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## Review Article

# Clinical evaluation and surgical options in acetabular reconstruction: A literature review

Asim Qamar Ahmad<sup>a</sup>, Ran Schwarzkopf<sup>b,\*</sup><sup>a</sup> University of California, Irvine School of Medicine, Irvine, CA, USA<sup>b</sup> Division of Adult Reconstruction, Department of Orthopaedic Surgery, NYU Langone Medical Center, Hospital For Joint Diseases, New York, NY, USA

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## ABSTRACT

The purpose of this paper is to review the clinical indications for acetabular reconstruction in patients with underlying peri-prosthetic segmental and cavitary defects, evaluate steps in pre-operative planning, and present the American Academy of Orthopaedic Surgeons (AAOS) and Paprosky classification systems to categorize acetabular defects. We also present a review of the current surgical techniques to reconstruct the acetabular socket which includes a cementless acetabular component with morselized bone, structural allograft, jumbo and oblong cups, reinforcement rings, bone cages, custom triflange acetabular constructs, and trabecular metal components.

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## 1. Introduction

Total hip arthroplasty (THA) is perhaps the most recognized operation in the field of orthopedic surgery and regarded as a benchmark treatment of end-stage hip joint disease. The aging population and growing incidence in obesity will continue to increase the number of hip replacements. Despite excellent clinical results, many patients outlive the typical lifespan of implants with approximately 17% of all primary hips eventually failing and requiring revision.<sup>1</sup> Acetabular revision in the context of poor bone stock is a technically challenging procedure; therefore, it is imperative for the arthroplasty surgeon to understand the advantages and disadvantages of the available acetabular component systems. In this paper, we review clinical indications for acetabular revision, radiographic

classification systems, and pre-operative planning. We also include a summary of available acetabular component systems and highlight unique features.

## 2. Clinical evaluation

Clinical presentation depends on the fundamental etiology for acetabular implant failure, which include aseptic loosening, infection, instability, wear, trauma, and osteolysis.<sup>2</sup> Groin or buttock pain is a characteristic patient complaint associated with acetabular implant failure while thigh pain is often associated with femoral implant failure.<sup>2,3</sup> A comprehensive medical history and focused physical exam should be performed on all patients regardless of clinical presentation. Laboratory studies including complete blood count (CBC),

\* Corresponding author.

E-mail address: [schwarzk@gmail.com](mailto:schwarzk@gmail.com) (R. Schwarzkopf).<http://dx.doi.org/10.1016/j.jor.2015.10.011>

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erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), nuclear scans, and aspiration arthrogram with culture and sensitivity are recommended when underlying infection is suspected.<sup>4</sup> Pre-operative templating requires an upright weight-bearing anteroposterior (AP) pelvis, femoral lateral, and full-length views to evaluate the extent of disease. Judet views can help detect acetabular column disease. Furthermore, 3D pelvis CT scans provide ancillary evidence of osteolytic lesions as plain films often underestimate the degree of bone loss. Multiple studies report that CT scan is better than plain film at identifying peri-acetabular osteolytic lesions.<sup>5-8</sup> Frail cortical bone is often difficult to distinguish from bone cement in poor quality films. Finally, CT angiogram of pelvis vasculature and possible vascular surgery consultation may be necessary when Kohler's (ilio-ischial) line is interrupted and the acetabular component is markedly displaced.

### 3. Classification of acetabular defects

An ideal radiological classification system provides accurate and standardized algorithm to evaluate the extent of bone loss, assist in pre-operative planning and clinical management. Acetabular defects are routinely described using the American Academy of Orthopaedic Surgeons (AAOS) and Paprosky classification system.

The AAOS classification system categorizes lesions into cavitory, segmental, combined cavitory and segmental, pelvic discontinuities, and arthrodesis.<sup>9</sup> Cavitory defects are localized within the acetabular cavity and do not involve the anterior, superior, and posterior rim. Cavitory defects include any kind of dome lesion. Segmental defects occur along the acetabular rim and include the medial wall. Segmental defects are subdivided into anterior or posterior. Pelvic discontinuity occurs when anterior and posterior columns separate and disrupt the rostral hemipelvis from the distal aspect.<sup>10</sup> It constitutes less than 5% of all acetabular revisions and requires careful planning.<sup>10</sup>

The Paprosky classification system uses pre-operative imaging and intraoperative assessment to describe acetabular defects.<sup>11,12</sup> Using this classification system, acetabular defects are graded from Type I to Type III based on location and extent of bone loss (Fig. 1).

Technical goals in acetabular revision are to reconstitute bone stock, restore anatomic hip center of rotation, limb-length, offset, and secure the prosthesis to the native

acetabular socket.<sup>13</sup> These steps are necessary to reduce risk of post-operative dislocations, increase wear time, and avoid particle-induced osteolysis that may permanently alter hip biomechanics.<sup>13</sup> A number of options are available to help the arthroplasty surgeon achieve sufficient acetabular bony contact and return hip center to normal anatomic position, including the use of bone cages, allografts, jumbo and oblong cups, triflange implants, and porous acetabular metal augments. The decision to proceed depends on the localization and extent of disease, patient anatomy, and experience of the arthroplasty surgeon.

### 4. Cavitory defects

Cementless hemispheric acetabular components are generally used for patients with cavitory defects. Small cavitory defects can be reamed with a larger size reamer to increase contact area between native bone and implant. The acetabular shell is then impacted into the socket and transacetabular screws are placed in the posterior quadrants to provide ancillary fixation to the ileum and ischium. Anterosuperior and anteroinferior placements of screws increase the risk of injury to external iliac and obturator vessels respectively and should be done with care.

#### 4.1. Morselized bone grafts with a cementless acetabular cup

Over-reaming large cavitory defects may cause further damage to pre-existing bone along the acetabular rim and should be supplemented with morselized bone grafts.

Cementless hemispheric acetabular components with morselized cancellous bone allografts are generally used in the setting of type 1 Paprosky contained defects with an intact rim, columns, and dome.<sup>14,15</sup> The literature recommends that at least 50% host bone contact is needed to prevent mechanical loosening between the prosthesis and native bone.<sup>1,2,14</sup> Femoral head, distal femur, and acetabular allografts can be used to fill in the gaps. The operating surgeon may consider autogenic graft as they are less immunogenic, but difficult to harvest in some patients with pathological bone disease.<sup>14,15</sup> Intraoperatively, the arthroplasty surgeon uses a bone mill or rangeur to generate small chunks of bone that are impacted with a smooth acetabular impaction domes. Reverse reaming technique can be used alternatively to impact bone into the acetabular socket.<sup>15</sup> Subsequently, the cup is pressfit and

Type	Defect
I	Acetabular rim, anterior and posterior column intact and supportive.
IIA	Teardrop intact. No ischial lysis and > 50% host bone contact
IIB	Moderate superolateral migration > 50% host bone contact
IIC	Medial migration with preserved peripheral rim
IIIA	Substantial superolateral migration, < 50% host bone contact
IIIB	Significant superomedial migration, < 50% host bone contact, substantial ischial lysis and full obliteration of teardrop
IIIC	Pelvic discontinuity

Fig. 1 – Paprosky classification of acetabular defects.<sup>12,13</sup>

secured to the pelvis with multiple screws for ancillary fixation.

## 5. Segmental defects

Under circumstances of substantial superior segmental defects, the arthroplasty surgeon may consider placing the joint in a superiorly elevated position using a cementless hemispherical cup as described previously or restore hip center with supplementation of bulk allograft or using a larger size cup.

### 5.1. Jumbo and oblong cups

Cup parameters may be altered to augment fixation when standard hemispheric cups are incapable of providing necessary fixation in patients presenting with segmental and combined defects.

A jumbo cup increases contact area to provide appropriate biologic fixation and can be combined with a large femoral head to increase stability in the post-operative setting. Gustke et al. reported low rates of aseptic loosening (1.5%), 98% implant survival at 4 years and 96% at 16 years using a jumbo cup in a series of 196 cases.<sup>16</sup> Paprosky Type III hips with moderate to severe teardrop, superolateral acetabulum, and posterior column deficiencies should be reconstructed using a device that provides better fixation than a jumbo cup, like a acetabular augments or cup-cage construct.

An oblong cup is designed to have a longer diameter in the longitudinal plane relative to the transverse plane.

### 5.2. Bone cages with allografts

Bone cages are generally indicated in Type III defects with moderate superior hip center displacement, disruption of the teardrop, and Kohler's line. The cage is constructed from titanium alloy and thought to transfer load off the acetabular socket and onto the peri-acetabular bone through adjustable iliac and ischial flanges that provide intimate contact with native bone when secured to the pelvis using cancellous screws.<sup>10,17</sup> Cages protect underlying bone graft from lysis and permit remodeling with native bone. True survivorship of cages is unclear but has ranged from less than 70% to 100% according to Sembrano et al. who report that the end-points of

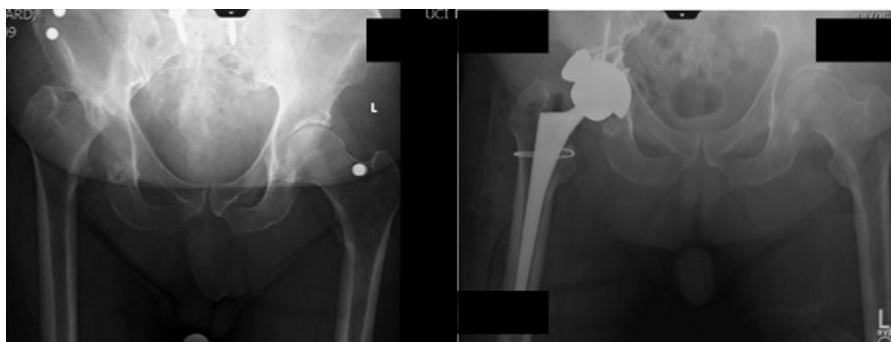
each study varied depending on time of cage removal, evidence of radiographic loosening, and reason for revision.<sup>17-27</sup> Regis et al. reported an 87% (49/56) survival rate at a mean follow-up of 11.7 years in type IIIA (32%) and IIIB (68%) hips using cages and structural allografts using radiographic evidence of bone ingrowth and remodeling as the primary endpoint.<sup>28</sup> The major disadvantage of cages includes high complication rates previously reported by multiple authors.<sup>14,29-32</sup> There is a higher risk of neurovascular injury since large exposure of the ileum and ischium is needed to anchor the cage.<sup>29-31</sup> In addition, cages generally fail to incorporate native bone in the long run because the non-porous surface makes ingrowth problematic.<sup>17</sup> There is a stronger association with fatigue failure when cages are used in patients with pelvic discontinuity.<sup>14,32</sup>

### 5.3. Reinforcement rings with allografts

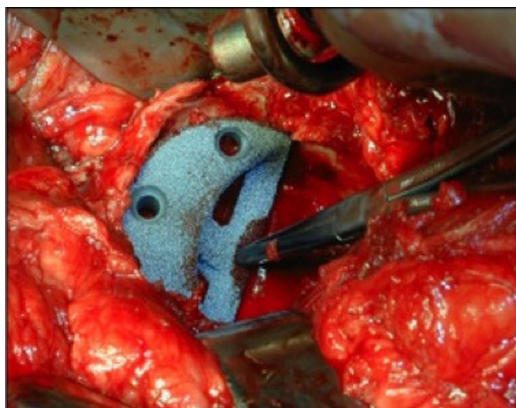
Reinforcement rings are designed to manage contained cavitory and minor segmental defects with more than 50% of native bone intact. Like cages, rings protect allograft from biomechanical lysis. Rings contain pliable flanges that can be adjusted intraoperatively to increase contact area with native bone. Flanges are secured to the ileum and ischium with cancellous screws to relieve stress forces placed on incompetent native bone.<sup>10</sup> Still, biological fixation is a concern since rings are made from a biologically incompatible material.<sup>10,33</sup> Failure rates as high as 25% have been reported in the literature.<sup>33</sup>

### 5.4. Trabecular metal cups and augments

Porous trabecular metal (Zimmer, Warsaw, IN) components made from tantalum provide excellent biological fixation in Type II and III acetabular defects with moderate to severe superior hip center migration and teardrop lysis.<sup>29</sup> Trabecular metal (TM) components are approximately 70-80% porous and high shear strength profile reduces micromotion between native bone and prosthesis. Tantalum is like cancellous bone with a previously reported modulus of elasticity between 2.5 and 3.9 MPa to prevent stress shielding.<sup>29,34-36</sup> Mid-term studies have so far yielded good results using tantalum augments in acetabular reconstruction. Weeden and Schmidt reported 98% success rate using radiograph failure as the primary endpoint with trabecular metal augments and notably



**Fig. 2 – Pre and postoperative imaging showing acetabular reconstruction using porous metal augmentation in a Paprosky Type IIIA hip. The patient is 72-year-old male with history of avascular necrosis of the right hip.**



**Fig. 3 – Intraoperative view of a porous trabecular augment used in acetabular reconstruction.**

only 1 case (4%) of aseptic loosening in 26 hips at the minimum follow-up of 2 years (range, 2–4 years).<sup>36</sup> Del Gaizo et al. reported 97.3% survival rate with aseptic loosening as the endpoint in 37 Paprosky Type IIIA hips with a mean follow-up of 60 months (range, 26–106 months).<sup>37</sup> Longer follow-up studies are needed to capture long-term survival and loosening rates. The potential to produce metal debris may warrant further studies to analyze the effect of tantalum on surrounding tissues (Figs. 2 and 3).

## 6. Pelvic discontinuity

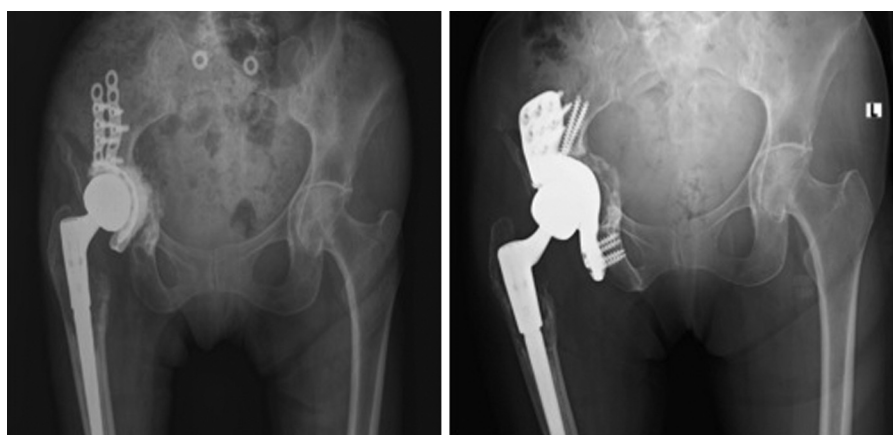
### 6.1. Custom triflange implants

Triflange implants are custom-made, porous coated titanium alloy components considered a final therapeutic salvage option in patients with pelvic discontinuity and/or prior radiation to pelvis. A triflange construct is designed from pelvis CT scans with metal subtraction software converted

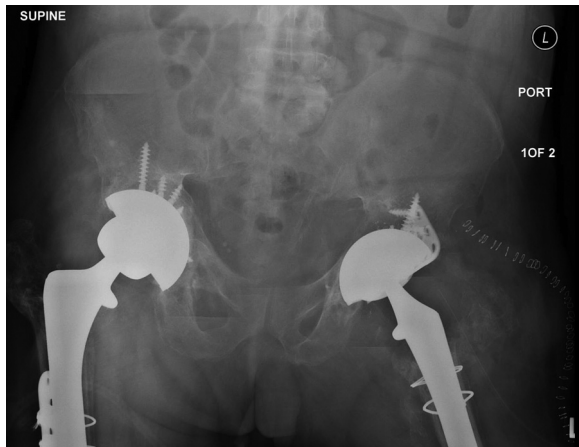
into a three-dimensional (3D) representation of the patient's hemipelvis. The implant manufacture generates individualized implants from the respective imaging (Fig. 4). Some authors have reported variable results with triflange components. DeBoer et al. reported no cases (0/20) requiring revision and average Harris Hip Score (HHS) of 80 at 10 years post-op.<sup>38</sup> Taunton et al. reported a revision rate of 30% (20/57) at 5.4 years and 21% dislocation rate most likely attributable to instability generated from pre-operative trochanteric escape performed in 51% of patients and possible traction injury to the superior gluteal nerve during exposure.<sup>31</sup> When comparing manufacture costs, triflange components are priced similar to other constructs used to treat pelvic discontinuity, including the “cup-cage” construct, a trabecular metal cup with an antiprotrusio cage (Zimmer, Inc, Warsaw, IN, USA). The typical cost of the triflange construct (cup, screws, and polyethylene liner) is \$12,500 and cup-cage construct is \$11,250.<sup>31</sup> The major drawback of the triflange construct is it may take several months to prepare the implant for surgery.<sup>31,38</sup>

### 6.2. Cup-cage construct

The cup-cage construct is an alternative option to correct large acetabular defects and pelvic discontinuity. Using this technique, a porous metal cup is secured to host bone and allograft if used; acetabular distraction technique can be used in cases of pelvic discontinuity (see Section 6.3). A bone cage is subsequently anchored to the porous cup (Zimmer, Inc., Warsaw, IN, USA). The rationale behind is the cage removes loading forces on the cup and allows time to optimize ingrowth of new bone into the cup.<sup>39</sup> Cup-cage reconstruction has yielded encouraging short-term outcomes, including one study that demonstrated no clinical or radiological evidence of loosening in 23 out of 26 (88.5%) hips with an average follow-up 44.6 months (range 24–68).<sup>40</sup> Despite the main concern that cages having a tendency to undergo fatigue failure, combining a biologically compatible porous cup with the cage may counteract the high failure rates associated with using just cages, longer-term data is needed to validate the longevity of this construct<sup>39,40</sup> (Fig. 5).



**Fig. 4 – Postoperative radiograph demonstrating the use of a patient specific custom-made triflanged acetabular component in a 74-year-old patient with previous history of multiple hip arthroplasties.**



**Fig. 5 – Postoperative radiograph showing a well-seated cup-cage construct.**

### 6.3. Acetabular distraction with porous cup

The acetabular distraction technique is another novel approach for managing pelvic discontinuities. While the techniques described above utilize screws and plates to compress nonunion and achieve mechanical fixation, the underlying basis of acetabular distraction is the address nonunion of fracture lines using distraction to expand the defect and create elastic recoil forces to compress the porous metal construct.<sup>41</sup> Intraoperatively, a Cobb elevator is used to delineate the fracture line and debridement of the granulation tissue and reaming is performed to define bone suitable for fixation using augmentation.<sup>41</sup> Sporer et al. reported good mid-term results using acetabular distraction including one case (1/20) requiring revision for aseptic loosening at 9 months.<sup>42</sup> At 4 years follow-up, four hips demonstrated migration of the acetabular component but were clinically stable. The acetabular distraction technique is a reasonable option for many patients but the long-term data is limited in the regard.

## 7. Conclusion

In summary, many constructs are available to achieve sufficient acetabular bony contact and return hip center to normal anatomic position; including the use of bone cages, allografts, jumbo and oblong cups, triflange implants, and porous acetabular metal augments. It is important to understand the advantages and disadvantages of the available acetabular component systems to deal with poor bone stock.

## Conflicts of interest

The authors have none to declare.

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