Chapter 3
Prosthetic Component Fixation and Bone Defect Determine Acetabular Revision Surgery

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Introduction

Acetabular revision surgery can present a considerable technical challenge to surgeons depending on the type of cup fixation and the intraoperative bone defect. The decision surgically to treat osteolytic lesions around well-fixed acetabular components or to observe them is made on the basis of the presence or absence of symptoms, as well as the size, location, and rate of progression of the lesion. The relative urgency of surgical treatment is based on the potential adverse consequences of waiting. Catastrophic consequences are loss of superior supporting bone resulting in a segmental bone defect that would convert a cavitary-contained defect into an uncontained segmental defect. Another very difficult-to-solve consequence is the loss of anterior and posterior column support, which results in a pelvic discontinuity. While a superior defect can be visualised on an anteroposterior (AP) radiographs, pelvic discontinuity can require oblique radiographs and computed tomography (CT) scans to assess the integrity of the posterior and anterior columns. For patients at risk of developing these complications, surgical treatment is indicated [1].

Osteolytic Lesions Around Well-Fixed Acetabular Components. Timing of Surgery

The natural history of osteolysis and the timing of surgical intervention is not clearly defined. Timing of surgical intervention for polyethylene wear and asymptomatic osteolysis is complicated by different factors: (1) osteolysis is difficult to quantify

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only using two-dimensional radiographs; and (2) it is difficult to predict when complete wear-through of the poletyhelene liner or catastrophic loosening of the socket due to bone less will finally occur [2]. Asymptomatic patients with radiographically wear but no evidence of ostelysis should be advised of this and undergo yearly evaluations. Although most patients develop symptoms and associated osteolysis, osteolysis can be radiographically diagnosed without symptoms, but, and as soon as osteolysis is seen, socket should be revised regardless of symptoms. The development of radiographic lysis means a higher degree of technical difficulty for the reconstruction. From the perspective of the revisión surgery, there is great value in an early intervention in the face of polyethylene wear and pelvic osteolysis [3]. Mehin et al. advise that osteolysis affecting 50% of the cup contour is more predictive of loosening than the amount of affected area [4]. Changing the polyethylene liner while possible should be considered before allowing the osteolysis to affect cup fixation.

While bone destruction in the acetabulum is associated with loosening in cemented total hip arthroplasties, the surgeon is not faced with removing a well-fixed socket during revision surgery. In contrast, the surgeon frequently must decide whether to remove a well-fixed porous-coated cup when reoperating for osteolysis and polyethylene wear. The first strategy is to remove the well-fixed cup, graft defects, and revise the cup. A second strategy involves doing a liner exchange with debriding and grafting of osteolysis lesions. According to the cup fixation type of fixation, Maloney et al. [5] classified patients with acetabular osteolysis in three types:

1. **Type I**. The porous-coated cup is radiographically stable. in addition, the polyethylene is replaceable. For the liner to be replaceable different criteria must be met: (1) The cup is not malpositioned. If the cup is malpositioned, cup must be removed to avoid recurrent postoperative dislocation; (2) The locking mechanism for the modular component must be intact so the replacement of the liner is stable; (3) The metal shell must not be damaged secondary to head penetration; (4) The polyethylene liner must be of adequate thickness, a mínimum of 6–8 mm.
2. **Type II**. The metal shell is radiographically stable, however, because of factors noted previously (malpositioned cup, a damaged metal shell, locking mechanism failure, poor cup design, impossibility of providing a liner with adequate thickness), the well-fixed cup is removed.
3. **Type III**. The cup is loosened. The only treatment is to revise the cup.

Type I. Treatment When the Cementless Cup Is Radiographically Stable and the Polyethylene Is Replaceable

When a preoperative evaluation determines that a case is potentially Type I, it is necessary to confirm at the time of the revision surgery (Fig. 3.1). After dislocating the hip, the acetabular line and screws are removed. The stability of the

Fig. 3.1 Anteroposterior radiograph of a hip shows a stable cup with significant polyethylene wear and a rounded and well-limited osteolytic cavity

metal-backed shell is also confirmed manually. If Type I classification continues, accessible osteolytic lesions are debrided and grafted with particulate graft material. A new polyethylene liner is inserted and it should be as thick as possible (Fig. 3.2) [5].

Maloney et al. [5], in a series of 40 hips with a mean follow-up of 3.5 years (Type I cases), exchanged the polyethylene liner and debrided the ostolytic lesion. Allograft bone chips were packed into the lytic defect in 29 patients. In the remaining 11 patients, the lesion was debrided but not grafted. At final follow-up all acetabular cups were stable and no new lesions were identified. One third of the lesions had resolved completely regardless of whether they received graft material. The remaining two thirds of the lesions had decreased in size. Maloney et al. [6] suggest that the replacement of the liner and elimination of the source of the high particle load is more important than removing all of the granulation tissue. Leaving the metal shell prevented complete debridement of the granuloma because it made it more difficult to access the entire lesion [6].

Several techniques can be used to graft bone in osteolytic defects when there is a well-fixed acetabular component. The technique depends on the accessability of the lesions. Lesions in the anterior column and pubic symphysis are difficult to assess

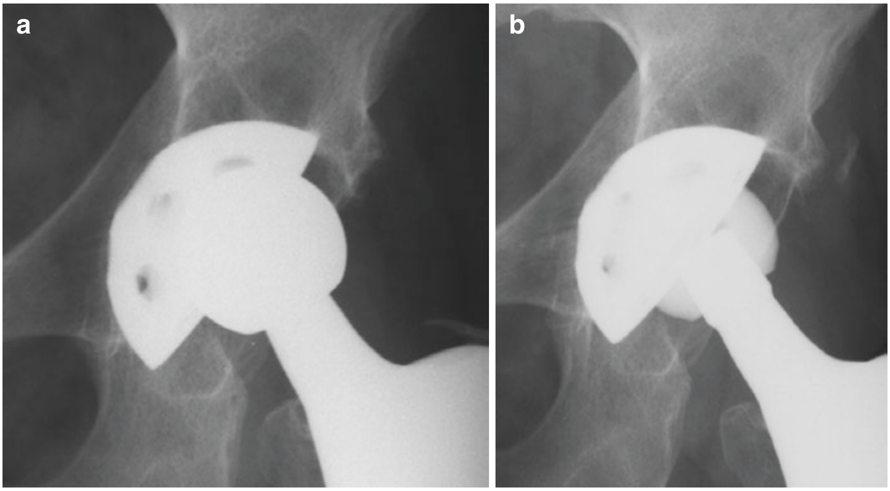

Fig. 3.2 (**a**) Anteroposterior radiograph of hip a shows a radiographically stable cementless cup and replaceable polyethylene. (**b**) Osteolytic lesions were debrided and grafted and a new polyethylene liner was inserted with a ceramic femoral head

with a stable socket [7]. Therefore only a liner change is done and these lesions are not grafted. In a well-fixed socket with screw holes, the osteolytic lesions can be grafted through the holes. The process of placing graft through such a small area is labor-intensive and usually results in less than optimum grafting. Different series report good results using simple devices to facilitate the accessing and debriding of the granulomata and grafting of dome lesions, such as special cones made in different diameters and a long cylindrical body with a funneled top, or chondrotome shaver blades [7, 8].

Modular component exchange surgery is considered more benign for the treatment of polyethylene wear and osteolysis than full actabular revisión and has induced no significant intraoperative complications [9, 10]. However, Boucher et al. [11] report in a series of 24 patients who had an isolated polyethylene liner exchange for wear or osteolysis, at a mean of 56-months follow-up time, six hips (25%) had dislocation. Griffin et al. in a series of 55 patients treated with modular exchange, reported 18% of patients experienced postoperative dislocation, three of which required re-revision surgery. One additional patient required re-revision due to catastrophic failure of the socket after 5 years [9]. Hip instability is the problem associated to this procedure, so more stable constructs should be emphasized. Alberton et al. using a 32-mm-diameter femoral head, report a significantly lower clinical risk of dislocation [12]. However, the necessity for a fairly thick polyethylene component did not permit the use of a larger femoral head with modular exchange surgery. The new highly cross-linked polyethylene may allow the use of larger femoral heads and thinner liners [13]. Talmo et al. also report that 14 hips (25%) with acetabular revision used this technique, and of these in eight were revised due to liner dislodgment [14].

Type II. Treatment When the Cementless Cup is Radiographically Stable But the Polyethylene Is Not Replaceable

When the preoperative or intraoperative evaluation determines that the clssification should be Type II, the surgeon has to be prepared to remove a stable cup. This has the potential to result in major bone destruction producing segmental defects in the medial wall of the acetabulum, the posterior or anterior columns, and even pelvic discontinuity [5]. Carefull attention to the preoperative radiographs is necessary and helps the surgeon to plan the optimal technique for removing a stable shell (Fig. 3.3). An ingrown cup that is abutting the medial wall should not be removed with space occupying tools (curved osteotomes). Peters et al. found that the revision component size was an average 6.5-mm larger due to the increase in the acetabular cavitary diameter when curve osteotomes were used [15].

The cementation of a new polyethylene liner into damaged shells has been done and may enable retention of old cups when there is a deficient locking mechanism or matching liners are unvailable for patients classified as Type II [16]. Cementing a liner into a stable socket is a good alternative for suitable patients who have a well-fixed cementless cup with an inner diameter that is larger than the outer diameter of the cemented liner. Biomechanical testing of cemented polyethylene liners has shown initial fixation strengths that exceed conventional locking mechanisms [17]. Clinical reports with follow-ups of as many as 6 years have shown survival in 90% of cases [17, 18]. This technique requires the proper patient selection, accurate sizing of the new liner, careful preparation of the substrate of the liner and the shell, and good cementing technique. The potential advantages of this technique are less surgical morbidity, more rapid surgery and patient recovery.

The use of new cup extraction systems has been very useful to limit bone destruction during cup removal. Mitchell et al. report excellent results in a series of 31 hips with well-fixed cementless sockets using the Explant Acetabular Cup Removal System (Zimmer, Warsaw, Indiana). The time taken to remove the cup did not

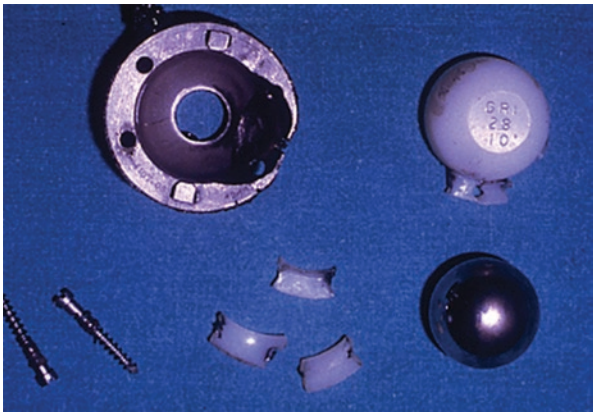

Fig. 3.3 Photograph shows an explanted cementless cup due to a liner rupture, the polyethylene is not replaceable

exceed 5 min in any hip. The median difference between the size of the removed component the size of the new cup was 4 mm, indicating that no more host bone was removed than the thickness of the blades. The classification of the intraoperative bone defect did not change in any hip following implant removal [19].

After removing the metal shell, granulomatous tissue and osteolytic defects are debrided. Depending on the intraoperative bone defect after removing the stable shell, the surgeon must be prepared to solve possible major bone defects using the necessary graft material and tools to reconstruct the defects.

Talmo et al. [14] in a series 128 revisions involving a well-fixed Harris-Galante Porous (HGP-I) or HGP-II acetabular component found that, of the hips that underwent modular liner exchange at revision, 14 hips (25%) required re-revision of the socket., 8 for liner dislodgement, 3 for osteolysis, 2 for dislocation and 1 for aseptic loosening. Of the hips that underwent liner cementing, six (27%) were re-revised: four for dislocation and two for loosening. Of the hips that underwent revision of a well-fixed shell, four (15%) required re-revision, two for dislocation and two for loosening. For these authors using new acetabular cup removal systems, complete revision of the socket is more reliable than liner exchange or liner cementation.

Type III. Revision Surgery in Loosened Acetabular Cups

Cup loosening produces bone defects and cup migration. The bone defect determines the technique used in acetabular cup revision [20]. Cup migration also make it necessary to reconstruct the centre of rotation of the hip to place the cup in the anatomic rotation centre of the hip to obtain a good clinical result [21]. Restoration of the bone stock and the hip rotation centre of the hip remain a problem in acetabular revision surgery.

As yet there is little consensus on acetabular revision surgery because there is a wide variety of available implants and techniques and questions regarding the possible use of morselised and structural bone-allograft that can be necessary when there is severe bone loss [6, 22]. Although preoperative planning is necessary in order to forestall potential difficulties, the intraoperative findings determine what intervention will be performed. The cup requires appropriate acetabular bone stock support. There must be enough medial bone stock and supportive rims to obtain a long-term result. A pelvic discontinuity that may be very difficult to diagnose, makes it necessary to stabilise the acetabular columns before implanting the cup [23].

Classification of Acetabular Defects

The use of an adequate system to classify the acetabular defects helps plan the operation. However, the different classifications have not been universally validated. The Paprosky et al. system [24] is based on the extent of the bone defect, and allows the surgeon to choose the most adequate technique in every case. According to Paprosky, types 1 and 2 represent a bone loss of less than 30% of the acetabular surface, type 3A represents a bone loss of between 30% and 50%, and type 3B is a defect affecting more than 50% of the acetabular surface.

Minor Acetabular Bone Defects Paprosky Types 1 and 2

Cemented Techniques in Acetabular Revision Surgery

Conventional cemented techniques without additional bone grafting were widely used in acetabular revision surgery in the seventies and early eighties. The long-term results of revision surgey using early cementing techniques were inferior to those of primary surgery [25–28]. The use of a cemented socket alone requires healthy bone and an intact acetabular rim to be effective. Radiolucent lines around the socket are frequent in revision surgery, increase in width progressively over time, and must be considered a sign of prosthetic loosening [27]. This lack of initial fixation in revision surgery may be due to residual tissue debris or an inadequate bone-cement interlock on the smooth sclerotic bed. The use of contemporary cementing techniques seems to have improved the results [29]. Currently, cement alone techniques in acetabular revision surgery should be used in non complicated cases with an adequate bone bed, for old and less active patients (Fig. 3.4). The early clinical results in revision surgery can be similar to those obtained in primary surgery, but the radiographic signs must be assessed, even in asymptomatic patients,

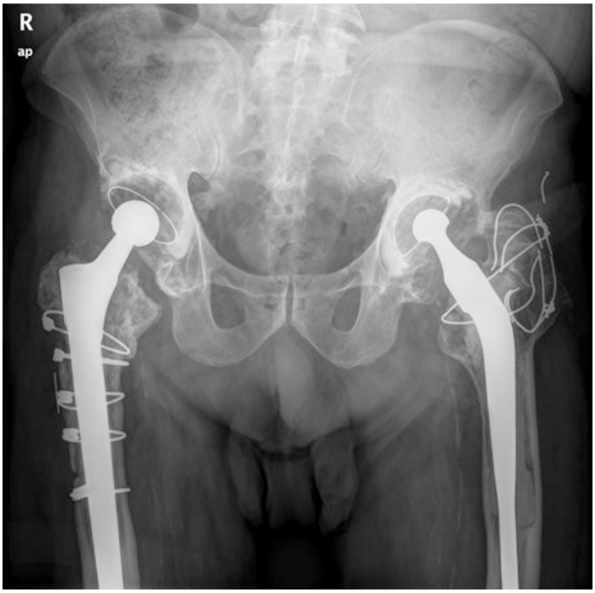

Fig. 3.4 Anteroposterior radiograph of pelvis shows bilateral revised cemented total hip arthroplasties. Radiolucent lines around both components are clearly visible in both prostheses

to check for progressive widening of radiolucent lines, which indicate poor bone-cement fixation that causes late failures. Any major bone defect counter indicates the use of cement alone techniques [27].

Cementless Porous-Coated Cup in Revision Surgery

A hemispherical titanium porous cementles cup supplemented with screws and frequently associated with morsellised allografts is currently used in most institutions for revision surgery and shows excellent results [30–34]. Supplemental fixation with multiple screws is advised in revision surgery to minimise micromotion and promote bone ingrowth. Screws should be placed not only posterosuperiorly into the dome of the acetabulum but also inferiorly into the ischium [34]. Good results should be expected in cases with a bone defect less than 30% and poor results in cases with a bone defect greater than 50% [33]. A major bone defect rarely reproduces the geometry of the implant, in these cases, contact between the cup and the healthy bone is very poor, and osseointegration is not obtained. Intimate apposition of the acetabular component against intact viable host is necessary to obtain a good result, and if the only viable host-bone is high on the acetabulum, the cementless cup must be placed here. When the cup is implanted in a vascularised bone bed, cup fixation should be similar to that obtained in primary surgery. Morsellized graft associated with a porous cementless cup is only useful in small cavitary defects. Biologic fixation of a cementless porous-coated cup is not to be expected in regions supported by solid allograft [35, 36].

The use of new biomaterials, such as porous tantalum trabecular metal, have afforded a superior capacity for bone ingrowth that make the use of hemispherical cementless cups feasible for acetabular revision despite marked bone loss. Tantalum has excellent mechanical and biological compatibility with host bone and induces bone ingrowth with complete osseointegration of the scaffoldat 4–6 months. Different series report encouraging results in revision surgery [37–41]. The incidence of radiolucent lines observed around the tantalum trabecular metal acetabular components is lower than that displayed around the conventional porous-coated components [37]. The excellent osteoconductive properties of porous tantalum trabecular metal may enable stronger biologic fixation even when limited viable bone host is available [42]. The properties of tantalum trabecular metal promote bone formation even across periacetabular defects up to 5 mm in width [43]. Ingrowth is easily obtained if the component is initially stable. In Paprosky types 1 and 2 acetabular defects, excellent stability can be achieved by the tight press-fit of the tantalum trabecular metal components (Fig. 3.5) [37]. Although the use of tantalum trabecular metal cups improves the press-fit of the cups in revision surgery, we do not yet know yet the minimum bone bed necessary to obtain an adequate and reliable osseointegration [44].

Newer porous titanium trabecular cups have a similar architecture to the porous tantalum trabecular metal cups, with 60–70% porosity and pore diameter ranging from 250 to 650 μm. Basic science studies have validated both porous metals by demonstrating excellent bony ingrowth potential as well as mechanical strength

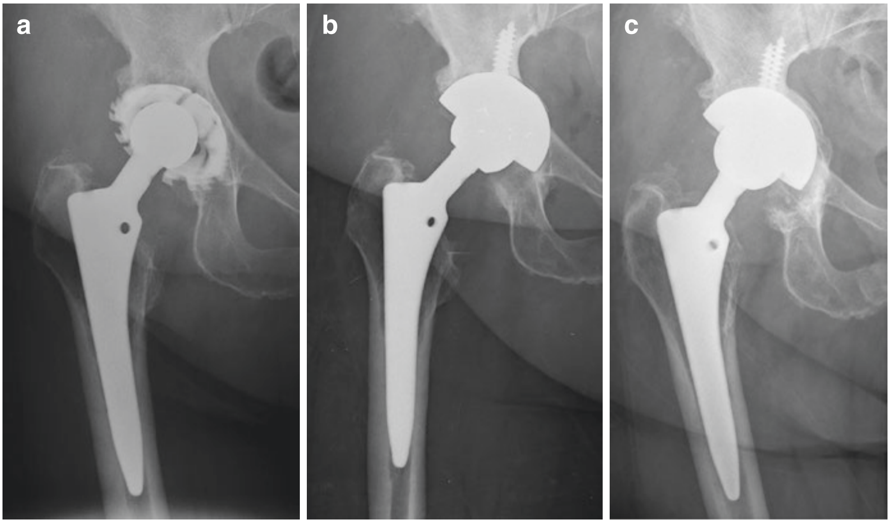

Fig. 3.5 (**a**) Preoperative radiograph shows a loosened cementless cup. (**b**) A porous tantalum cup was used in revision surgery. (**c**) Two years later medial wall remodelling was observed and the clinical outcome is good

[45, 46]. Gallart et al. reported a series of 67 revisions using trabecular titanium cups with a mean follow-up of 30.5 months, eight patients underwent cup re-revision: two for loosening, three for infection, and three for hip dislocation. The remaining cases did not present radiological signs of loosening [47]. None of the cases with Paprosky type I classifications needed revision, while four with type II and four with type III needed revision. Ayers et al. in a series using RSA, found no significant difference in proximal migration between tantalum and titanium acetabular cups over a 5-year follow-up period [48].

Laaksonen et al. in a large registry approach compare the clinical outcome of porous-tantalum cups with other cementless designs [49]. Authors found similar results for implant survival in both groups for first-time revision. They were also unable to identify a "protective effect" by porous tantalum cups against re-revision for infection. Severe defects treated with tantalum augments were excluded from this study. Although trabecular metal could be slightly superior to cups with porous coating, more evidence is still needed before any definitive statements [50].

Major Acetabular Bone Defects (Paprosky Types 3A and 3B)

Uncemented hemispherical cups are the treatment of choice in small acetabular defects, but it is accepted that they will provide poor results when acetabular bone defects are greater than 50% [33]. Another limitation for these implants in revision hip surgery is bone resection. Although extra-large uncemented components have achieved good results [51], the extensive reaming required to obtain good bone contact with the host bone, which is more important in the antero-posterior diameter of the acetabulum, can ultimately affect implant stability [52]. In these difficult cases, we use metallic rings, oblong cups, tantalum cementles porous cup associated with tantalum augments, and the bone impacting grafting technique.

Metallic Rings

During the 1970s, Müller developed a metallic ring to increase a deficient acetabular bone bed. Burch and Schneider also developed an anti-protrusio cage. There are several similar designs today. These rings try to provide a greater contact between the implant and the acetabular bone bed in the hope of distributing the stresses over a greater area. In the early period only cement was used in conjunction with the ring to secure cup fixation. The Müller ring was used in segmental defects, and the Burch and Schneider cage was used in major defects [53].The advantages of antoprotrusio cages are that the reinforcement device seems to protect grafts from overstress, helps to restore the appropriate centre of rotation of the hip and support the polyethylene cemented cup. The best results obtained with the Müller ring are seen in cavitary and anterior segmental defects, while the Burch-Schneider antiprotrusio cage is indicated in major bone defects, but its use requires experience and good exposure, since the screws must be placed in zones with good bone stock [54]. Most series reporting poor long-term results have cases with only a cemented cup associated with a metallic ring. Allografts are currently associated with these devices and have improved those poor results. Grafts are protected from forces that might contribute to graft failure and allograft remodelling is frequently seen (Fig. 3.6). All series described the best results when metal rings were used in association with graft [53–56]. Coscujuela et al. [57], in a series of 96 acetabular revisions using a Burch-Schneider antiprotrusio cage with a mean follow-up of 8.1 years (range, from 5 to 13 years), found three re-revisions, one because of aseptical loosening and two because of deep infection. The Kaplan-Meier survivorship rate, with aseptic component loosening as the criterion of failure, was 92.4% (95% confidence interval, 85.1–99.8%) at 13 years. Radiographic evaluation determined that three cages were considered definitely loose. The distance from the prosthetic femoral head to the approximate anatomic rotation centre of the hip was lowered an average of 4.3 mm and lateralised an average of 1.3 mm.

Metal ring and cemented cup alone could be used for salvage surgery in elderly patients and in low-demand patients [58]. The Burch-Schneider antiprotrusio cage long-term survival rate compares favourably with that for other devices.

Oblong Cups

The purpose of an oblong cup is to obtain sufficient stability in both the anterior and posterior column of the acetabulum without sacrificing the longitudinal axis [59, 60]. This should allow the reconstruction of the anatomic centre of hip rotation and is desirable in order to obtain good results in acetabular revision surgery. Using these cups, different authors have reported excellent clinical and radiological results

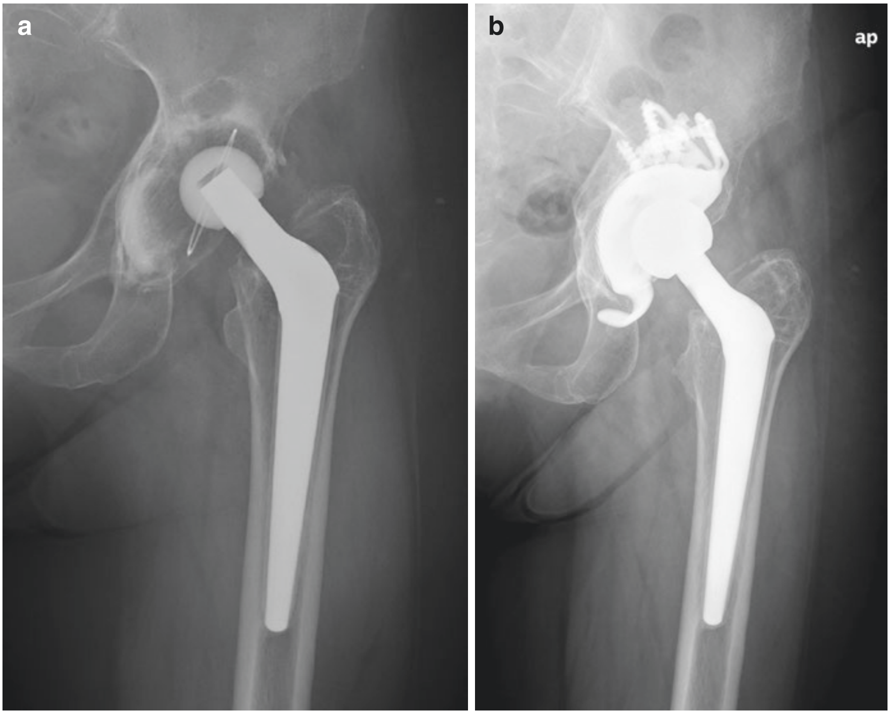

Fig. 3.6 (**a**) Preoperative radiograph shows a loosened cemented cup. (**b**) A metallic cage was used in revision surgery with a good clinical outcome

[60]. Herrera et al. reported a 14.2% migration rate that was greater in vertical cups and in major bone defects with an incomplete cup contact at the acetabular rim [61]. Landor et al. reported a survival rate for aseptic loosening of 90% at 12 years without deep infection in patients with different bone defects; they do not recommend these implants for large bone defects and also emphasize a need of correct cup positioning [62]. Garcia-Rey et al. report in a series of 46 hips with a mean follow-up of 7.2 years, four re-revisions (three due to aseptic loosening); the survival rate for re-revision due to aseptic loosening was 60.1% at 7 years, but the survival rate for radiological loosening at 7 years was 40.54% [63] (Fig. 3.7). Chen et al. reported an early rate of probable or definite loosening of 24% in a follow-up that ranged from 24 to 41 months; failure was greater with major bone defects and undersized components and they did not recommend the routine use of these types of implants [64]. Abeyta et al. reported the long term results of 15 hips using S-ROM (DePuy Johnson and Johnson, Leeds, UK) oblong bi-hemispherical cups; three cups were revised due to aseptic loosening and one showed complete radiolucencies around the cup [65]. On the other hand, Moskal et al. assessed 11 bilobed components in combined acetabular defects that did not require revision over a 5 year follow-up [66]. Although most series observe good results for oblong or bilobed cups, Babis et al. have reported poor results with the Procotyl E cup (Wright Medical Technology, Arlington, TN) in Paprosky defect type 3A and do not recommend this

Fig. 3.7 Postoperative radiograph shows an oblong cup used in revision surgery with a good clinical outcome

technique [67]. Many factors may be responsible for the acetabular cup loosening. A shorter horizontal distance was related to the appearance of radiological cup loosening in the Babis et al. study. Similarly, Surace et al. correlated the clinical results of the LOR cup to its proper postoperative positioning [68]. Bone defect is considered to be the most important factor in obtaining a good result in hip revision surgery. Several authors have reported worse results in major bone defects when oblong cups were used [60, 61]. Currently, clinical and radiological results for these oblong cup designs are not encouraging in medium term follow-ups. The high rate of radiological loosening is a concern since this failure was observed regardless of the grade of the bone defect. Although a good reconstruction of the center of rotation of the hip is frequently achieved, and the postoperative position is frequently correct, this was not enough to achieve an acceptable rate of radiological loosening with these cups. We recommend careful evaluation of the patient before using these types of devices in revision hip surgery.

Porous Trabecular Metal Cementles Cup Associated with Trabecular Metal Augments

The use of porous trabecular metal cementless cups is currently more and more associated with the use of trabecular metal augments [40, 69, 70]. The theoretical advantages are that, as augments are not oblong cups, there is not allograft risks such as disease and bone graft resorption, and well as the simplicity of their use. Different series report excellent results using this technique [71–74].

Acetabular component augments are added to reduce a large acetabular bone defect volume and restore the acetabular rim to aid in the support of the revision cup. A trabecular metal modular augment shaped like a partial hemisphere with rim screw holes is indicated when less than 50% host acetabular bone is present [75]. The acetabulum is reamed in the anatomic position for the eventual reconstruction until two points of fixation are achieved and this will determine the size of acetabulum. Once the desired cup position is identified, the augment is positioned to optimize the filling and fit to the bone defect and provide primary support for the acetabular component [37]. In cases presenting Paprosky type 3 defects, augment can be used to fill the large defect and allow for direct apposition of the tantalum surface to host bone (Fig. 3.8). Location and orientation of augments depends on the pattern of bone loss. It is more common to use augments with the wide base placed laterally and the apex medially. The revision acetabular cup directly contacts the augments, and the augments are necessary to achieve press-fit by the acetabular cup. Particulate bone graft is placd into any remaining cavity before implanting the cup in place. The interface between the revision shell and the augment is cemented to minimize micromotion and subsequent fretting. Multiple screws into both the ilium and ischium are used for fixation. In cases where augments may not provide adequate defect repair and component stability, an acetabular cage may be used [75–77]. Ballester and Sueiro also reported excellent results in a series of 35 patients with severe bone defects using buttress tantalum augments [71].

Impacting Morsellized Allograft and Cemented Cup

In the light of the good results with impacting autografts taken from the femoral head and a cemented cup in acetabular protrusio, Slooff et al. used a similar technique in acetabular revision surgery [78]. Impacted morselized bone allograft and cement in the acetabulum used in revision surgery have given good clinical results [79–81]. The use of metallic meshes converts segmental defects into cavitary defects, making it possible to the fill the cavity with bone-bank impacted morsellized allografts. After this, the cup is cemented onto the graft. In the impacting graft technique, open cancellous bone allows rapid revascularisation of the graft, and bone formation preceeds resorption, thus avoiding the loss of mechanical properties of the bone. What is more, the morsellized allograft can fill in an irregular bone defect [80].

We commonly use this technique in acetabular defects greater than 30%, where our porous cementless cups results have been poor [33]. In a series of 181 hips with either a Paprosky grade 3A (98 hips) or grade 3B defect (83 hips) [82], 12 hips were re-revised and 17 hips showed bone resorption. The total cumulative probability of not having a probable or definite radiographic loosening after 8 years was 94.6% in Paprosky grade 3A hips and 85.9%in grade 3B hips ($p = 0.0453$) (Fig. 3.9). Placing the acetabulum in the anatomic position is important for good long-term results

Fig. 3.8 Postoperative radiograph shows a porous tantalum cup associated with a tantalum augment, with a good clinical outcome

[83, 84]. The mid-term results for impacted bone allograft and cemented all-polyethylene cups are more favorable in Paprosky grade 3A than in Paprosky grade 3B hips and acetabular reconstruction allows anatomic positioning of the cups and promotes good final results. Van Haaren et al. [85] report a high rate of failure with impaction bone grafting in large acetabular defects, including those with pelvic discontinuities. Our series excluded cases with pelvic discontinuity because major bone defects associated with pelvic discontinuity usually require complex acetabular reconstructive techniques using cages or plates, which effectively excluded them from the series [23]. Buttaro et al. suggested considering metal mesh, impaction

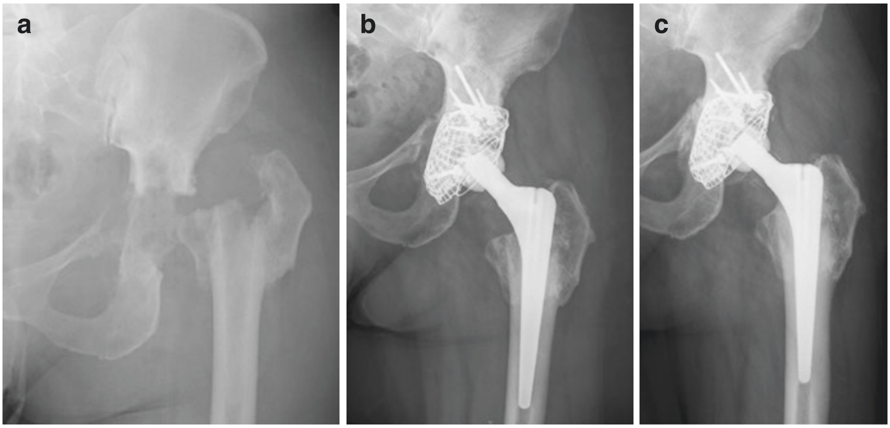

Fig. 3.9 (**a**) Preoperative radiograph of the hip after removal of a metal-metal total hip arthroplasty that developed a pseudotumor and a bone defect at the acetabular medial wall. (**b**) Postoperative radiograph shows impacting bone grafting in the acetabulum and a cementless femoral stem than were used in revision surgery. (**c**) The bone defect is remodeled at 7 years. The clinical result is excellent

bone grafting, and a cemented acetabular component when reconstructing acetabular defects of medium severity, but advised treating severe combined deficiencies with an acetabular ring [86]. Waddell et al. report their American experience in 21 patients with Paprosky 3B acetabular defect who underwent total hip arthroplasty revision using impacting bone grafting [87]. After an average follow-up of 47 months for the entire series, one patient has had radiographic loosening without symptoms at 120 months postoperatively. No patients have been revised for a related reason. Authors concluded that impacting bone grafting is a reliable technique for the treatment of Paprosky 3B acetabular defects. As in other series [80], the impression at re-revision was that the original bone graft had been incorporated, and a new bone impacting grafting was performed because part of the existing graft looked viable and well incorporated to the host-bone. Radiological assessment of bone graft resorption is difficult when impacted bone allograft has been used with cement in an acetabular revision, but the cup and remodeled graft is clearly stable. Most hips presented uniform graft and host bone radiodensity. Histologic studies of cup loosening in humans report bone substitution, but at a slower rate than in animal models [88–91]. The open structure of the cancellous bone graft, associated with cement, permits good vascularization, and thus bone substitution takes place without mechanical loosening [79]. Board et al. report in an in vitro study that strain, as from vigorous graft impaction and postoperative loading, can transform bone allograft from osteoconductive to osteoinductive, since BMP-7 was found to be released from the graft in proportion to the strain imposed on it [92]. Clinical studies using PET to evaluate the spatial and temporal development of bone formation after acetabular revision surgery report that the impacted bone allograft had transformed to living bone [93].

Cup migration and bone graft resorption are some of the limitations after acetabular impaction bone grafting in revision surgery when used for large segmental defects. Garcia-Rey et al. have reported in a series of 204 hips that the survival rate for loosening at 15 years was 83.2 ± 12% for Paprosky Type defect 3A and 72.5 ± 12% for group 3B defects (Mantel-Cox, p = 0.04) [94]. The survival rate for loosening was lesser when using rim meshes (Mantel Cox, p = 0.008). Patients with a bone defect 3B and a metallic mesh rim had a higher risk for loosening (p = 0.047; Hazard Ratio: 2.36, Confidence Interval 95% (IC) 1.01–5.5, and, p = 0.026; OR: 3.7, CI 95%: 1.13–12.4, respectively). Rigby et al. explain that the mechanism of failure of these cups consisted of movement and rotation of the cup/cement composite within the graft [95]. This was followed, eventually, by the mesh being pulled off the reconstructed rim. Failure of the metalwork did not initiate the rotation and migration process. Another possible explanation for the high failure rate in this series could be that in large segmental defects the absence of superior bony support leads to a large amount of bone graft placed at the most loaded area above the acetabular component. Owing to insufficient support for the bone graft, it is likely that micromovement of the prosthesis results in implant failure [85]. RSA studies have shown that almost all impacted sockets migrate in the postoperative period, although the rate of migration decreases with time. Ornstein et al. report that 41% of the sockets were still found to be migrating 18–24 months after surgery [96]. Mohaddes et al. conducted a randomised study with 17 years follow-up, including RSA, and concluded that cemented fixation with bone grafting in acetabular revision surgery results in higher proximal migration [97]. Better results for cemented fixation would probably have been obtained if bigger graft particles and a more consistent impaction technique had been used. It could also be argued that the increased proximal migration of the cemented acetabular components is due to a different pattern of bone remodelling when cemented fixation is used in conjunction with bone impaction grafting. Garcia-Rey et al. also concluded that impacting bone grafting improves the reconstruction of the rotation of the hip center in acetabular revision surgery [94]. Although results are good for large contained or medial defects, hips with a large segmental rim defect may need other options for reconstruction in these challenging surgeries. A large metal mesh does not avoid cranial femoral head migration when there is a large segmental defect of the acetabular roof. Porous trabecular metal augments associated with impacting grafting technique have obtained good early results in this situation (Fig. 3.10). The combination of biological fixation offered by tantalum and impaction grafting seems to generate an adequate cranial support for the cemented cup [98–100]. We must perform more prospective comparative and ideally, randomized studies examining impacting bone grafting versus metal augments as well as the results of impacting bone grafting with and without the augments.

Pelvic Discontinuity

Pelvic discontinuity (acetabular disassociation) is one of the more challenging situations for the hip arthroplasty surgeon to manage. Pelvic discontinuity is a distinct form of bone loss. Occurring in association with total hip arthroplasty, in which

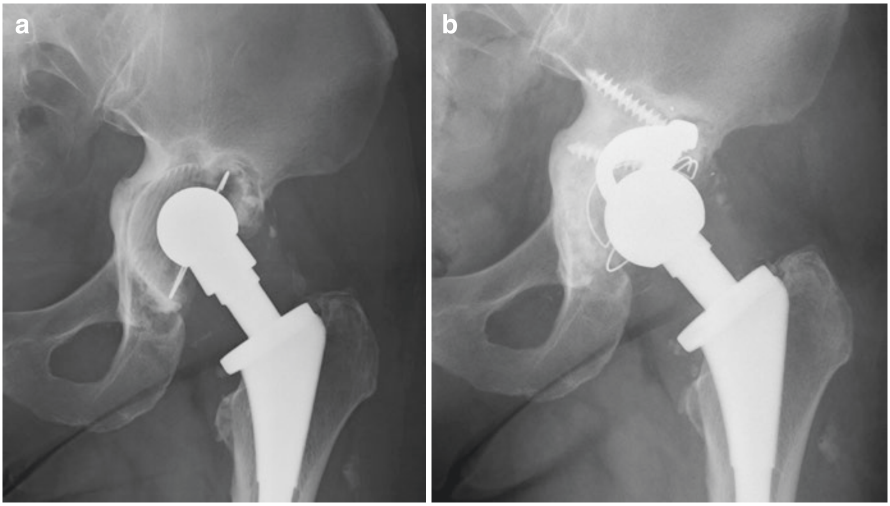

Fig. 3.10 (**a**) Anteroposterior radiograph of a hip shows a failed impacting bone grafting of a revised cup. (**b**) A new impacting bone graft associated with tantalum augments were used in re-revision surgery

there is loss of structural bone between the superior and inferior part of the pelvis resulting from bone loss or fracture through the acetabulum [23, 38]. Its incidence is rare, around 0.9%, and several surgical techniques including ilioisquial cages, or acetabular plates have been recommended [23]. Preoperative diagnosis is important to avoid surgical complications. The radiographic findings include a visible fracture line through the anterior and posterior columns, medial translation of the inferior aspect of the hemipelvis relative to the superior aspect (seen as a break in Köhler's line), and rotation of the inferior aspect of the hemipelvis relative to the superior aspect (seen as asymmetry of the obturator rings) on a true anterioposterior radiograph [23]. However, the diagnosis of pelvic discontinuity using standard imaging views (i.e., anteroposterior, pelvic inlet and outlet views) is challenging because the prosthetic implant can obstruct full visualisation of the defect, especially if the posterior column is involved. Multiple reports support the superiority of the computed tomography (CT) over traditional radiographs in monitoring periprosthetic osteolysis [101, 102]. Massive acetabular bone loss is the most common cause of pelvic discontinuity, making a reliable means of monitoring osteolysis in the hip arthroplasty patient important. Leung et al. found that while radiographs were able to detect at most 52% of osteolytic lesions, CT scans were able to detect 87% [102].

Intraoperative diagnosis of pelvic discontinuity can be made by placing stress on the inferior hemipelvis in the anteroposterior direction and observing any disassociated movement between the superior and inferior portions of the acetabulum. This approach can be limited by the fracture line not being very mobile. Furthermore, visual assessment also presents challenges because the fracture line may pass through areas of bone loss or be filled with fibrous tissue [23].

Berry et al. [23] subclassified the AAOS Type IV defect (pelvic discontinuity) into three subgroups: Type IVa, if the pelvic discontinuity is associated only with cavitary defect and or mild-moderate segmental bone loss; as Type IVb if the discontinuity is associated with more severe segmental or combined bone loss; and as Type IVc if it was associated with previous irradiation of the pelvis with or without cavitary or segmental bone loss. Rogers et al. distinguish acute and chronic pelvic discontiniutes [38]. Acute pelvis discontinuity is secondary to a blunt trauma or iatrogenic intraoperative trauma to impact the uncemented componenet into the acetabulum. A "T "pattern or transverse acetabular fracture is frequent in these cases, and the resulting bone loss is moderate and the acetabular reconstruction relatively simple, however, the posterior column must be stabilized with a reconstruction plate initially in addition to revising the acetabulum. Chronic pelvis discontinuity is secondary to septic or aseptic periprosthetic bone loss. The bone loss is frequently severe and reconstruction requires the use of an ischial cage or a cup-cage. The diagnosis is frequently not obvious before surgery, despite the use of CT and oblique x-Ray. Therefore, a high-level of suspicion should be maintained during surgery, with the possibility of a pelvic discontinuity specifically being checked after any initial gente reaming [38].

Reconstruction Techniques

Porous Metal Components The implantation of the acetabular component is complex and complications and poor results are frequent. A hemispheric acetabular component alone does not provide adequate implant stability in patients with pelvic discontinuity and a number of different methods have been used for reconstruction depending on the degree of severity. The best results are obtained in patients who do not have severe segmental acetabular bone loss (Type IVa) and are worse in those with severe segmental or combined defects (Type IVb) or those who have previously been treated with irradiation in the pelvis (Type IVc) [23].

Internal Fixation with Acetabular Reconstruction In cases of acute pelvic discontinuity with moderate segmentl bone-loss, the use of a compression posterior column plating supplementing a trabecular metal acetabular revision shell can solve the problem depending on the size and nature of the cavitary defect that is the result of stabilizing the posterior column. Plates are used in conjunction with acetabular reconstruction to stabilize the pelvic discontinuity (Fig. 3.11). Dual plating of posterior and anterior columns and plating of just the posterior or anterior column have been described in the literature [38, 103, 104]. Dual plating requires combined ilioinguinal pelvic and posterior surgical approaches to the hip. Berry et al. found unfavorable results using plating with a cemented cup, and none of the five cases had good long term survivorship [23]. Better results were found in the eight cases in whom a cementless cup and dual or single plating was used: four (three type IVA and one type IVB) had satisfactory results, while the other four (all type IVB) did not. Stiehl et al. used structural allografts with dual plating or single column plating.

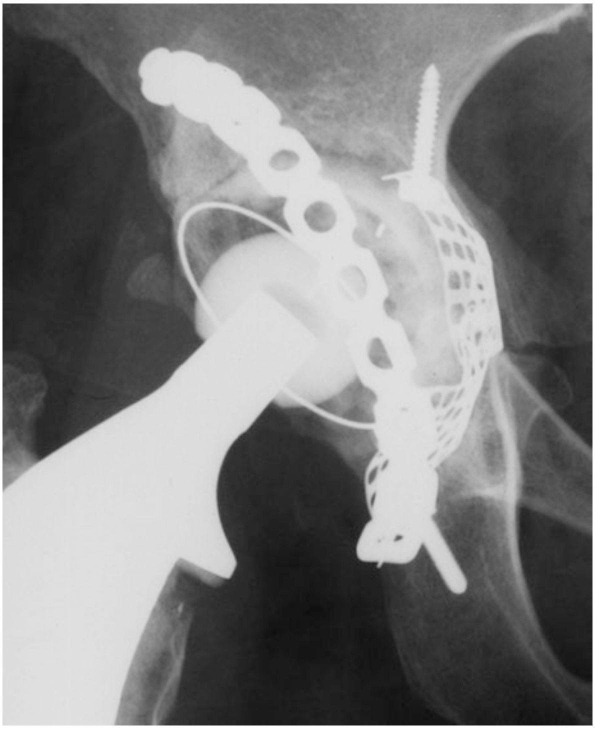

Fig. 3.11 Anteroposterior radiograph of the hip shows a pelvis discontinuity after an acetabular fracture that was treated using an acetabular plate recontruction to stabilize the posterior column and total hip arthroplasty

Of the 10 pelvic discontinuities, seven out of the nine Type IVB and the single Type IVC pelvic discontinuities shaved actual healing of the discontinuity. The utility of fixation was called into question in these cases by the high complication rate of 60%. Eggli et al. used plating of either the posterior or anterior column along with reconstruction using allograft chips covered by autograft [104], and at a mean follow-up of 8 years, reported reoperation had occurred in two of the seven cases but at their last follow-up, all cases demonstrated a stable and healed pelvic discontinuity. Rogers et al. used compression plating of the posterior column, revision cup, and screw supplementation in eight of their patients with acute pelvic discontinuity and, at a mean follow-up of 34 months, there were no further revisions in any of those eight cases [38].

Metallic Rings The Kerboull plate was developed in 1974 to address pelvic discontinuity [105]. The vertical plate is proximally fixed to the ilium via screw fixation and distally via a hooked end that inserts under the inferior acetabular margin. It has traditionally been used with bone grafts, providing the grafts with mechanical support, to address areas of acetabular bone loss. The failure rate during the period analyzed was only 5% (three hips) and these were due to partial or complete resorption of allograft. However, in their study only 12 of the 60 hips had Type IV acetabular bone loss (AAOS) and the remainder (48 hips) had Type III loss [105]. The study did not specify how the Type IV hips fared with this reconstruction technique. The promising results in the above study need validation with further studies focusing on Type IV acetabular defects.

Acetabular Distraction with Porous Acetabular Cup The acetabular distraction technique is another novel approach to managing pelvic discontinuities. Paprosky et al. [106] recommend the use of metal acetabular augments to distract across the pelvic discontinuity, since the amount of bone loss along the posterior column is often too severe to provide direct bone apposition during compression plating. The goal of the distraction technique is to address the acetabular nonunion with distraction by expanding the defect and creating elastic recoil forces that should compress the porous metal construct and provide a stable construct. Intraoperatively, a Cobb elevator is used to delineate the fracture line and debride the granulation tissue followed by acetabular reaming that is performed to better define the acetabular bone that is suitable for fixation using augmentation [107]. The location and severity of bone loss determine the type and position of the acetabular augments used to enhance initial component stability. Augments are frequently used to reconstruct portions of the anterosuperior aspect of the acetabulum as well as the posteroinferior aspect; they provide two secure points of fixation for the acetabular component. A porous acetabular cup, which is 6–8 mm larger than the hemisferic reamer that engaged the anterior and posterior columns, is used to distract the superior hemipelvis from the inferior hemipelvis. Multiple screws are placed in ilium and ischium, and the augment is secured to the cup with polymethylmethacrylate [107]. Sporer et al. reported good mid-term results using acetabular distraction and only one case (1/20) required revision for aseptic loosening at 9 months, at the 4 year follow-up, four hips showed migration of the acetabular component but they were clinically stable [107]. The acetabular distraction technique is a reasonable option for many patients but the long-term data is limited in this regard.

Cup-Cage Construct In cases with chronic pelvic discontinuity or major column defects, different aurthors recommend the use of a cup-cage acetabular reconstruction owing to the inherent beneficial biological and biomechanical properties of porous tantalum metal [23, 38, 56, 71, 108, 109]. The cup-cage construct is a well-described technique to correct large acetabular defects and pelvic discontinuity. Using this technique, a porous metal cup is secured to host bone and allograft, if used. An acetabular cage is subsequently anchored to the pelvis. Placing a screw through both the cage and the cup adds a level of unity and stability to the construct. The rationale behind the cup and cage is that it removes loading forces on the cup and allows time to optimize ingrowth of new bone into the cup [74]. 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 of 44.6 months (range, 24–68) [110]. Another study with a mean follow-up of 82 months reported a survival rate of 87.2% for cup-cage reconstructions as opposed to just 49.9% for the group treated with only a cage [74]. Despite the use of new biomaterials, Rogers et al. report only an 8-year survivorship of 86.3% using cup-cage reconstructions [38]. Ballester and Sueiro [71] reported excellent results in a series of 35 patients with severe bone defects including five cases of chronic pelvic discontinuity using buttress tantalum augments with cup-cage construct; no mechanical failure had occurred in any hip and all patients had a radiographically stable cup. Radiographic assessment showed an improvement in the position of the rotation centre of the hip. Konan et al. [108] in a series of 24 patients with pelvic discontinuity treated using a cup-cage construct, at median 6-year (minimum 2 year, maximum 10 years) follow-up reported that one patient was converted to excision arthroplasty for infection. A further three patients required revision for instability but the cup-cage construct was not revised. The cup-cage construct is a viable method of dealing with a complex pelvic discontinuity. However, the failure rate due to loosening in most reports does prompt the need for further refinement of the technique and technology in this very challenging group of patients, as well as continued evaluation at the mid- and long-term so as to confirm the ongoing success of this method of reconstruction [111].

The cup-cage technique is technically challenging, and forceful impaction of the ischial flange of the cage into the ischium risks producing an iatrogenic pelvic dissociation [112]. Furthermore, the increased dissection required for placement of the ischial flange may increase the risk of sciatic nerve injury [113]. Sculco et al. report good results using the half cup-cage modification, designed to simplify cage insertion [112]. The half-cup cage involves removal of the ischial flange to create a single-flanged cup-cage construct. Sculco et al. found both full and half cup-cage constructs gave successful clinical outcomes in the treatment of major acetabular defects and pelvic discontinuities. Each method should be used on the basis of individual intraoperative findings, including the extent of bone loss, the quality of the remaining bone stock, and the presence of pelvic discontinuity.

Custom Triflange Implants Triflange implants are custom-made, porous-coated titanium alloy components considered to be a final therapeutic salvage option in patients with pelvic discontinuity and/or large acetabular defects. A triflange construct is designed and manufactured based on pelvic CT scans with metal subtraction software converted into a 3-D representation of the patient's hemipelvis. The manufacturer generates personalized implants from the corresponding images. Triflange components have had produced wide-ranging clinical results. DeBoer et al. reported zero cases (0/20) requiring revision of the triflange construct and average Harris Hip Score (HHS) of 80 at 10 years follow-up [114]. Taunton et al. reported a revision rate of 30% (20/57) at 5.4 years and a 21% dislocation rate most likely attributable to instability generated from he preoperative trochanteric escape performed in 51% of patients, as well as possible traction injury to the superior gluteal nerve during exposure leading to abductor muscle weakness [115]. When comparing manufacturing cost, triflange components are priced similar to other constructs used to treat pelvic discontinuity, including the cup-cage construct. The major drawback of the triflange construct is that it may take up to several weeks or longer to prepare the implant for surgery. However, custom triflange components may be the only viable reconstructive option for discontinuity with massive segmental bone loss [111].

The outcome for reconstruction of pelvic a discontinuity is dependent on many factors including the extent of bone loss associated with the discontinuity, severity of osteopenia, vascularity of the pelvic bone, chronicity of discontinuity and reconstruction technique. Healing of the discontinuity can be achieved more effectively for defects associated with cavitary or mild to moderate segmental bone loss (AAOS type IVa) than those with more severe bone loss or poor vascularity (AAOS types IVb and IVc). However, stable fixation of the revision component to the iliac portion of the pelvis may still be feasible with a cup cage or custom triflange reconstruction without union of the discontinuity.

Conclusion

The type of cup fixation and the degree of pelvic osteolysis determines the surgical technique to reconstruct the acetabulum and implantation of a stable acetabular component. Table 3.1 shows recommendations according to this variables. Table 3.2 shows results of different surgical techniques depending on the acetabular bone defect.

Table 3.1 Surgical techniques recommended depending on type of cup fixation and the degree of pelvic osteolysis in acetabular revision surfery

Socket fixation	Surgical technique
Type I: cementless cup stable and polyethylene replaceable	Retain shell, exchange liner, ± grafting
Type II: cementless cup stable but the polyethylene not replaceable	Revise socket ± bone grafting
Type III. Loosened socket	Revise component
Paprosky bone defect types 1 and 2	Porous cup± bone grafting
Paprosky bone defect type 3 A	Trabecular porous augment and cups/ impacting bone grafting
Paprosky bone defect type 3B	Impacting bone grafting ± porous augments
Pelvic discontinuity	
Acute pelvic discontinuity	Acetabular plates to stabilize the posterior column
Chronic pelvic discontinuity	Cup-cages/distraction technique

Table 3.2 Results of differents techniques used according to the acetabular bone defect in revision surgery

Author	Surgical technique	Year	Bone defect according to Paprosky	Number of cases	Follow-up (years)	Revised cups	Loosened cups
Garcia-Cimbrelo et al. [27]	Cemented cup	1995	1–3	180	11.5	19	29
Garcia-Cimbrelo [33]	Cementless cup	1999	1–3	65	8.3	7	18 (grade 3)
Fernandez-Fairen et al. [37]	Porous-tantalum	2010	1–3	253	6.1	2 (infections)	0
Coscujuela-Maña et al. [57]	Antiprotrusio-cage	2010	2–3	68	8.1	3 (2 infections)	°
Garcia-Rey et al. [64]	Oblong cups	2013	2-3A	45	7.2	2	8
Ballester-Alfaro et al. [72]	Tantalum augments	2010	3A-3B	19	2.2	0	0
Garcia-Cimbrelo et al. [82]	Impacting bone grafting	2010	3A-3B	181	7.7	12	14
Garcia-Rey et al. [94]	Impacting bone grafting	2015	3A-3B	204	10.4	14	24
Gallart et al. [47]	Trabecular titanium	2016	1–3	67	2.5	8	2

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