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Acetabular Revision in Total Hip Arthroplasty: Using Tantalum Uncemented Porous Metal Cups and Augments

Gregory T. Minutillo MD/MPH[1]
Aaron Gebrelul MD[1]
Kevin Pirruccio BA[2]
Neil P. Sheth MD[1]

[1]Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA

[2]Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA

Introduction

Total hip arthroplasty (THA) is one of the most successful surgical procedures in medicine.[1] As a result of their reproducible success, THAs are reportedly within the top five fastest growing procedures in the United States (US).[2] However, as THAs are performed in younger, more active populations with greater life expectancies, orthopaedic surgeons will increasingly encounter patients indicated for revision surgery as the population of patients living with a prosthetic hip continues to rise.[3,4] Approximately 50,220 revision THAs (rTHA) were performed in 2014, and Schwartz et al. predicted rTHA rates to increase by 43-70% by 2030.[5] In general, rTHAs are associated with longer lengths of inpatient hospital stays, more peri-operative complications, higher costs, and constitute a group of more technically demanding procedures.[6–8]

Revision THA encompasses reoperation of either the acetabular component, femoral component, or both. Acetabular revision is most commonly performed for the following etiologies: instability (33%), mechanical loosening (24.2%), implant failure (10.8%), periprosthetic osteolysis (8.1%), bearing surface wear (8.0%), peri-prosthetic infection (4.7%), and peri-prosthetic fracture (1.8%).[9,10] One of the most challenging problems facing orthopaedic surgeons at the time of revision is acetabular bone loss. The focus of this article is on the indications and techniques for the use of uncemented tantalum/porous metal cups and modular porous metal augments in the setting of acetabular bone loss.

Preoperative Evaluation

History, Physical Exam, Labs, and appropriate imaging should be obtained during evaluation for potential revision surgery. Hip pain should be defined based on its character, temporal course, exacerbating and alleviating factors, and any prior attempted treatments.[11] Groin pain with weightbearing should raise suspicion for an intra-articular pathology. Start-up pain is typically indicative of loosening of either one or both components.[12]

Gait examination provides insight into the status of the abductors, as well as overall patient mobility. The skin should be inspected for healed sinuses, superficial infections, and overall soft-tissue sleeve integrity. Prior incisions should be noted, as they may dictate the surgical approach employed for rTHA.

Leg-length discrepancies should be recorded as they may suggest hip center migration or other pathologies such as peri-prosthetic fracture or femoral component subsidence.[13] A thorough neurovascular exam should be performed to rule out confounding sources of pain. Provocative maneuvers may assist in identifying and localizing pain generators. A positive Stinchfield test (groin or deep gluteal pain that increases with a resisted straight leg raise), is associated with acetabular component or intracapsular pathology.[14,15]

All rTHA patients should have a serum erythrocyte sedimentation rate (ESR) and c-reactive protein (CRP) prior to surgery. Elevated inflammatory markers should prompt aspiration of the hip joint, with fluid sent for cell count with differential and culture. Current Musculoskeletal Infection Society (MSIS) criteria should be applied to determine the likelihood of infection.[16,17]

Standard weightbearing anteroposterior (AP) radiographs of the pelvis and hip, and cross-table lateral (L) of the hip should be obtained pre-operatively. Proper visualization of landmarks such as the anterosuperior column, teardrop, superior acetabular dome, and ischium or posteroinferior column are paramount to proper evaluation of acetabular bone loss. The increased resolution of CT scans detects acetabular bone loss with greater sensitivity than X-rays.[18,19] Metal artifact reduction sequence (MARS) MRI should be considered in the setting of failed metal-on-metal hip replacements to identify the presence of a pseudotumor.

Acetabular Bone Loss Classification

Surgeons must appropriately characterize the degree of bone loss in patients undergoing rTHA procedures before attempting to address acetabular defects. Paprosky et. al introduced a

classification system in 1994 favored by the authors of this chapter, as we believe it guides treatment of acetabular bone loss.[22] This classification utilizes four radiographic features to quantify and localize bone loss involving hip center position, the superior acetabular dome, the medial wall, and the posterior column.[11]

The bone loss pattern must then be classified in order to guide treatment. Type I defects exhibit minimal bone loss with no hip center migration, no ischial lysis, no teardrop osteolysis, and an intact Köhler's line. Type II defects exhibit hip center migration $<$ 3cm, in one of three directions, and thus are further subcategorized as type A, B and C. Type IIA defects demonstrate anterosuperior migration without ischial or teardrop osteolysis, and don't violate Köhler's line. Type IIB defects demonstrate superolateral migration with minimal ischial osteolysis, and without teardrop destruction or violation of Köhler's line. Type IIC defects demonstrate medial hip center migration with mild ischial osteolysis, mild teardrop destruction, and disruption of Köhler's line.

Type III defects are subdivided into Type A and B defects. Type IIIA defects ("up and out") exhibit $>$ 3cm of superolateral hip center migration, moderate ischial and teardrop lysis, and an intact Köhler's line. (Figure 1.) Type IIIB defects ("up and in") exhibit superomedial hip center migration, severe ischial and teardrop osteolysis, and a disrupted Köhler's line. (Figure 2.) Type IIC, IIIA and IIIB defects may be associated with chronic pelvic discontinuities, with the highest incidences seen with type IIIB defects.[11] The classification system is advantageous not only due to its descriptive and quantitative nature, but because it has demonstrated validity in correlating with intraoperative bone loss while having good reliability among observers.[23,24]

Intra-operative Bone Loss Assessment

In the case of rTHA, surgeons should select a surgical exposure that affords optimal visualization of the posterior ilium and posteroinferior column. The authors recommend a posterior approach to the hip, as this permits excellent access to the posterior acetabulum and is extensile.

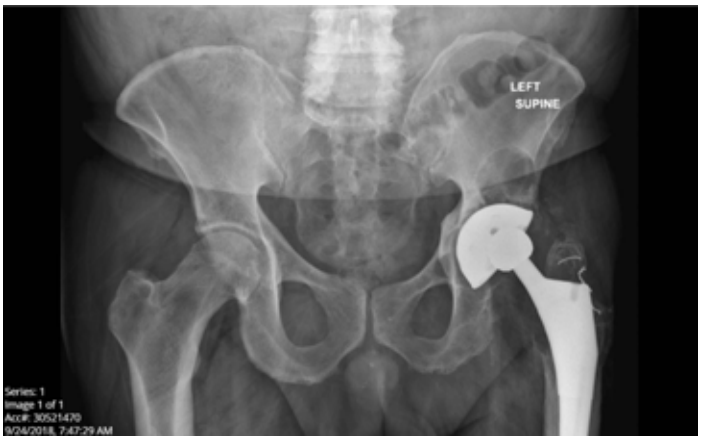

Figure 1. AP Pelvis x-ray of a patient with eccentric polyethylene wear and osteolysis. Following cup removal, the "up and out" defect would be classified as a Paprosky IIIA defect.

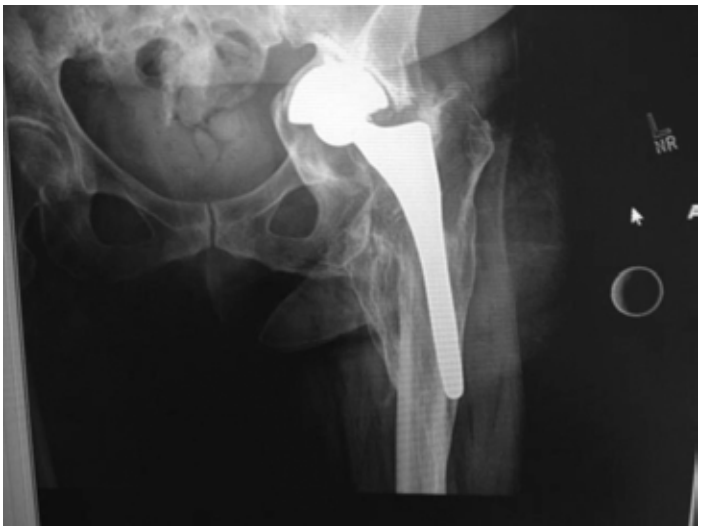

Figure 2. AP Pelvis x-ray of a patient with an "up and in" Paprosky IIIB defect without a chronic pelvic discontinuity. The stem is also malpositioned and will require revision.

Following adequate exposure, implant removal should be executed in a manner which minimizes iatrogenic bone loss. At this stage in the procedure, the surgeon can determine whether an isolated acetabular revision is indicated. The proceeding discussion will focus specifically on isolated acetabular revisions with porous tantalum shells and modular porous metal augments for severe acetabular bone loss.

Intra-operative assessment of acetabular bone loss begins with debriding the acetabular fossa. In cases of massive bone loss (such as Paprosky Type IIIA and IIIB defects), surgeons must orient themselves by identifying the true hip center using the location of the transverse acetabular ligament.[25] In cases when the TAL is difficult to identify, the inferior margin of the acetabulum can be located with the use of intra-operative fluoroscopy. For the purpose of this paper, we assume a chronic pelvic discontinuity is not present intra-operatively. However, this must be ruled out in all cases of acetabular revision when bone loss is encountered.

Type I and most Type II defects seldom require the use of modular porous metal augments, and can be treated successfully with a hemispheric component alone. However, Type IIIA and IIIB defects typically require additional structural support. Type IIIA defects are often reconstructed with uncemented, porous hemispheric implants combined with a modular, porous metal augments or a structural allograft. Type IIIB defects lack both anterosuperior and posteroinferior column support. An uncemented acetabular device must be used in some capacity with either a reconstruction cage, modular porous metal augments, or structural allograft.[10,11,26]

What is the function of your augment?

Revision acetabular reconstruction is executed with four key principles: (1) establishing intimate contact between the implant and host bone; (2) creating a stable construct with minimal micromotion; (3) implanting a construct that adequately distributes physiologic load to the remaining host

acetabular bone stock; and (4) achieving biologic fixation of the construct.[25]

Importantly, modular porous metal augments must serve a specific function. *Sheth et al.* described the use of augments to fall into two broad categories based on their function: primary stability vs supplemental fixation. The authors explain that an augment provides primary stability when used to address intracavitary defects, and provides supplemental fixation for extracavitary defects.[27] Intracavitary defects are those which directly involve the anterosuperior and/or posterorinferior columns of the acetabulum.

Extracavitary defects involve the posterosuperior wall or dome. (Figure 3.) The function of the augment will determine whether the augment should be placed prior to or following cup insertion. All augments should be unitized to the cup with cement.

Acetabular Revision for a Paprosky IIIA Defect using Tantalum/Porous Metal Cups and Augments.

The surgeon should initiate the reconstruction with sequential hemispheric reaming on reverse in the anatomic location of the native hip center. Reaming is performed until interference fit of the reamer is achieved between the anterosuperior and posteroinferior columns. If there is adequate support, a tantalum acetabular revision shell can be opened and implanted in the appropriate version and inclination. Adjuvant screw fixation with 4-5 screws with good purchase is required, and 1-2 screws should be placed in the ischium and/or superior pubic ramus to avoid abduction failure of the construct.

Attention should then be turned to the location of the defect where an augment is appropriate. In the case of an "up and out" Paprosky IIIA defect, the defect is superolateral, and the augment here will provide supplemental fixation. (Figure 4) Once a satisfactory fit between both the augment and the acetabulum has been achieved, the augment should be secured with screws and unitized to the cup with polymethylmethacrylate (PMMA) cement.[25]

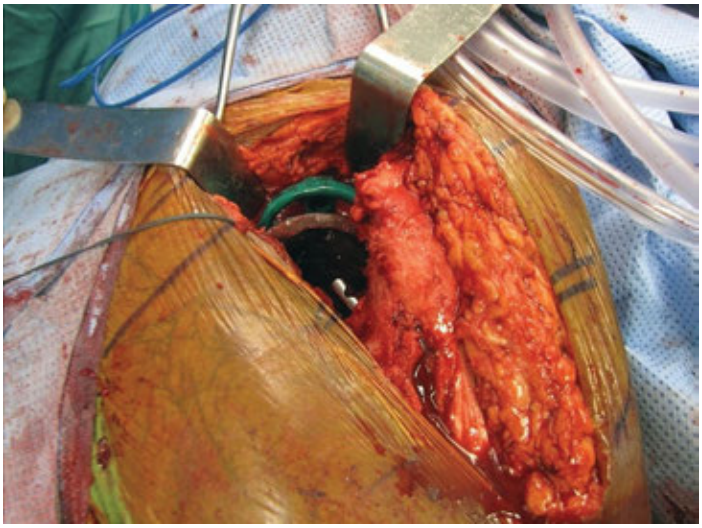

Figure 3. Intra-operative image demonstrating a posterosuperior trial augment in place. The real augment will provide supplemental fixation to the overall construct, is placed after the cup is inserted, and is unitized to the cup with cement.

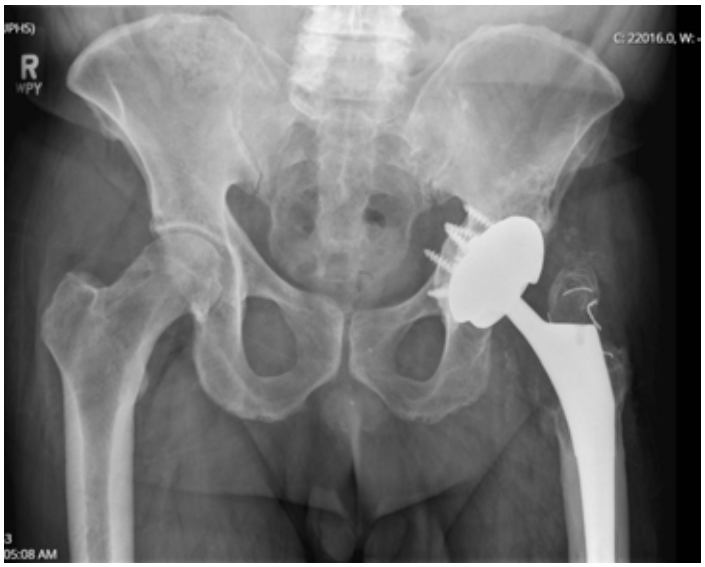

Figure 4: AP Pelvis x-ray of the patient in Figure 1 at 24 months following reconstruction of the Paprosky IIIA defect. The defect was reconstructed with a porous tantalum shell with a modular porous metal augment posterosuperiorly.

Acetabular Revision for a Paprosky IIIB Defect using Tantalum/Porous Metal Cups and Augments

Paprosky IIIB defects represent the most severe acetabular bone loss patterns. These defects are commonly referred to as "up and in" defects exhibiting >60% loss of acetabular bone stock. Following acetabular exposure, and ruling out a chronic pelvic discontinuity, the reconstruction begins with reverse reaming at the anatomic location of the acetabulum. Due to the degree of anterosuperior column bone loss, an augment is typically needed to reconstruct the anterosuperior column. In the setting where the cup being implanted is larger than 66 mm, an augment can be placed anterosuperiorly for intracavitary reduction which decreases the acetabular size by 1 cm and brings the hip center inferior and lateral—closer to the native hip center.[25,27] In cases with massive defects, two augments may be placed into the defect prior to cup insertion; this is known as the Dome technique.[28]

Augments provide primary stability to the overall construct when placed for the purpose of reconstructing the anterosuperior column. (Figure 5.) The augment is secured with screws, and a reamer is used to ream on reverse between the augment and the host posteroinferior column. Once interference fit is achieved between the reconstructed anterosuperior column and the native posteroinferior column, the reamer disengages from the reamer handle and can be used as a surrogate cup.

Once the cup size has been chosen, cement should be placed on the augment interface where it will contact the cup. Following cup insertion in the appropriate position, adjuvant screw fixation with 4-5 screws and at least 1-2 inferiorly placed screws (i.e., "kickstand" screws) should be performed, with the latter serving to prevent abduction failure of the cup.

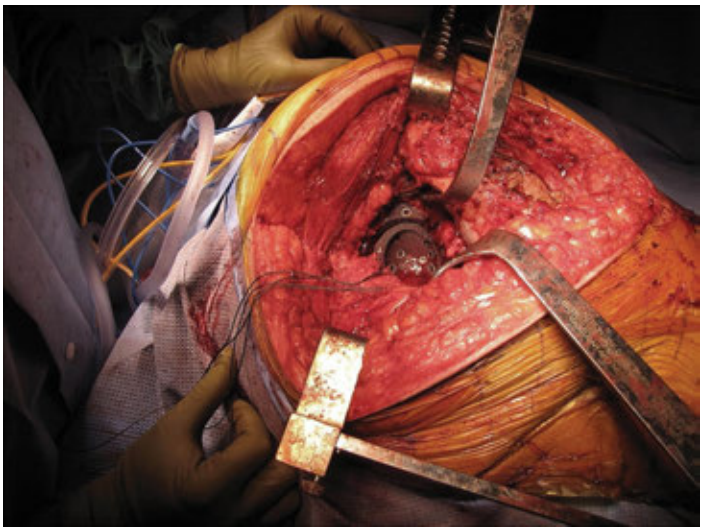

Figure 5. Intra-operative image demonstrating an augment used to reconstruct the anterosuperior column. The augment will provide primary stability to the overall construct, is placed prior to cup insertion, and is unitized to the cup with cement.

Appropriate sites for kickstand screw insertion include the ischium and superior pubic ramus. At this time, a decision is made whether a posterosuperior augment is needed for supplemental fixation. If adjuvant screw fixation is inadequate due to the amount or integrity of the residual bone stock, an augment for supplemental fixation should be used. (Figure 6)

For supplemental fixation, an "orange slice" augment is placed posterosuperiorly against host bone. The augment is secured with screws placed across the dome of the acetabulum. PMMA cement should be interposed between the augment and the hemispheric cup interface. For both Paprosky Type IIIA and Type IIIB defects, a liner is cemented into position. In both cases, cementation will create a locked construct less prone to failure.

Post-Operative Management

Patients should receive appropriate perioperative antibiotics at the time of surgery. We recommend obtaining tissue cultures at the time of revision. Patients are kept touchdown weightbearing for ± weeks and then advanced to 50% weightbearing for an additional ± weeks. At 12 weeks, patients are typically advanced to weightbearing as tolerated if they have demonstrated no interval change in component position on serial, post-operative radiographs.

Summary of Clinical Outcomes

Outcomes for rTHA for Paprosky IIIA and IIIB defects with uncemented porous cups and augments have been encouraging. The majority of studies over the past decade report excellent survivorship with short to mid-term follow up.[29-35] The results with this technique, when accounting for all causes (infections, recurrent dislocations, periprosthetic fractures etc.), demonstrate a low failure rate (< 10%). When looking at failure rates specifically for aseptic loosening, survivorship has been reported as high as 100% at the short to mid-term follow-up.[30-35]

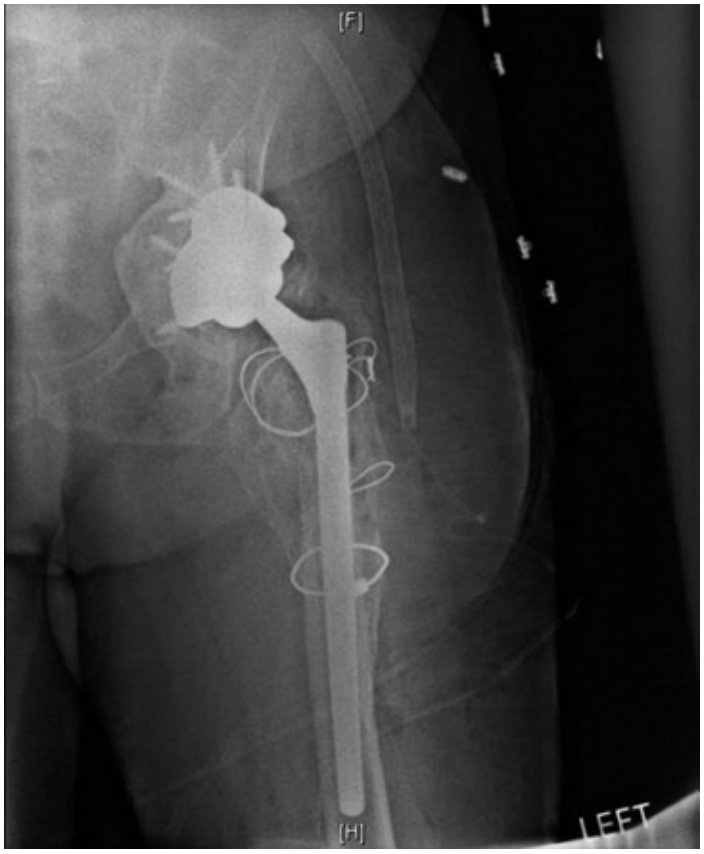

Figure 6. AP hip x-ray of the patient in Figure 5 immediately following reconstruction of the Paprosky IIIB acetabular defect and femoral stem revision. The reconstruction was performed with a tantalum revision shell and a posterosuperior modular porous metal augment for supplemental fixation.

Similar clinical success was also observed in studies with mid to long-term follow-up. Most recently, *Lochel* et al. presented their findings in 31 patients with 10 year follow-up and reported 92.5% survivorship of the acetabular component.[36] The rate of revision for aseptic loosening in this cohort was 5.6%, with failures attributed to poor screw fixation. Two of these failures required acetabular revision for a chronic pelvic discontinuity.

Jenkins et al. also published similar results in 2017 after following 28 and 22 Paprosky Type IIIA and IIIB acetabular defects, respectively.[38] They reported 100% survivorship at 5 year follow-up, and 97% at 10 years with aseptic loosening as the primary endpoint. It should be noted that of the two failures, one did not utilize the described technique with multiple screws and PMMA cement between the augment and the acetabular shell– this may suggest further support for the technique we describe in this chapter. The authors reported decreased survivorship at 7 years in hips with an associated chronic pelvic discontinuity.

The study with the greatest number of combined Paprosky IIIA and IIIB defects was performed by *Grappiolo* et al. They reported on 42 Type IIIA and 13 Type IIIB defects and demonstrated 96.4% and 92.8% survivorship at 2 and 5 years, respectively. Of the four acetabular revisions, three were due to aseptic loosening and 1 one was due recurrent instability.

Table 1. Reported outcomes for the use of uncemented porous cups and augments for Paprosky III (A&B) acetabular bone loss

Author	Year	N	Defect Type	Mean Follow up	Outcome
Lochel J.[36]	2019	53	22 IIIA 9 IIIB	10 years	92.5% survivorship at 1 years. 3 aseptic loosenings believed to be from in adequate screw fixation
O'Neill, C.J.[29]	2018	38	29 IIIA 9 IIIB	36 months	3 revisions: 1 for deep infection. 2 for aseptic loosening. Four of the IIIB defects exhibited pelvic discontinuity.
Eachempati, K.K.[30]	2018	41	36 IIIA 5 IIIB	39.4 months	100% survivorship. In one patient, augments were used to provide both primary stability and supplemental fixation.
Jenkins, D.R.[38]	2017	58	28 IIIA 22 IIIB	5 year minimum	2 revisions (3%): 1 of which had pelvic discontinuity
Flecher X. [39]	2017	51	7 IIIA 5 IIIB	6.8 years	16 of the 51 hip constructs used augments. 1 patient required revision for septic loosening. 100% survival for aseptic loosening at 64 months. Global survivorship was 92.3% at 64 months.
Grappiolo, G.[37]	2015	55	42 IIIA 13 IIIB	53.7 months	Survival rate at 2 and 5 years was 96.4% and 92.8%. Four (7.3%) of 55 hips underwent acetabular components revision: three cases of loosening (5.4%), and one of recurrent instability (1.8%) were reported
Meneghini, R.M.[31]	2015	8	7 IIIA 8 IIIB	16.5 months	No failures reported
Butayong E.D.[32]	2014	24	19 IIIA 3 IIIB 2 PD*	37 months	2 failures due to septic loosening. 92% still demonstrated osteointegration.
Molicnik, A.[33]	2014	25	6 IIIA 3 IIIB 1 PD*	20.5 months	100% survivorship with respect to aseptic loosening
Abolghasemian, M.[40]	2013	34	18 minor column defect 14 major column defect 2 PD*	64.5 months	3 cases of aseptic loosening, 2 of which had PD at time of revision
Gehrke, T.[41]	2013	46	18 IIIA 28 IIB	46 months	2 of these hips demonstrated aseptic loosening, both of which were IIIA defects.
Del Gaizo D.J.[42]	2012	37	37 IIIA	60 months	One patient underwent revision for aseptic loosening. 7 were revised for periprosthetic femur fracture; 3 for infection; 2 for recurrent dislocation
Davies, J.H.[43]	2011	46	21 IIIA 11 IIIB 4 PD	50 months	100% Survivorship with respect to aseptic loosening
Flecher, X.[44]	2010	72	23 IIIA 8IIIB	4 years	100% Survivorship with respect to aseptic loosening
Van Kleunen, J.P.[34]	2009	97	19 IIIA 16 IIIB	45 months	100% Survivorship with respect to aseptic loosening
Weeden S.H.[35]	2007	43	33 IIIA 10 IIIB	2.8 years	26 constructs had augments, 10 of which had pelvic discontinuity. 1 failure due to loosening due to sepsis (98% survivorship).

Even in the face of such positive results, the majority of these studies fail to distinguish isolated Type IIIA and IIIB defects from defects with an associated chronic pelvic discontinuity. This is an important distinction which may dictate the use of an alternative technique for acetabular reconstruction rather than those described in this chapter. In 2018, *Eachempati* et al. studied isolated IIIA and IIIB defects without an associated chronic pelvic discontinuity in 41 patients.[30] They reported 100% survivorship at mean 39.4 months follow -up. This study reinforces the concept of considering isolated Paprosky IIIA and IIIB defects and those with an associated chronic pelvic discontinuity as separate entities. It also illustrates the effectiveness of the techniques described in this chapter, assuming patients have been properly indicated.

Summary

In this this chapter, we detailed key principles of evaluating and surgically managing acetabular bone loss. We identify two severe acetabular defect patterns, Paprosky IIIA and IIIB without pelvic discontinuity, as indications for the use of tantalum/porous hemispheric cups and augments. While these augments come in various shapes and sizes, the ultimate use of these augments depend on their function. When appropriately employed, uncemented porous metal cups and augments may serve as powerful tools for improving revision THA outcomes. Although longer term clinical studies are needed, available data on the use of this technique in the setting of severe acetabular bone loss is very promising.

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