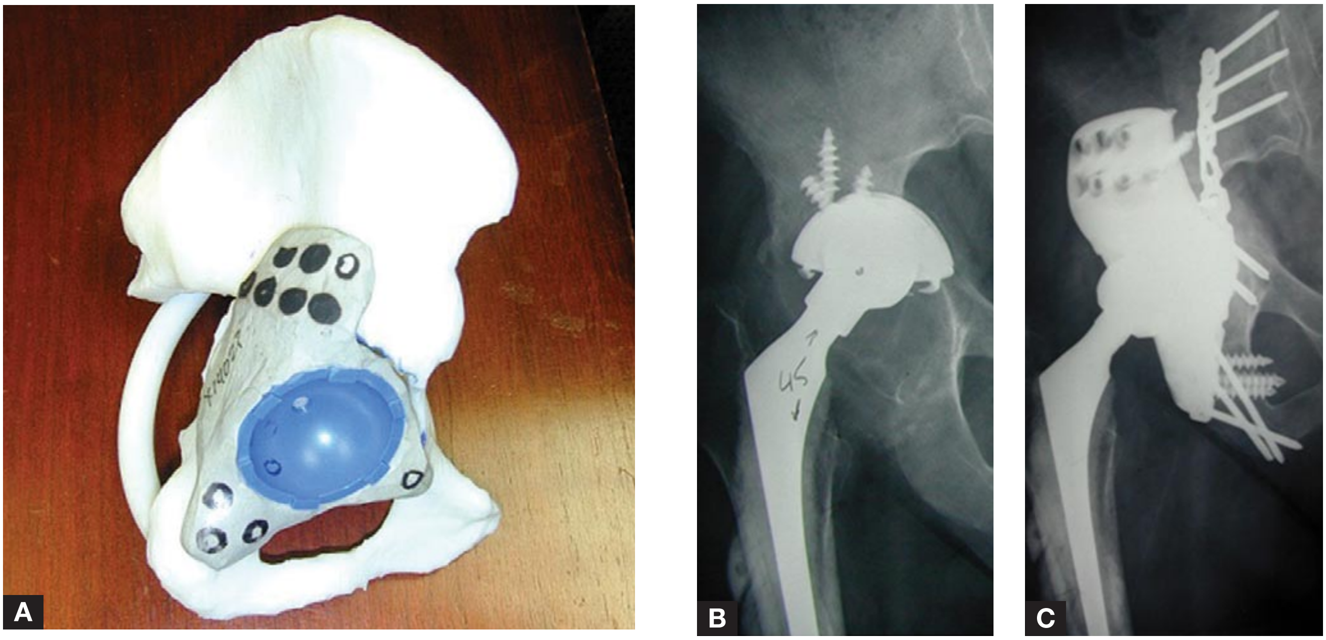

Figure 4. (A) Computer-generated model of a patient's hemipelvis with clay model of custom triflanged acetabular component (CTAC) in place. Thin-cut computed tomography scan of pelvis is used to create hemipelvis model with accurate replication of location and degree of bone loss. CTAC is designed from this model. Preoperative (B) and postoperative (C) radiographs show loose acetabular component, severe osteolysis, and pelvic discontinuity reconstructed with CTAC and posterior column reconstruction plate.

ously treated with pelvic irradiation.[39] The optimal treatment for these patients is unclear. Reconstruction cages appear to be necessary for these large defects, as column plating and bulk allograft reconstruction alone resulted in a revision rate of 47% at a mean follow-up of 83 months.[40] Berry and colleagues[39] suggested that these conditions were best treated with a single structural bone graft protected with a reconstruction cage; all 13 reconstructions for severe bone loss or prior pelvic irradiation reconstructed with a Bürch-Schneider cage were stable at a minimum follow-up of 2 years. However, Paprosky and colleagues have reported poor results with this technique at longer term follow-up and suggested use of TM components and augments as treatment for this problem.[36,41-43] At a mean follow-up of 54 months, 1 of 12 patients reconstructed with TM acetabular components and augments had radiographic loosening, whereas 8 of 12 patients treated with structural allograft and reconstruction cage had radiographic loosening or required an acetabular revision.[36,42] Of 15 pelvic discontinuities treated with acetabular cages and allograft, 5 were revised because of aseptic loosening; in addition, 3 were radiographically loose.[41]

Sporer and colleagues[36] suggested that, in light of these findings, pelvic discontinuity cases with diminished healing potential may be best treated with TM acetabular components. As bone loss and poor vascularity make compression plating of the discontinuity difficult or impossible, large TM cups are impacted into the acetabular defect, distracting the discontinuity. In effect, the TM cup acts as an internal plate. At a mean follow-up of 2.6 years after using this technique for pelvic discontinuity, all 13 patients had increased patient outcome scores, and only 1 showed evidence of radiographic loosening.[36]

CTACs have also demonstrated excellent results for revisions with massive bone loss and pelvic discontinuities. In most cases, screws were initially placed in the ischial flange where the bone was typically the most osteolytic. Fixation of screws into the iliac flange often reduced the discontinuity and derotated the inferior half of the hemipelvis into alignment with the superior half. The posterior column was not plated. Freeze-dried allograft bone was placed at the discontinuity site. At a mean follow-up of 10 years, 18 (90%) of 20 pelvic discontinuities treated with the CTAC demonstrated healing. No components were revised.[32]

Summary

Acetabular revision arthroplasty in the face of major bone loss is one of the most difficult operations in orthopedic surgery. Unfortunately, much of the literature in the area of pelvic discontinuity and acetabular reconstruction with major bone loss suffers from the fact that many reported acetabular reconstruction techniques do not filter out major bone loss (type 3 or pelvic discontinuity) from lesser defects. Thus, in many studies, it is difficult to determine if the reported good outcomes of a particular reconstruction technique are the result of a disproportionately larger number of simpler bone defects in that series.

The primary goal of surgery is to obtain a stable, durable reconstruction. Secondary goals include reconstituting bone stock, restoring the hip center of rotation to the anatomical location, and minimizing leg-length discrepancies. Although many cementless techniques (high hip center placement, jumbo cups, oblong cups) may achieve stable acetabular reconstruction in the presence of major (Paprosky type 3) bone loss, bone stock is not reconstituted, and the hip center of rotation may not be returned to the normal location. Structural grafting, in theory, may accomplish both the primary goal and the secondary goals of reconstruction.

Concerns about structural grafting arise when less than 50% of the acetabular component is supported by host bone in either cemented or cementless reconstructions. In these situations, the graft should be supported by a reconstruction cage extending from the ilium to the ischium, thus partially unloading the graft and allowing for transfer of weight-bearing stresses from the cage to the ilium. Although current-generation cages are 1-piece and nonporous, newer porous-coated, modular devices allow for biological fixation and for the ability to trial, thus enhancing the durability and stability of the reconstruction. Pelvic discontinuity in the presence of major bone loss remains a difficult reconstructive problem in acetabular revision surgery. However, early and intermediate-term success with TM constructs and CTACs in reconstructing pelvic discontinuity has been promising and warrants longer term follow-up.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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