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Operative Techniques in
Orthopaedics

Management of Complex Acetabular Revision With Bone Loss

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The management of acetabular bone loss during revision arthroplasty can be a difficult challenge. There is a wide variety of potential defects, as well as numerous implants and treatment strategies available to manage the problem. The assessment of the severity and location of bone loss preoperatively is imperative as remaining acetabular bone stock drives reconstruction options. This paper will describe the preoperative assessment, the acetabular defect classifications, proposed treatment algorithms, and the surgical options available to achieve a successful outcome when managing acetabular bone loss in revision arthroplasty.
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Introduction

Total hip arthroplasty (THA) has revolutionized the manner in which orthopaedic surgeons treat hip arthritis. It is one of the most cost-effective healthcare interventions as measured by cost per quality-adjusted life years gained. However, despite THA being recognized as "the operation of the century,[1]" it is estimated that approximately 17% of all primary THA eventually fail and will require revision surgery.[2-4]

The most common indications for THA revision are osteolysis, aseptic loosening of the THA implants, mechanical instability, periprosthetic joint infection, malpositioned components, polyethylene wear, periprosthetic fracture, and/or implant failure.[5] It is noted that the acetabular component in involved in greater than 50% of THA revisions. Acetabular component revision is a challenging problem faced by arthroplasty surgeons due to the potential bone deficiency that may be present. In general, the degree of acetabular bone loss at time of revision surgery will drive the reconstructive option/s available to the surgeon.

This article will review the preoperative clinical, laboratory, and radiographic evaluation, acetabular bone loss classification systems, preoperative planning, and reconstructive acetabular options and their respective outcomes.

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Preoperative Evaluation

Barrack et al[6] notes the first and most crucial step toward successful completion of a revision total joint arthroplasty is adequate preoperative planning.

A successful surgical outcome begins with a methodical preoperative evaluation. The preoperative evaluation should include a thorough history regarding the patient's symptoms and prior surgical procedures, a detailed multisystem physical exam, laboratory evaluation, and radiographic evaluation.

Clinical History and Physical Exam

Obtaining a detailed patient history is one of the most valuable components of the preoperative evaluation. The surgeon must be thorough in obtaining the history in order to identify a clear source of the patient's symptoms.

Pain will be one of the most common complaints and therefore it is imperative to systematically ascertain important details regarding the patient's pain. The arthroplasty surgeon should determine the location, onset, characterization, associations, time course, exacerbating and alleviating factors, and the severity of the pain. Acetabular component pain most commonly presents as groin or deep gluteal pain. Additionally, the groin or deep gluteal pain is often exacerbated with a straight leg raise. Thigh pain is more classically associated with issues with the femoral component. Infection tends to present with night pain or severe pain at rest, while component loosening generally presents as start-up pain.

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The surgeon should also inquire about all prior surgical procedures. This should include symptoms prior to undergoing the procedure as well as the postoperative course. All prior surgical outcomes including complications should be documented. Complications such as postoperative dislocations, infections, need for antibiotic course, wound drainage, deep vein thrombosis, hematoma, periprosthetic fractures, length of hospital and the need for skilled nursing facility stay should be documented in the medical chart.

Laboratory Evaluation

The preoperative work-up for a revision surgery should include infection studies. These include erythrocyte sedemetation rate (ESR) and c-reactive protein (CRP). If either are elevated or if the clinical suspicion is high, a joint aspiration should be performed. The synovial fluid should be sent for cell count, cell differential, and culture results.

Additionally, the surgeon should also obtain a nutritional lab assessment, and if indicated a nicotine level and drug screen as part of the preoperative evaluation in appropriate patients. Smoking and malnutrition are modifiable risk factors that may decrease the rist of perioperative complications including wound healing and infeciton.

Radiographic Evaluation

Detailed radiographic assessments are performed preoperatively to assess for acetabular bone stock deficiencies. The location and severity of acetabular bone loss will determine the type of acetabular revision surgery that needs to be performed, the type of implants that will be used, and the success of the revision surgery.

Preoperative imaging assessment in acetabular revision surgery traditionally included a standard anteroposterior (AP) pelvis, an orthogonal view of the involved hip, and full-length femur films. Full projection of the prosthesis on these films was required. Preoperative Judet views are beneficial to visualize the implant-bone interface and defects of the anterior and the posterior columns.

It can be extremely difficult to notice and interpret subtle changes on a single radiograph.[7] Moreover, several studies have concluded that plain radiographs underestimate the size of osteolytic lesions and may not even detect small lesions.[8,9] However, the examination of serial radiographs is considered to be the most important radiological investigation for assessing acetabular bone loss in a patient that underwent a previous THA.[10] Serial radiographs are able to demonstrate disease progression, as well as, changes to the stability of the acetabular component over time. Therefore, it is imperative to try and obtain all of the patient's old radiographic imaging dating back to their first postoperative image from their primary surgery.

With the sensitivity of a single plain radiograph being as low as 60% in identifying osteolysis, the use of CT scan has been advocated for in all patients undergoing an acetabular revision. CT scans are 3-dimensional images that are able to provide the surgeon with more detailed data regarding the location, quantity, and associated boney defects of any periacetabular osteolysis. Furthermore, CT scans also provide a more precise assessment of the patient's femoral and acetabular component version when compared to plain radiographs.[11]

Sporer et al[12] and Sheth et al[13] recommend obtaining further imagining with a 3-dimensional CT reconstruction with contrast or an angiography to evaluate the proximity of the pelvic vessels, ureter, and bladder to the acetabular component if extensive medial migration (ie, Kohler's line interrupted) of the acetabular component is present.

Implants

During the preoperative evaluation it is important to accurately identify the patient's current implants. Special extraction tools may be required for certain implant designs and arrangements will need to be made to have them available in the operating room. Prior identification of the patient's current implants will help to limit any intraoperative surprises, decrease operative time, and helps optimize the surgical outcome for the patient. Implants can have a major influence on surgical decision-making. Older implants may not be modular. Furthermore, it is important to know head sizes, neck lengths, and liner options available for the patient's current components.

Classification Systems for Acetabular Bone Loss

Several classification systems have been proposed for acetabular bone loss. These classification systems are used to guide management, predict the extent of bone loss, facilitate communication among surgeons, compare outcomes, and provide a framework for research.[14-16] The 2 most commonly used classification systems for acetabular defects are the American Academy of Orthopaedic Surgeons (AAOS) Classification System and the Paprosky Classification of Acetabular Bone Loss.

AAOS Classification System

The AAOS classification system was first described in 1989 by D'Antonio et al[17] after evaluating 83 AP and lateral radiographs and correlating the subsequent intraoperative findings. Five defects are described. Type 1 defects are segmental deficiencies, which is any loss of acetabular supporting structures. Type II defects are cavitary deficiencies. Cavitary deficiencies have a volumetric loss of bony substance within the acetabular cavity without compromising any structural support of the acetabulum. Type III defects are a combination of Type I and Type II defects. Type IV defects refers to pelvic discontinuity which is a severe deficiency of the anterior and posterior columns with total separation of the superior from the inferior acetabulum. Type V defects are defined as a hip arthrodesis. Despite being the most referenced classification system for acetabular bone loss, its clinical application is limited as it is a descriptive classification that does not provide the surgeon with a guide for reconstruction options.

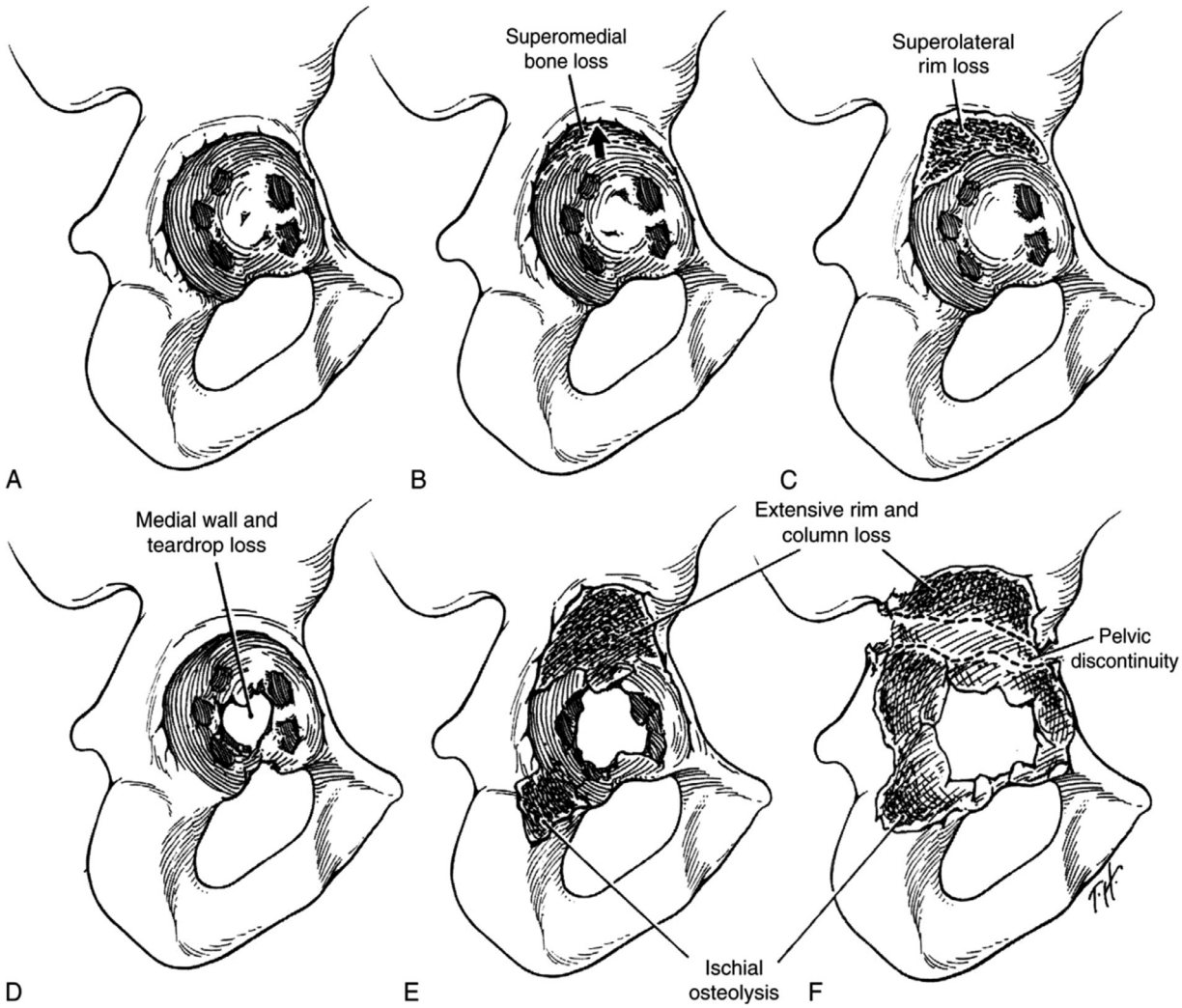

Figure 1 Paprosky classification. (A) Type 1, (B) Type 2A, (C) Type 2B, (D) Type 2C, (E) Type 3A, and (F) Type 3B (pelvic discontinuity).

Paprosky Classification of Acetabular Bone Loss

The Paprosky Classification of Acetabular Bone Loss was first described by Paprosky et al in 1994 after review of 147 failed acetabulum. The Paprosky Classification is based on the severity of acetabular bone loss and the ability to obtain a cementless fixation for a given bone loss pattern (Fig. 1).[18] It is ultimately divided into 3 different types with increasingly severe degrees of bone loss. Types II and Types III are then further subdivided. Ultimately, this classification system assists surgeons in their implant selection and reconstructive options based on preoperative AP pelvis radiographs and intraoperative trial component stability.

The Paprosky Classification system uses a preoperative AP pelvis radiograph to assess acetabular bones loss and hip migrations. There are 4 components of the AP pelvis radiograph the arthroplasty surgeon assesses: the teardrop, hip center migration, Kohler's line, and the presence or absence of ischial lysis. The teardrop on an AP pelvis radiograph assesses the medial wall. The hip center migration is assessed by viewing the superior wall and/or dome of the acetabulum. Kohler's line on an AP pelvis radiograph represents the anterior column and/or medial wall. The presence of absence of ischial lysis is assess by viewing the posterior column and/or wall (Table 1).[19]

Type I defects overall have minimal deformity of the acetabulum and tend to be localized bone lysis. The medial wall of the acetabulum is intact. The superior wall and/or dome is intact and therefore there is no hip center migration. Kohler's line is also intact and there is no ischial bone lysis. There is considered to be >50% cancellous bone in the bone bed of the acetabulum for Type 1 defects.

Type II defects have an overall distortion of the acetabulum. The acetabular bone bed is considered to be less than 50% cancellous bone. In general type II defects have deficient acetabular walls with intact acetabular columns and less than 2 cm of hip center migration. Type II defects are divided into 3 subclasses better based on the location of the defect and the resultant direction of the acetabular component migration.

Table 1 Preoperative Radiographic Findings of Acetabular Bone Loss by Type of Paprosky acetabular Defect

Pre-operative Radiographic Findings of Acetabular Bone Loss by Paprosky Classification				
Type of Defect	**Component Migration**	**Ischial Osteolysis**	**Teardrop Osteolysis**	**Kocher Line**
I	None	None	None	Intact
IIA	<2 cm directly superior	None	None	Intact
IIB	<2 cm directly superior or superolateral	None	None	Intact
IIC	Cup medial to Kohler line	Mild	Obliterated	Disrupted
IIIA	<2 cm superolateral	Moderate	Moderate	Intact
IIIB	>2 cm superior and medial	Severe	Obliterated	Disrupted

Type IIA defects have less than 2 cm of direct superior hip center migration due to superior lysis with a sufficiently intact superior rim. The intact superior dome prevents component lateral displacement, while the intact teardrop will prevent component medial displacement. The posterior columns are also intact.

Type IIB defects are characterized by an absent superior dome to the acetabulum. This will allow for superior and lateral acetabular component migration as the superior rim acts as a laterally supporting buttress to the component.

Type IIC defects have medial wall lysis with an absent teardrop resulting in medial migration of the acetabular component (less than 2 cm). The superior dome is intact which will prevent any superior displacement.

The hallmark of a Type III defects is an unsupportive rim. Overall, Type III defects have severe bone loss. There is extensive global erosion of the acetabulum, greater than 2 cm of hip center migration, and loss of supporting structures of the acetabulum. These defects may be associated with pelvic discontinuity.

Type IIIA defects have moderate to severe lysis of the superior dome, medial wall, and ischium. The posterior column as well as the acetabular walls are considered to be nonsupportive with the amount of bone loss present in the structures. However, Kohler's line remains intact which will prevent significant medial displacement of the acetabulum component. Type IIIA defects are noted to have hip center migration greater than 2 cm in the superior lateral direction. It is known as an “up and out" deformity. A classic description of this deformity is to think of the acetabulum as a clock and the superior rim deficiency is from the 10-o'clock to the 2-o'clock position and approximately 30%-60% of the supporting bone stock is destroyed.

The most severe acetabular bone loss defects are the Type IIIB defects. These have greater than 2 cm of superior medial migration, and are considered to have loss of all supporting acetabular structures including both walls and both columns. The superior medial migration is generally known as an “up and in” deformity. Again, considering the acetabulum as a clock, the acetabular rim is deficient from 9:00 to 5:00 which represents greater than 60% destruction of the acetabular supporting structures.

It should be mentioned that the original description of the Paprosky Classification in 1994 denotes hip center migration as more or less than 2 cm,[19] but a more recent publication in 2013 increases hip center migration to less than or greater than 3 cm.[13]

Surgical Techniques

General Principles

During acetabular component revision surgery, the surgeon strives to create a stable and durable construct and restore the hip's center of rotation to its anatomical location.

Fixation methods for acetabular component reconstruction may be either biological or nonbiological. Nonbiological fixation attempts to achieve mechanical stability without osseointegration of the acetabular component to the host bone.[12] Examples of nonbiological techniques include acetabular cages or roof rings. On the other hand, biological fixation attempts to achieve osseointegration of the acetabular component with the host's bone. This is achieved by direct contact of a biologically compatible component to the host bone. Examples of biological fixation include porous metal cups and augments. Several studies have noted that biological fixation has superior durability and is preferred, however osseointegration becomes difficult with larger acetabular bone defects.[20,21] It has been historically promulgated that 50% surface area contact between viable host bone and the acetabular component is required for successful osseointegration.[22] However, many surgeons have argued that factors such as component size, and quality of host bone, likely affect the percentage of contact required for osteointegration and therefore feel the 50% surface area contact is rather arbitrary.[23]

The reconstructive options in acetabular bone loss will vary upon the type of defect, patient's age, and host bone contact. The following subsections will discuss the indications, surgical techniques and current outcomes of various treatment options used by arthroplasty surgeons for acetabular component revision surgery with associated acetabular bone loss.

Algorithmic Treatment Approach for Acetabular Deficiencies

Sporer et al[12] established a treatment algorithm for acetabular revisions based on the preoperative assessment of component migration, extent of acetabular bone loss identified intraoperatively, and the inherent stability of trial components. (Table 2).[12] Using the algorithm, surgeons are able to formulate a surgical plan including the reconstruction method, the type of implants, and the need for biologic or nonbiologic fixation techniques for the acetabular revision surgery.

Table 2 Intraoperative Assessment of Acetabular Bone Loss and Inherent Stability of Trial Components by Type of Paprosky Acetabular Defect

Intraoperative Assessment of Acetabular Bone Loss and Implant Trial Stability by Paprosky Classification		
Type of Defect	**Acetabular Status**	**Inherent Stability of Trial Components**
I	1. Rim and columns intact 2. Small, focal area of bone loss	Full inherent stability
IIA	1. Oval enlargement of bone loss and superior osteolysis with intact rim 2. Host bone contact >50%	Full inherent stability
IIB	1. Uncontained superior rim defect <33% 2. Intact anterior and posterior rim and column 3. Host bone contact >50%	Full inherent stability
IIC	1. Medial wall defect 2. Rim intact and supportive	Full inherent stability
IIIA	1. Circumferential defect of 33%-50% between 10 and 2 o'clock positions 2. Host bone contact 40%-60%	Partial inherent stability
IIIB	1. Host bone contact <40% 2. Circumferential defect >50% between 9- and 5-o'clock positions	No inherent stability

Surgical Options for Paprosky Type I and Type II Defects

Cementless Hemispherical Acetabular Component

A cementless hemispherical component featuring a porous or roughened ingrowth surface are used to treat acetabular defects that can be contained, rendered contained, or where rim fixation can be achieved (ie, Paprosky Type I and II acetabular defects). Multiple studies have demonstrated this surgical technique is reliable in achieving both osseointegration and long-term durability.[24-26]

The level of the true acetabulum is identified by placing a retractor in the obturator foramen to signify the inferior border of acetabulum. Next, the hip center is localized by successively larger reamers until the anterior and posterior columns are engaged and bleeding cancellous bone is exposed. Trial components are then used to assess the stability of the acetabular socket as well as degree of component coverage. Sporer et al[27] reports if the trial cup is placed in 40° of vertical inclination and 15° of anteversion then it is not uncommon to see uncoverage of the acetabular component posterosuperiorly. The study notes that 5%-20% uncoverage posterosuperiorly of the acetabular component occurs in most acetabular defects, and the surgeon should avoid attempting to place the acetabular component more vertically to improve coverage due to the increase risk of dislocation and wear. If inherent stability of the trial is not achieved augments placed into the defect may be necessary. The augments are affixed to the remaining acetabulum with the trial in place. The acetabular component is then unitized to the augment with cement at final implantation.

Type IIA (cavitary defect) and type IIC (medial bone loss) defects are filled with bone graft at this time in their respective deficiencies. A reamer 2 mm smaller than the last reaming is used in reverse to impact bone into the acetabular socket.[28]

A cementless hemispherical acetabular cup approximately 2 mm larger than the last reamer used is now placed and provided initial fixation. The initial fixation is then augmented with multiple acetabular screws posterosuperiorly, inferiorly, and into the ischium to minimize micromotion.

Several studies have demonstrated favorable midterm (minimum, 5- 0 years) results using noncemented acetabular sockets for revision THA with a rate of aseptic loosening ranging from 0% to 11% and >90% survivorship with aseptic loosening as the end point.[20,26,29,30] Della Valle et al[24] reported cup survivorship >96% using aseptic loosening as the end point in the longest clinical follow-up (mean, 15 years; maximum, 19 years) of noncemented acetabular cup use in revision THA.

Surgical Options for Paprosky Type III Defects

The hallmark finding of all type III defects is a significant segmental deficiency in the acetabular rim. This deficiency results in an inability to provide sufficient initial component stability to achieve reliable biological ingrowth. Acetabular reconstruction of type III defects often require a structural allograft, metallic augments, custom implants, or cage reconstructions.

Paprosky Type IIIA Defects

Type IIIA defects have superolateral migration of the hip center of greater than 3 cm which results in an acetabular dome and column deficiency that is unable to provide enough stability to be treated with a cementless hemispherical component alone. Treatment options include a cementless hemispherical component with bulk structural allograft, or with metal augments. Metal augments are preferred over allograft by the authors as it obviates the concern for disease transmission and graft resorption.

Cementless Acetabular Component with Metal Augments

Metallic augments in addition to an acetabular component are required when the patient's acetabular rim is not intact and the trial is not stable. In general, this would constitute Paprosky type III A and B defects, however metallic augments are also used in the reconstruction of Paprosky type II defects to improve component stability. Metal augments have been use for years in the management of severe acetabular bone loss.[27] Metal augments optimize the surface area of bone contact and acetabular cup positioning to allow for osseointegration and bone ingrowth. The metal augments function to restore the acetabular bone stock void while also is providing support for the cementless cup.

The metallic augments are made of a highly porous biomaterial made from elemental tantalum or titanium that is similar to cancellous bone in with structure, function, and physiology.[31] Moreover, trabecular metal has a high shear strength profile that further allows the augments to reduce micromotion between the defect and acetabular cup. Augments are available in an array of shapes and sizes providing options to the surgeon to specifically address the acetabular bone loss pattern. Superior segment defects are reconstructed using a metal augment in the flying buttress position, while medial defects are reconstructed using a metal augment in the footing position. In terms of the Paprosky classification, Paprosky type IIIA defects are reconstructed with a superior metal augment that acts as a buttress, while Paprosky type IIIB defects without pelvic discontinuity, are reconstructed with metallic augments positioned on the inferior aspect of the ilium.

After surgical exposure and removal of prior components, the surgical technique begins by placing a retractor into the obturator foramen to identify the location of the true acetabulum. Next, sequential larger reaming occurs until the anterior and posterior acetabulum are involved to define the normal hip center and to also further evaluate areas of structural bone deficiency. A trial component is then placed followed by the selection of the most appropriate shaped and sized augment to fill the segmental defect to provide optimal support to the acetabular component. If needed, a reamer can be used to prepare the segmental defect to allow for better housing of the metallic augment. The augment is than stabilized to the defect with screws. If needed, morselized bone graft is now placed into any remaining acetabular defects. Afterwards, the noncemented acetabular shell is impacted in place and its fixation is enhances with multiple acetabular screws. The fixation of the acetabular cup is then further enhanced by cementing between the contact area of the cup and the augment.

The use of cementless acetabular component with porous metallic augmentation demonstrated favorable clinical results in the management of various types of acetabular deficiencies. Sporer and Paprosky[32] reported on of 28 hips classified as Paprosky type IIIA defects that were revised using a trabecular metal acetabular component supported with a superiorly placed trabecular metal augment. At a mean follow-up of 3.1 years only 1 hip required re-revision for recurrent instability. All other hips were deemed to be radiographically stable constructs. Van Kleunen et al[33] reported no cases of aspectic loosening at 45 months after evaluating 97 hips with Paprosky types II, IIIA, and IIIB defects that were revised using a cementless acetabular shells with porous metal augments. Jenkins et al[34] performed a retrospective review of 58 hips with Paparosky type IIIA (28 of 58 hips) and IIIB (22 of 58 hips) that underwent revision surgery with porous tantalum augments with clinical and radiographic follow-up of 5 years. Using failure as aseptic loosening requiring repeat revision surgery, there was a 97% survivorship within this cohort at 5 years. While the use of metallic augments seems promising, longer term follow-up is needed.

Paprosky Type IIIB Defects

Type IIIB has a defect of the anterior column and anterior wall leading to proximal migration of the acetabular component. A medial wall deficiency is also present and the hip center presents with an "up and in" deformity. Type IIIB defects have a high association with pelvic discontinuity and therefore the surgeon must by cognizant to assess for pelvic discontinuity prior to addressing the known acetabular defect. If the surgeon fails to recognize pelvic discontinuity and address it, the acetabular discontinuity will continue to move and stable fixation will never occur. The superolateral segmental bone less associated with type IIIB defects can be treated with hemispherical components with multiple metal augments, an acetabular cage, structural bulk allograft, or custom implants that span from the iliac wing to ischium. Type IIIB defects are extremely challenging to treat as they are combined cavitary and segmental defects without superior acetabular coverage. Paprosky IIIB defects are often require defect bridging techniques to allow for component stability with the host bones. The goals of bridging technique are the same as defect matching, however with defect bridging techniques the objective is to obtain stability with the pelvic bones not the deficient acetabular rim.[35]

If pelvic discontinuity is present, then an intraoperative assessment of its acuity will have to be performed to determine the proper treatment options. Acute pelvic discontinuities have a high healing potential and therefore are surgically treated by using a compression plate over the disassociation. On the other hand, the poor healing potential of chronic pelvic disassociations will not respond to compression and are therefore managed with the implants described for type IIB or with pelvic distraction with a jumbo cup.

Ring and Cage Reconstruction

Acetabular reinforcement rings and cages are an established method of treatment for severe acetabular bone loss when stability of uncemented hemispheric acetabular component is unachievable or when biologic fixation of a porous implant is unattainable due to the minimal amount of remaining host.[36,37] Traditionally surgeons use 1 of 2 types of rings: the acetabular roof reinforcement rings or antiprotrusion cages. The roof reinforcement rings protect the superior acetabular dome while the antiprotrusion cages protects the entire acetabulum since they extends from the superior ilium inferiorly to the ischium.

Cages function to transfer load onto the periacetabular bone from the acetabular socket through superior and inferior flanges. The superior flange is fixed into the ilium and inferior flange is fixed into the ischium. The flanges allow for adequate contact with native bone when secured to the pelvis using cancellous screws.[38] Reinforcements rings have flanges secured to the ileum and ischium with cancellous screws to relieve stress forces placed on native bone.[38] The ring flanges can be adjusted intraoperatively to increase contact area with native bone (Fig. 2a and b).

The reconstruction of severe acetabular bone loss with rings and cages allows the surgeon to restore the patient's native hip center. Furthermore, the rings and cages provide a uniform load to the bone graft that stimulates bone remodeling and allows for graft incorporation into the host bone.[39] Sheth et al[13] note the major advantages of rings and cages are the ability to cement the liner in correct placement independent of the position of the cage or ring and the elution of local antibiotic protection from the cement. However, a major disadvantage to both cages and rings are they are mostly nonporous and therefore do not enable biologic fixation made from. This ultimately can result in fatigue failure of the construct leading to fracture or loosening resulting from lack of biologic fixation.[38]

Cup-Cage Reconstruction

The cup-cage construct is defined by a porous cup that is placed in the host acetabulum, and then a cage placed within the shell that spans the ilium to the ischium. The cage functions to shield porous cup from loading forces and in doing so, allow time for biologic fixation with the cup and host bone.[40]

Intraoperatively the surgeon will ream the acetabular defect until bleeding bone is encountered. Next, morselized bone graft is used to fill any acetabular defect. The bone graft can be packed into the acetabulum using reverse reaming technique as noted earlier. Once packing is complete, a high-porosity metal acetabular component is press-fit into the acetabulum. Acetabular screws can be used to provide additional initial stability. The surgeon then takes care to dissect out the outer table of the ilium avoiding the superior gluteal neurovascular structures. A cage is now sized and placed into the hemispherical component so the superior flange of the cage can be fixed to the ilium and the inferior flange of the cage can be fixed to the ischium with screws. Finally, a polyethylene liner is cemented into the cage with the desired version and inclination.

Kosashvili et al[41] demonstrates promising short-term result using a cup-cage construct. At an average follow-up time of 44.6 months they noted no clinical or radiological evidence of loosening in 23 out 26 hips (88.5%) that underwent reconstruction with a cup-cage technique. Historically, the concern with cages has been the fear of fatigue failure due to the inability to undergo biological fixation. However, the combination of a porous cup may prove to counter act the high failure rates of cages in the past due to fatigue failure.[40,41] Studies with long-term follow-up will be needed to assess the durability of a cup-cage construct.

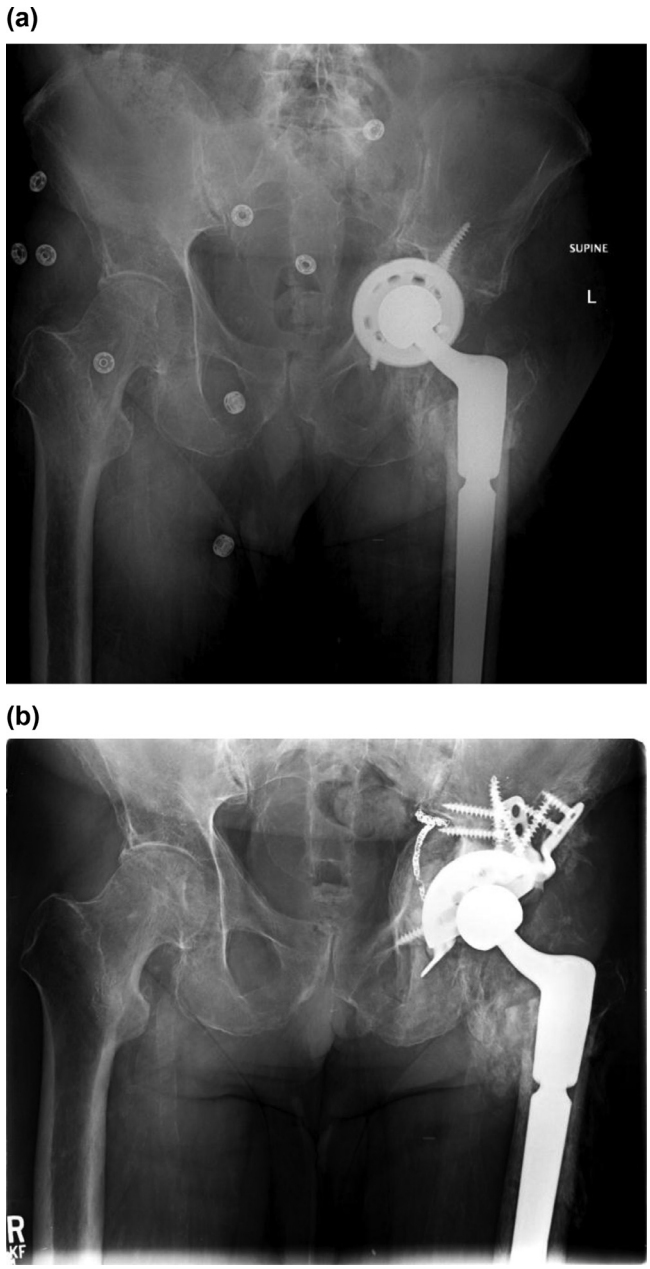

Figure 2 (a) Preoperative x-ray of a 73-year-old male who underwent a total hip conversion at an outside institution 3 weeks prior to presentation. Unfortunately, the acetabular component had migrated into the pelvis causing pelvic discontinuity. (b) Postoperative x-ray utilizing a cage construct.

Triflange Reconstruction

The custom triflange acetabular component is patient-specific implant that is custom-designed to accommodate severe bone loss. The name triflange is derived from the 3 flanges (ilium, ischial, and pubic) that are attached to the acetabular component. The custom triflange implant is indicated in severe acetabular bone loss that exceed the limits of defect-matching techniques. This would include Paprosky IIIB acetabular defect, pelvic discontinuity, previously failed acetabular reconstructions with cages or porous metal

augments, and insufficient acetabular bone stock unable to reconstruct using other methods. Infection is a contraindication to using the custom triflange.

In contrast to off the shelf cages, custom triflange components have porous ingrowth surface and often hydroxyapatite-coating to allow biologic fixation.[42] These implants function to span the critical acetabular defects and obtain initial stable fixation into the ilium, ischium, and pubis via its 3 flanges. The flanges provide areas of contact for screw fixation within the pelvic bones. Since there is a deficient rim of remaining acetabular bone, the cup stability comes from relatively better quality bone of the ilium, ischium, and pubis. The iliac flange tends to provide the largest surface available for contact and therefore generally has the most screws holes.

Unlike other reconstruction options, the decision to use this implant must be made preoperatively since the component is custom designed and manufactured to fit individual's patient pelvis. Since this implant is custom made prior to the surgery it cannot be modified intraoperatively with exception of modular insert choices. This makes the design phase of the implant one of the most crucial parts of the reconstruction. The implant design begins a with a multiplanar CT Scan from the iliac crest through the mid femur or distal to the current femoral component. The imaging is sent to the manufacture at which time a 3D printed model is created with all the current components removed. This 3D printed model is then sent to the surgeon who will begin his surgical planning. The surgeon will need to mark any periacetabular bone that will be removed, the preparation of the acetabular bone, planned removal of any osteophytes, outline the geometry of the flanges, plan for the types of screws to be used as well their length and placement. From time of initial contact by the surgeon to the completion of the implant is approximately 6 weeks.[43]

Intraoperatively, an extensive approach is needed to fully expose the ischium, ilium, and pubis. The superior gluteal nerve and vessels are at risk when trying to accurately place the iliac flanges.

Concerns regarding the triflange construct include its high cost,[43,44] the time required for planning, the feasibility of biologic ingrowth, the potential long-term effect of a stiff metal construct on host bone, the potential for damage to surrounding anatomical structures due to its extensile exposure, and its lack of modularity. Berend et al note that cost of a triflange component ($12,500) is similar to other reconstruction methods including the use of 2 trabecular metal augments, screw and polyethylene liner ($14,500), and also that of an acetabular component cage trabecular metal construct ($11,250).[44]

Variable results with custom triflange components have been reported in the literature. Dennis[31] reported 3 failures, 1 which required subsequent revision, in 24 revision cases following triflange cup insertion at a mean of 4-years follow-up. All 3 failures were due to loosening. In 2007, DeBoer et al[45] reported on 20 hips (18 patients) that underwent triflange component insertion for massive acetabular bone loss and pelvic discontinuity. At a mean follow-up of 10 years, DeBeor et al noted none of the 20 hips required subsequent revision. They further reported a 90% (18 of the 20 hips) radiographically evident healing rate of the pelvic discontinuity. The remaining 2 hips were noted to be radiographically stable in the series despite persistent discontinuity. The overall dislocation rate in the series was 25%. However, Taunton et al[44] reported a revision rate of 30% in 57 hips at a mean follow-up of 5.4 years and 21% dislocation rate.

Conclusion

Acetabular revision surgery aims to restore normal hip mechanics and provide long-term stable fixation. The surgery can be complicated by the variation in remaining acetabular bone quality and bone stock, which will affect the mechanical stability and osteointegration of the acetabular component. Recent technological advances in orthopaedic implants, have allotted for a variety of acetabular reconstruction techniques. However, there is no consensus among orthopaedic surgeons as to which implant and technique is most successful in acetabular revision surgeon.

Successful acetabular revision outcomes require meticulous preoperative planning. It is imperative the surgeon evaluate the quality, amount, and location of acetabular bone loss. Classifying the acetabular bone loss by Paprosky type allows the surgeon to predict and plan for all reconstructive possibilities.

The majority of acetabular bone defects can be treated with a cementless hemispherical component as this surgical technique has demonstrated excellent long-term outcomes.[24] Hipfl et al[46] notes that with improved designs of orthopaedic implants, a cementless hemispherical component shows encouraging clinical results even when there is less than 50% contact between the component and host bone. However, reconstruction using only a cementless hemispherical component is inadequate in cases of extensive acetabular deficiencies, such as Paprosky type IIIA and type IIIB defects. In these cases, successful surgical outcomes depend on addressing structural bone defects and achieving stable biologic fixation when possible.

In a 2019 systemic review, Volpin et al[47] confirmed successful outcomes using diverse techniques for acetabular revisions associated with bone loss. In general, the optimal surgical technique is often selected based on the location and extent of acetabular defect, the presence or absence of pelvic discontinuity, availability of implants, as well as, surgical expertise and preference.[48] In conclusion, no single technique for acetabular reconstructions with associated bone loss has shown superior results.[48]

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