A Review Paper

Acetabular Component Revision in Total Hip Arthroplasty. Part I: Cementless Shells

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Abstract

Magnitude and location of acetabular bone defects dictate the type of reconstruction required. For the majority of reconstructions, a porous-coated hemispheric shell secured to host bone with multiple screws is the implant of choice. This reconstruction is feasible provided at least 50% of the implant contacts host bone. When such contact is not possible, and there is adequate medial and peripheral bone, techniques using alternative uncemented implants can be used for acetabular reconstruction. An uncemented cup can be placed at a "high hip center." Alternatively, the acetabular cavity can be progressively reamed to accommodate extra-large cups. Oblong cups, which take advantage of the oval-shaped cavity resulting from many failed acetabular components, can also be used. The success of these cementless techniques depends on the degree and location of bone loss and on the presence of pelvic discontinuity.

Reconstruction of the failed acetabular component and management of acetabular bone loss constitute one of the most complex problems in orthopedic surgery. Often, extensile exposures with soft-tissue releases are required to visualize and reconstruct the acetabulum, particularly when structural grafting is required. Preoperative and intraoperative classification of bone defects dictates the type of reconstruction required. The majority of revisions can be managed with cementless techniques. The primary goal is to obtain stable fixation to host bone. Secondary goals are to restore the hip center of rotation to its normal location, reconstitute bone stock, and restore leg-length discrepancies.

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Surgical Exposures

Revision of the acetabular component presents several challenges, including safe removal of existing implants and cement, stable implantation of revision prostheses and bone graft, and preservation of the soft-tissue envelope and abductor mechanism. These challenges might require special, more extensile approaches and might not be sufficiently addressed with the conventional approaches used for primary hip arthroplasty.

Posterolateral Approach

The posterolateral approach is a universal approach that can be used for simple cup revisions and for more complex revisions requiring structural allograft. This approach requires release and subsequent repair of the external rotators and posterior capsule. The acetabulum is exposed by retracting the femur anteriorly. Adequate mobilization of the proximal femur might require several soft-tissue releases, including insertion of the gluteus maximus on the posterior femur, the anterior capsule, and the reflected head of the rectus femoris. The advantages to this approach are preservation of the abductors and good exposure to the proximal femur and acetabulum, including the ischium and posterior column. There is limited exposure, however, to the anterior column.[1]

Sliding Trochanteric Osteotomy

The sliding trochanteric osteotomy might be useful when more extensive exposure to the acetabulum is required.[2] The osteotomy is performed in the sagittal plane, begins just medial to the insertion of the gluteus medius into

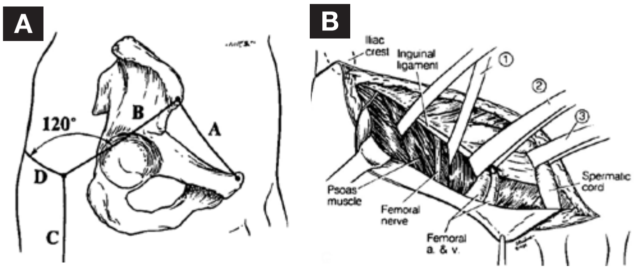

Figure 1. Extensile triradiate approach to hip. (A) Incision of extensile triradiate approach with ilioinguinal extension. (B) Mobilized bundles: (1) psoas muscle and femoral nerve, (2) femoral vessels, (3) spermatic cord or round ligament. Abbreviations: a., artery; v., vein. Reproduced with permission from: Stiehl JB, Harlow M, Hackbarth D. Extensile triradiate approach for complex acetabular reconstruction in total hip arthroplasty. *Clin Orthop.*1993;(294):162-169.

Figure 2. Acetabular component implanted at high hip center.

the greater trochanter, and extends distally beyond the vastus ridge. The gluteus minimus remains attached to the greater trochanter, and the vastus lateralis remains attached to the distal aspect of the osteotomized segments. This differs from a standard trochanteric osteotomy in which this distal attachment is released, allowing the osteotomized fragment to be reflected proximally. The retained attachment to the vastus lateralis restricts proximal migration of the greater trochanter and might minimize the incidence of trochanteric nonunion.[2]

Extensile Triradiate Approach

The extensile triradiate approach to the acetabulum provides access to both the internal and external surfaces of the pelvis. This approach has been used successfully to treat massive acetabular bone loss requiring total acetabular allografts, pelvic discontinuity requiring plating of the acetabular columns, and severe protrusio involving potential vascular or urologic compromise (Figures 1A, 1B).[3] A standard posterolateral incision is made from the posterior superior iliac spine toward the tip of the greater trochanter and extending down the femoral shaft (Figure 1A). The fascia lata and gluteus maximus are divided, and the short external rotators are released from the posterior aspect of the greater trochanter, exposing the hip capsule. An anterior limb is extended from the tip of the greater trochanter to the anterior superior iliac spine and can be extended further medially into the ilioinguinal approach. This portion of the exposure involves accessing the superior pubic ramus, quadrilateral plate, pelvic brim, and sacroiliac joint through "windows" created by the iliopsoas musculature and the femoral vessels (Figure 1B).[3]

Classification of Bone Defects

The extent of acetabular reconstruction required in revision hip surgery is dictated by the degree and location of bone loss. Therefore, classification of acetabular bone defects helps guide treatment. The American Academy of Orthopaedic Surgeons (AAOS) Committee on the Hip developed a classification system for acetabular defects. This system has 2 basic categories: segmental and cavitary. A segmental defect (type I) is any complete loss of bone in the supporting hemisphere of the acetabulum. A cavitary defect (type II) represents volumetric loss in the bony substance of the acetabular cavity, but the acetabular rim remains intact. Segmental and cavitary defects can be superior, anterior, posterior, or medial and can occur simultaneously (combined defects, type III). Pelvic discontinuity (type IV) is a defect across the anterior and posterior columns with total separation of superior acetabulum from inferior acetabulum. Arthrodesis (type V) suggests that the acetabular cavity is filled with bone, making identification of the true acetabulum difficult.[4]

Paprosky and colleagues[5] developed an acetabular defect classification system that is based on presence of supporting acetabular structures (ie, superior dome, medial wall, anterior column, and posterior column). According to this system, in type 1 defects, bone loss is minor; rim, walls, dome, and columns are intact, and contact between the acetabular component and host cancellous bone is higher than 50%. In type 2 defects, the columns are intact, but the rim and walls are distorted. In type 2A defects, there is a generalized oval enlargement of the acetabulum. Superior defects are present, but the superior rim is intact. In type 2B defects, the superior rim is absent. In type 2C defects, there is localized destruction of the medial wall. In type 3 defects, there is major acetabular bone loss; the columns are nonsupportive, and the rims, walls, and dome are severely compromised. There is more than 2 cm of proximal migration. In type 3A defects, superior bone loss extends from the 10-o'clock position to the 2-o'clock position around the acetabular rim. There is moderate destruction of the teardrop and ischium. The medial wall is present, so the component usually migrates superolaterally. In type 3B defects, there are more extensive superior rim and dome destruction, complete destruction of the teardrop, and severe lysis of the ischium resulting in superomedial component migration.[5]

Cementless Revisions

Most cementless revisions of the acetabulum have fared better than cemented reconstructions have.[6-9] For the majority of acetabular revisions, cementless techniques can be used. In the absence of significant structural bone loss, a hemispheric metal shell supported with multiple screws can be used to reconstruct the acetabulum. With minor bone loss, excellent results have been observed with morselized bone grafting and cementless cups.[10-15] When there is major structural bone loss (Paprosky type 3 defects), placing a smaller porous-coated cup against intact superior bone ("high hip center") or using extra-large cups (jumbo cups) or oblong cups might obviate the need for structural grafts and reconstruction cages.

Hemispheric Porous-Coated Cups

The vast majority of acetabular revisions can be reconstructed with a porous-coated hemispheric metal shell. Cementless components inserted with screws have had good intermediate to long-term results.[10-12,14-20] Most published articles on midterm to long-term outcomes of uncemented porous-coated acetabular components for revision hip arthroplasty have focused on the Harris-Galante (HG) series (HG-I and HG-II; Zimmer, Warsaw, Ind). Compared with the HG-I cup, the HG-II cup has additional locking tines, a thicker shell, and larger screws (6.5 mm).

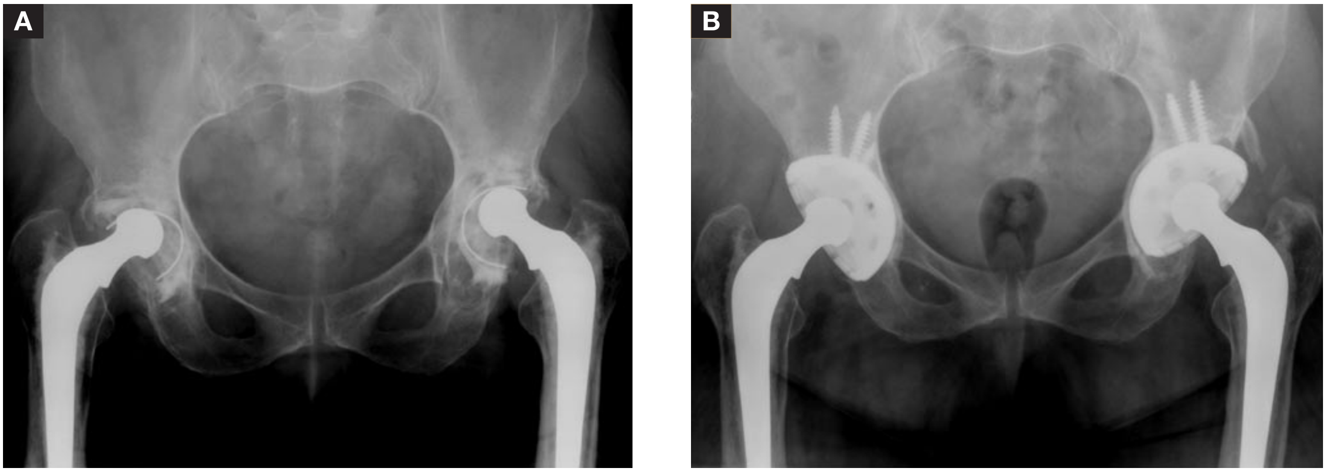

Figure 3. Acetabular revision with extra-large porous-coated components. (A) Failed bilateral cemented acetabular components. (B) Revision of both components using extra-large (jumbo) porous-coated components.

In a study with a 5-year-minimum follow-up, 95 acetabular revisions using either HG-I or HG-II components were found to have a 10-year survivorship of 90.5% with cup revision as the endpoint. Nine shells (9%) were revised: 4 (4%) for dislocation, 4 (4%) for aseptic loosening, and 1 (1%) for liner dissociation.[15] In another study, 122 hips revised with HG-I or HG-II components were followed for a minimum of 10 years.[14] Survival rates were 91% (10 years) and 88% (12 years) with revision for any reason as the endpoint. The rate of aseptic loosening was 11% (5 sockets revised, 8 radiographically loose). In another study with a 10-year-minimum follow-up, 3% of 61 acetabular revisions reconstructed with the HG-I cup demonstrated radiographic evidence of aseptic loosening of the acetabular component.[20] These results represent significant improvement over those obtained by the same surgeon performing acetabular reconstruction with cement. In a study of 81 cemented acetabular revisions followed for a minimum of 10 years, 16% were revised for aseptic loosening, and 19% for radiographic loosening.[7]

After a mean follow-up of 15 years, 14% of the components in 138 acetabular revisions with the HG-I cup were revised. Survivorship was 96% when the endpoint was considered to be revision for loosening or radiographic evidence of loosening.[11,12,21] This series has performed extremely well at short-term and intermediate follow-up, with no revisions for aseptic loosening up until the most recent study.[11,12,16,17,19]

Good results have been also reported for press-fit cups of other designs when used in acetabular revision arthroplasty. In a study of 134 acetabular reconstructions performed with either the Arthropor cup (Joint Medical Products, Rutherford, NJ) or the Solution cup (DePuy, Warsaw, Ind), 95% of cups were stable at a 12-year-minimum follow-up.[22] A study of 47 cementless acetabular revisions using the AML Duraloc component (DePuy) found 6-year survivorship (mean follow-up, 58 months) to be 92% when the endpoint was revision for aseptic loosening or radiologic loosening.[23] In a study of 72 acetabular revisions using a hydroxyapatite-coated uncemented hemispherical component (ABG HA-coated; Stryker, Winterthur, Switzerland), survivorship was 98.1% after a mean follow-up of 7.6 years and with aseptic loosening of the cup as the endpoint.[24] In a recent report on use of the Zweymüller cup—a conical, corundum-blasted threaded cup (Alloclassic Zweymüller CSF cup; Zimmer) used for revision acetabular surgery—radiographic evidence of loosening was found in 8% of cases. Survivorship at 6 years was 95%.[25]

In the studies just mentioned, bone loss worse than Paprosky type 3A was avoided. With higher degrees of bone loss, use of structural bone graft to stabilize the acetabular component appears to yield poor results. After a mean follow-up of 8 years, 22% of 65 cementless acetabular revisions using different hemispheric cups (PCA, Howmedica, Rutherford, NJ; Duraloc, DePuy; HG, Zimmer; Omnifit, Osteonics, Allendale, NJ), had poor clinical results. Structural grafts were used in 14 reconstructions, moderate to severe graft resorption occurred in 13 of these cases, and 22 hips demonstrated evidence of radiographic loosening.[26]

Designers of newer cups have focused on using hydroxyapatite coats or trabecular metal (TM; Zimmer) to enhance biological fixation. Dorairajan and colleagues[27] reported on 50 acetabular revisions using a porous hydroxyapatite-coated cup. At a mean follow-up of 5 years, the re-revision rate was 6% for recurrent dislocation. TM is a highly (80%) porous material composed of tantalum over a carbon framework. When compared with the 30% porous material used in conventionally sintered cups, TM has higher bone ingrowth potential. Its 550-mm pore diameter is within the limits considered optimal for ingrowth of bone and soft tissue and is similar to that of trabecular bone.[28] Unger and colleagues[28] reported early results (mean follow-up, 3.5 years) on 60 revision acetabular reconstructions using TM. Most cups were implanted without screw fixation. Mean Harris Hip Score (HHS) improved from 75 points before surgery to 94 points at final follow-up. There was

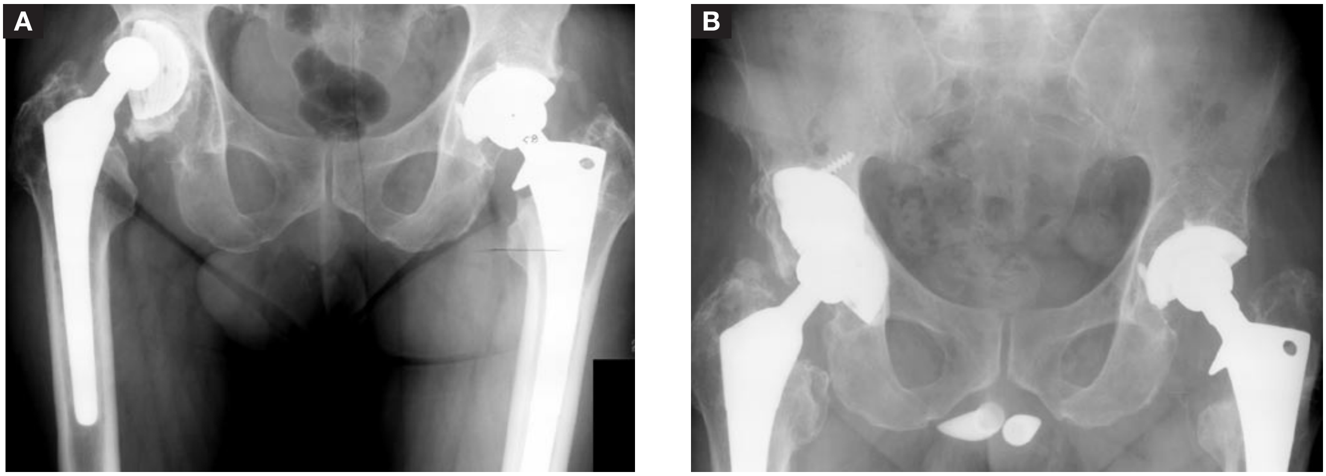

Figure 4. Acetabular revision with bilobed components. (A) Failure of right acetabular component with superior bone loss. (B) Reconstruction with bilobed acetabular component.

1 revision for aseptic loosening and 7 dislocations.[28] Investigations are under way to determine if the higher bone ingrowth potential of TM (vs conventional porous coatings) will allow for stable long-term fixation with less than 50% host bone contact.

High Hip Center

When osseous support at the normal hip center is insufficient because of destruction of superior acetabular bone, use of a hemispheric press-fit cup at the anatomical center of hip rotation might not be possible. Often, these acetabular failures migrate along the axis of hip joint reaction forces to create an acetabular recess in which the superoinferior dimension is larger than the anteroposterior dimension.

A viable option in treating these defects is to place a smaller cementless hemispheric shell against the superior margin of the acetabular defect, the so-called high hip center (Figure 2). Dearborn and Harris[29] reported on 46 acetabular revisions in which the HG-I or HG-II acetabular component was placed with screws against superior bone stock at least 35 mm proximal to the inter-teardrop line. The rate of mechanical loosening was 6%. Dislocations occurred in 5 patients (11%), and 3 patients had recurrent dislocations.

This technique has the advantage of not using structural bone graft and cement but also has several potential disadvantages. Impingement and subsequent dislocation can occur with placing small cementless cups at high hip centers. The 11% rate of dislocation with this technique is higher than the rates in other series of cementless acetabular revisions.[11,12,14,15,19,29] Recurrent dislocations and abnormal hip biomechanics with increases in hip joint reactive forces might in part explain the higher rate of aseptic loosening of the femoral and acetabular components with this technique. In addition, bone stock is not reconstituted, making future revisions difficult. Finally, limb-length discrepancy must be reconstituted on the femoral side, whereas the defect is on the acetabular side—a possible contributor to abnormal hip joint biomechanics.[29]

Jumbo Cups

In the revision situation, extra-large, porous-coated sockets (so-called jumbo cups)[30] have several advantages over standard-sized implants. Most bone defects are filled by the socket itself, making structural grafting unnecessary. These implants maximize surface contact between the porous-coated cup and the host bone and increase the area over the pelvis over which forces are dissipated. Finally, the center of hip rotation is translated laterally and inferiorly to, in most revisions, a more anatomical location (Figures 3A, 3B). Reaming is initially centered in the acetabular defect. Progressively larger reamers are used until a hemispheric bed of cancellous acetabular bone is prepared.[30] To provide cup stability with this technique, it is important to preserve as much rim as possible.

In their series, Whaley and colleagues[30] defined extra-large sockets as having a minimum outside diameter of 66 mm (men) or 62 mm (women). They based this definition on the fact that these sizes were 10 mm larger than the mean implant diameters used for primary hip arthroplasty with the same cup design at their institution. They reported on 89 acetabular revisions using extra-large porous-coated hemispherical cups (HG-I or HG-II). At a mean follow-up of 8 years, survivorship was 93% with removal for any reason as the endpoint.[30] The 4 failures for aseptic loosening occurred in patients with marked acetabular bone loss or therapeutic pelvic irradiation. The most common complication was dislocation (11 patients). Potential explanations are that jumbo cups might prevent soft-tissue attachment close to the femoral head or might allow impingement of the femur against the acetabular component.[30]

Dearborn and Harris[31] reported on 24 acetabular revisions using a hemispherical acetabular component (HG-I or HG-II) more than 65 mm in diameter. At a mean follow-up of 7 years, no acetabular component had been revised or was radiographically loose. Obenaus and colleagues[32] and Patel and colleagues[33] had similar results—cup survival rates higher than 90% at intermediate follow-up.

A disadvantage of this technique is that host bone stock is not restored. In addition, because many superior defects are oblong, and their superoinferior dimension is larger than their anteroposterior dimension, converting the oblong to a hemisphere with progressive reaming might disrupt the posterior wall and column, which are critical for implant stability.[30]

Oblong and Bilobed Cups

Often, the superior acetabular defect seen in revision arthroplasty is oval, and reaming to convert this to a hemisphere to accept a jumbo cup might compromise structural support, as described earlier. An option in this situation is to use oblong or bilobed cups (Figures 4A, 4B). Oblong cups are smaller in the mediolateral and anteroposterior dimensions compared with a hemispheric component of the same superoinferior diameter. This theoretically results in decreased risk for reaming the anterior and posterior columns or disruption of the medial wall with subsequent protrusion.[34-38] The advantages of oblong cups are increased surface contact area between porous metal and native acetabular bone and avoidance of structural bone graft. In addition, the metal shell houses an oblong polyethylene inlay designed to normalize the hip center of rotation. A disadvantage of this cup is that host bone stock is not reconstituted.[34-38]

Berry and colleagues[34] reported on 38 acetabular revisions reconstructed with oblong porous-coated components (SROM [standard range of motion]; DePuy). All patients had superior segmental defects. At a mean follow-up of 5 years, only 1 patient had acetabular loosening. HHS increased from 54 points before surgery to 90 points after surgery. Mean center of rotation was 37 mm superior to the inter-teardrop line before revision and 25 mm superior to the same line after revision. HHS improved from 54 points before surgery to 90 points after surgery.[34] DeBoer and Christie[35] reported similar good results for 18 patients treated with oblong porous-coated cups (SROM) for AAOS type III (segmental and cavitary) defects. At a mean follow-up of 4.5 years, no components had migrated, and the hip center of rotation had been reduced from 38 mm superior to the inter-teardrop line before surgery to 17 mm superior to the same line after surgery. HHS improved from 41 points before surgery to 91 points after surgery.[35]

Proper preoperative selection is critical to the success of this reconstruction method. Chen and colleagues,[38] reporting on 41 acetabular revisions using an oblong cup (Joint Medical Products, Rutherford, NJ), found a loosening rate of 24%. Eight of the 14 hips with preoperative component migration of more than 2 cm and disruption of the Kohler line—a line connecting the most lateral aspect of the pelvic brim and the most lateral aspect of the obturator foramen on an anteroposterior radiograph of the pelvis—had a loose or probably unstable oblong component. There was a high rate of failure with a defect of the medial acetabular wall and ischial osteolysis or obliteration of the teardrop, suggesting that preoperative superior migration of more than 2 cm and a medial wall defect are contraindications to this technique.[38] Pelvic discontinuity is also a contraindication to use of these components.[36]

Complications

Several complications are associated with use of cementless components. Failure of fixation secondary to lack of adequate bone ingrowth might result when contact between implant and host bone is less than 50%. Such reduced contact, found with larger bone defects (Paprosky type 3), often requires structural grafting and reconstruction cages.[38] Pelvic discontinuity, also a contraindication for the techniques described here, often requires stabilization of the discontinuity with posterior plating as the initial step in acetabular reconstruction.[36,38,39]

Rates of dislocation after placement of a component at a high hip center are high probably because of femoroacetabular impingement.[29] Impingement is also a factor in the dislocations that occur with extra-large cups, as the proximal femur can abut the margin of the acetabular component.[30] With isolated acetabular revisions, in which the femoral component is left intact, the extensive soft-tissue dissection and capsulectomy required for exposure of the acetabulum when the femoral component is not removed might contribute to the high dislocation rate (20%) found in some series.[18] Furthermore, the extensive soft-tissue release required for adequate exposure in the revision setting might also contribute to the high dislocation rate.[1] Meticulous soft-tissue and capsular repair and postoperative bracing might reduce the magnitude of this problem.

A new complication is early postoperative transverse acetabular fracture after revision with an uncemented cup.[40] Its most likely causes are further weakening of the remaining pelvic bone stock as a result of the progressive reaming performed to obtain a press-fit of a large porous-coated component and the stresses placed on the bone with early weight-bearing. This complication requires open reduction and internal fixation with pelvic reconstruction plates. Limiting the amount of columnar bone reamed and protecting early weight-bearing might reduce the incidence of this complication.[40]

Summary

Successful reconstruction of the acetabular component during revision hip arthroplasty requires preoperative and intraoperative classification of the magnitude and location of host bone defects and selection of appropriate implants and bone graft methods to obtain stable fixation on host bone. If possible, bone defects should be reconstituted, hip center of rotation should be restored to the anatomical location, and leg-length discrepancies should be equalized. For most reconstructions, a porous-coated hemispheric shell secured to host bone with multiple screws is the implant of choice. These reconstructions are successful provided that contact with host bone is at least 50%. The recent introduction of TM cups with their higher ingrowth potential might reduce the area of host bone required for implant contact, but longer follow-up studies are required to assess this.

For minor cavitary defects, morselized graft in combination with a press-fit hemispheric cup is a good reconstruction method. With more significant loss of superior supporting bone, an uncemented cup can be placed on superior host bone at a high hip center. Although results with this technique have been good, and structural bone grafting is avoided, there are disadvantages: impingement, dislocation, and failure to restore normal hip biomechanics and bone stock.

Good results have been reported with extra-large hemispherical components (jumbo cups), which have the benefits of maximizing surface contact between porous-coated cup and host bone and restoring the hip center of rotation to a more anatomical location. However, the dislocation rate with these components (12%)[30] is higher than that with conventional cups, likely because of impingement and soft-tissue laxity. They also do not restore bone stock, and placement might require excessive reaming of the posterior column, potentially compromising implant stability.

Oblong cups take advantage of the oval cavity noted with most failed acetabular components. Although outcomes at intermediate follow-up appear promising, proper patient selection and avoidance of these components in cases of preoperative superior migration of more than 2 cm and medial wall defects are critical to the success of these techniques.

Severe bone loss, lack of structural support, and pelvic discontinuity might result in failure of these techniques and then additional procedures, including posterior column plating and use of cage-type and custom acetabular components or TM implants.

Authors' Disclosure Statement

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

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