(ii) Current techniques and new developments in acetabular revision surgery

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Summary
Revision of a failed acetabular component is one of the most challenging aspects of revision hip arthroplasty. The revision hip surgeon must have a systematic approach to preoperative, operative and post-operative management. The majority of acetabular revisions can be performed using uncemented "jumbo" components, however severe bone loss can make reconstruction difficult. An advanced skill set including practical knowledge of extensile exposures, special techniques in removal of components, management of bone defects, and reimplantation of revision components, is essential. The various surgical options available to the revision surgeon are discussed in this article with particular focus on new techniques, instruments, materials and prostheses which may make this challenging area less complex to manage and may improve outcomes for patients in the future.

Introduction
Acetabular revision is perhaps the most challenging facet of revision hip reconstruction for the arthroplasty surgeon. Exposure may be difficult due to obliteration of the normal tissue planes from previous surgery and distortion of the anatomy. In addition acetabular bone stock may be grossly deficient leading to difficulties both with obtaining acetabular fixation with sufficient host bone contact and reproducing the hip centre, leg length and joint stability. Fractures of the acetabulum may be present or occur intraoperatively and neurovascular structures lie within close proximity.

It is therefore necessary for the revision arthroplasty surgeon to be mindful of possible intraoperative eventualities and to be armed with the necessary techniques, skills and inventory to manage them. Meticulous preoperative planning is required to ensure a satisfactory outcome.

Preoperative planning
The surgeon must know the details of the implanted components including prosthetic sizes, femoral trunion size, acetabular locking mechanism and the available liner options. Bone defects should be estimated and bone graft (morsellised or structural) should be available. In this regard, applying a classification system of acetabular bone...
defects may aid to guide management. Inventory should include instruments for extraction of the components and prostheses to re-implant.

Intra-pelvic migration of cement or components may warrant a preoperative angiogram to diagnose involvement of vascular structures and consultation from a general or vascular surgical colleague for assistance with operative exposure may prove beneficial.

The exclusion of infection, by use of blood tests and the judicious use of joint aspiration, is mandatory in all revision surgery. While no absolute guidelines for interpretation of inflammatory markers exist, however in the absence of another cause an ESR greater than 30 mm/h or a CRP greater than 10 warrant careful consideration of preoperative hip joint aspiration.

The operative procedure can then be divided into 4 phases; exposure of the acetabulum, extraction of implanted components, assessment and management of acetabular bone defects and re-implantation of revision components.

**Exposure**

Surgical approach is dependant on various factors such as the surgeons preference and experience, previous surgical approach and anticipated reconstructive challenges. For instance, if a pelvic discontinuity exists, the posterior column may require plating and then a posterior approach to the hip is preferable. In most cases, the approach with which the surgeon is most adept is best, although it is imperative that the chosen approach is extensile. Some form of trochanteric osteotomy (standard, sliding or extended) is often required to enhance either femoral or acetabular exposure. If revision of the femoral component is also required and a trochanteric osteotomy or variation is used, this may also improve access to the acetabulum.

**Extraction of implanted components**

The surgeon must have revision instruments including osteotomes, gouges, drills and high-speed burrs. The interface between the cement and bone should be exposed circumferentially. For removal of a cemented acetabular component, the prosthesis should initially be disrupted from the cement mantle and then the cement should be carefully removed using gouges and osteotomes to disrupt the cement bone interface in a piecemeal fashion with the minimum of bone loss. For removal of an uncemented acetabular component, the polyethylene liner should be disengaged from the shell and any screws removed. A 6.5 mm screw inserted through a 4.5 mm drill hole in the polyethylene will disengaged the liner from the cup in most instances where a proprietary liner removal tool is not available. The bone prostheses interface can be broken with a series of curved gouges or the use of more specialised instruments such as the *Explant* (Zimmer, Warsaw, Indiana). Use of the *Explant* device requires re-insertion of the polyethylene liner or suitable trial liner after acetabular screw removal has been performed (Fig. 1).

**Assessing and managing acetabular bone defects**

Preoperatively plain X-ray, CT scanning and MRI scanning can be used to attempt to assess acetabular bone defects. In general the defects seen on imaging will underestimate the intraoperative status. The AAOS and Paprosky classifications of acetabular deficiencies are useful in guiding further surgical management.

The remainder of this article will outline the options currently available for revision surgery of the acetabular component with a focus on new developments.

**Uncemented acetabular revision**

In our practice, the majority of acetabular revisions are performed using uncemented revision acetabular components when greater than 50% host bone contact is available for implantation. The use of these so called “jumbo” cups has become the workhorse of acetabular revision surgery. Excellent outcomes have been reported for the use of uncemented acetabular revision with 12–15-year survivorship of 81–96%.

The complexity of acetabular revision is determined by the amount and location of acetabular bone defects present. It is not uncommon for patients to present with several years of relatively minimal discomfort with large osteolytic defects and or migration of the acetabular components. The Paprosky classification of acetabular deficiency describes the amount of host bone contact for implantation of the prosthesis and takes into account the amount of rim, dome and anterior and posterior columns available.

In Paprosky type 1 defects, bone loss is minimal and can usually be treated using an uncemented acetabular component supported by multiple screws and morsellised bone
that of a stable ingrown component even in the presence of revision acetabular component will initially be worse than failure. It is important to note that the fixation of any component is solid, but the process of osteolysis may continue without surgical intervention and may eventually lead to destruction of the inferomedial wall and teardrop.

As the defect in the acetabulum is usually greater superoinferiorly rather than antero-posteriorly the AP diameter of the acetabulum will need to be widened to accommodate a hemispheric component. The posterior column is the most important structure for implant stability and thus after superior bone defects have been addressed, the anterior wall should be preferentially reamed until adequate component stability is gained. Uncemented acetabular components can also provide good long-term fixation in the presence of a pelvic discontinuity once the posterior column has been stabilised by plating.

In principle, the amount of acetabular reaming should be kept to the minimum required to achieve adequate host bone contact and stability.

The position of uncemented acetabular components should ideally be 45° of lateral opening with 15–25° of anteversion. This may be difficult in the absence of usual anatomical landmarks. In particular, the component will often be uncovered superolaterally although this is preferable to a component placed too vertically. In addition, efforts to restore correct anteversion will often result in the cup being uncovered posteriorly. As a general rule, somewhere between 50% and 70% of contact with host bone is required for long-term implant stability.

Uncemented acetabular components should then be augmented with multiple screws into the ilium. The superior quadrant, described by a line between the ASIS and ischium and its bisector, is the safe area for placement of acetabular screws. Screws may also be required posteriorly into the ilium and anteriorly into the pubis, however this carries the increased risk of neurovascular damage.

It has been our post-operative protocol to keep patients touch weight bearing for the first 6 weeks post-operatively, then gradually increase weight bearing by the 3-month mark.

Isolated polyethylene liner exchange and bone grafting

Osteolysis behind a well-fixed uncemented acetabular component is a relatively common radiographic finding at our institution. Patients are often asymptomatic as the fixation is solid, but the process of osteolysis may continue without surgical intervention and may eventually lead to failure. It is important to note that the fixation of any revision acetabular component will initially be worse than that of a stable ingrown component even in the presence of retro-acetabular osteolysis. Therefore, one option for this clinical problem is to perform an isolated polyethylene liner exchange, often combined with bone grafting of the defect, to halt the production of particle debris. Indeed, this is one of the prime rationales for the production and widespread adoption of modular acetabular components.

The acetabular component suitable for this technique must be satisfactorily positioned and stable at the time of surgery, with a well designed locking mechanism which allows for exchange of liner. It is preferable to have multiple options for liner and head exchange including a range of head sizes and neck lengths, and lateralised, lipped or antverted liners. Osteolytic defects may then be addressed by cancellous bone grafting.

Bone grafting may be performed in several ways. Dome covers or screws may be removed and cancellous graft packed through these portals into defects. Specialised curettes with various angled necks have been designed specifically for working through dome and screw holes allowing improved debridement of granulation and osteolytic tissue (Wright Medical, Mississauga Canada.) It is possible to impact large quantities of cancellous graft through screw holes. Circumferential clearing of soft tissue from the bone prosthesis interface will often demonstrate defects around the cup which can also be used to debride and impact bone graft. Fenestrations in the superolateral ilium through which access may be gained may be made using a burr or osteotome. Bony septa are often present from the pelvis to the uncemented shell and are sometimes visible through rim defects or windows. These septa are critical for the continued stability of the implant and should be carefully preserved during debridement and grafting.

High dislocation rates following isolated liner exchange have been reported, particularly with the posterior approach, and thus adequate intraoperative stability must be confirmed prior to closure. At our institution, using a direct lateral approach, dislocation has not been a complication of this procedure. If there is any question that stability cannot be maintained intraoperatively, or that the acetabular component is not well fixed, then complete acetabular revision should be performed.

Cementing a polyethylene liner into a well-fixed uncemented shell

Another option for consideration in acetabular revision is the technique of cementing a liner into a well fixed cup. This option is applicable to a stable well-fixed shell with a non-modular liner that can be removed, or a modular liner with a poor or damaged locking mechanism, and where the cup to be retained has proven good long term survivorship. The retained acetabular component should have an internal diameter large enough to accommodate the outer diameter of a polyethylene liner plus a 2 mm cement mantle. Patients with a history of dislocation may be treated by cementing a captured liner and good outcomes have been reported with use of this technique.

For cementation of all polyethylene liners into an uncemented shell we use a high-speed metal cutting burr to make radial and circumferential grooves in the metal of the socket (2–3 mm deep) prior to cementing, and size the
liner aiming for a 2 mm cement mantle. In addition, where a modular liner is being used, the backside should be roughened or grooved to improved cement fixation. Generally, we aim to use the largest bearing size available and use an anterolateral approach to minimise the risk of dislocation.

Use of structural bone grafts

The majority of acetabular revision surgery can be accomplished using morsellised allograft to deal with small to large cavitory bone defects. Structural bone grafts become necessary when there is insufficient bone stock available to provide adequate support for revision components. In the use of structural bone grafts size and complexity can range from using a femoral head to reinforce medial wall or superolateral rim defects to the use of total acetabular allografts in the case of massive defects.

Precise indications for use of structural allograft have not been defined, and the use at our institution (which is a tertiary referral centre for revision arthroplasty) is approximately 5% of revision cases.

Structural grafts are commonly used to manage superolateral acetabular defects in the presence of intact anterior and posterior columns. A femoral head or distal femur may be fashioned to make a “number 7” graft. The anteromedial quadrant of a femoral head is removed and the cancellous right angled bone surface so formed is placed over the superolateral acetabular rim such that the remainder of the femoral head is within the acetabulum and the neck is seated against the lateral ilium. The graft is then held in position using 6.5 mm screws with washers through the femoral neck portion of the allograft into the ilium such that they are well away from the acetabulum. The graft within the acetabulum is reamed to a hemispheric surface (Fig. 2).

If an uncemented revision socket is to be utilised, there must be greater than 50% host bone coverage as allograft bone will not reliably grow onto an uncemented socket. If less than 50% host bone coverage is present then a reconstruction ring should be chosen and fixed to the ischium and ilium with multiple screws at which point an all polyethylene cup is cemented into the construct. Postoperatively patients should be touch weight bearing for the first 6 weeks, with a gradual increase to 100% weight bearing by the 3-month mark.

Antiprotrusio rings and reconstruction cages

When inadequate bone stock precludes the use of an uncemented acetabular revision component, two types of implants are available for use. An antiprotrusio ring fits within the acetabulum supported by the intact acetabular rim whereas a reconstruction cage has flanges which can be attached to the ilium superiorly and into the ischium inferiorly, thus spanning the acetabulum. Both of these devices can provide a stable construct into which a polyethylene cup is cemented whilst providing protection and support for morsellised or structural bone graft (Fig. 3).

The antiprotrusio ring is used in smaller defects and has to some extent been supplanted by the use of large uncemented acetabular components. The reconstruction cage is used when defects are much larger, particularly when bone stock is deficient around the rim of the acetabulum. Both types of implants are attached to the acetabulum or pelvis with screws allowing a cemented cup to be inserted in the optimal position. As rings and cages do not incorporate to the host bone they may fail in the longer term. However, this may be an acceptable solution as the bone graft beneath them has usually remodelled by this stage allowing revision into an improved bed compared to the status prior to the previous revision. Rings or cages must be supported either
by host bone ideally or allograft to limit the chance of fatigue failure.

Reconstruction cages are sized with an external diameter equal to the last reamer used on the acetabulum. All bone grafting should be completed prior to insertion of the cage. The inferior flange of the cage can either be laid on the surface of the ischium (in close proximity to the sciatic nerve), or impacted into a groove cut into the ischium (more remote from the nerve).6 The superior flanges are then slid onto and contoured to the ilium and fixed with multiple screws. Screws may also be passed into the ischium through the inferior part of the cage. This results in a construct which is fixed solidly both superiorly and inferiorly and supported on either host bone or allograft throughout.

Trial acetabular liners can be used at this time to provide the surgeon an idea of the leg length, orientation and stability of the hip. An all polyethylene cup is then cemented into the cage in an orientation independent of the cage but aiming for approximately 45° of lateral opening and 15–25° of anteversion. To improve hip stability larger size heads can be used (36 mm) or a captured liner may be required for stability particularly in the presence of weak or absent abductors. Review articles would suggest that there is approximately 75% survivorship at 5–10 years in acetabular revision using reconstruction rings or cages.9

Impaction bone grafting with cemented all polyethylene cups

Impaction bone grafting is a technique which has now been used for more than 25 years with good clinical results.10 The technique involves packing a cavitative defect with cancellous bone graft to create tight solid form which will then support a cemented all polyethylene liner. The technique can also be used for larger segmental defects by contouring malleable metal mesh to reconstruct a rim or wall and thus convert segmental defects into cavitative defects. Primary implants can usually then be used. The technique allows bone stock to be restored which then remodels under load.

Excellent incorporation of these grafts has been demonstrated histologically from biopsy studies thus confirming restoration of bone stock.11 This technique is particularly applicable in young people where restoration of bone stock for future surgeries is desirable. The reconstitution of bone stock may also allow subsequent revision to an uncemented acetabular component in future should revision be required. The technique is not suitable for use in people who have undergone pelvic irradiation as the potential for revascularisation and reincorporation is reduced.

After wide exposure of the acetabulum and removal of any soft tissue or membrane from the bony surface, any areas of eburnated bone are drilled to encourage host bone bleeding. Estimation of the extent and location of bone deficiency is made with a trial acetabular liner. Stainless steel mesh (Acetabular X-change mesh, Stryker-Howmedica, Newbury, England) is then cut and contoured to the desired size and position and held in place with screws. Cancellous bone chips preferably 7–10 mm in diameter are then implanted into this area and impacted vigorously in layers using a series of specialised hemispheric punches which are sized to allow for approximately 3 mm of cement mantle. Cement is then pressurised into this bone surface and a cemented cup is implanted in the appropriate orientation.

Postoperatively, the patients are kept in touch weight bearing for the first 6 weeks then graduating up to full weight bearing by the three month mark with X-rays at both appointments. Survivorship of 78–93% at 20 years has been reported using this acetabular reconstruction technique.10

Bilobed uncemented acetabular components

Isolated superolateral acetabular rim defects with intact anterior and posterior walls can also be treated with a bilobed cup. A bilobed cup is a hemispheric cup with a partial hemispheric extension. A bilobed cup can better match the superolateral acetabular defect and can theoretically conserve the bone that reaming of the anterior and posterior walls to insert a jumbo uncemented acetabular shell would otherwise sacrifice. Similarly, these prostheses may be applicable in primary arthroplasty for arthritis secondary to high dislocation in developmental dysplasia of the hip. The hip centre can then placed in the anatomical position avoiding a high hip centre, in which the superolateral bone defect is filled with the superior lobe of the implant, providing further bone contact. In comparison with a jumbo hemispheric cup, one disadvantage may be that it can be technically more difficult to orientate the version of a bilobed cup thus making stability more difficult to obtain. Nevertheless for selected indications acceptable mid-term results have been demonstrated12,13 (Fig. 4).

Custom-made triflange components

The occurrence of massive pelvic osteolytic defects or pelvic dissociation is relatively rare in revision hip surgery. However, in the face of massive bone loss with or without pelvic discontinuity, a custom-made triflange reconstructive cage is an option for management of these difficult clinical problems.14 In comparison with a standard reconstruction cage, the custom triflange cage has the advantages of fitting the defect exactly, and, due to its specifically manufactured shape, the need for malleable flanges (which are weaker) is
removed thus providing a much more rigid and mechanically stronger construct than a standard cage. In addition it has the potential for osseous integration. The cost of such a customised component is significantly greater (upward of UK£3000) and its use is only indicated where a standard reconstruction cage would be inadequate.¹⁴

If pelvic X-rays (including Judet views) suggest a massive defect or pelvic dissociation, a three-dimensional CT reconstruction of the hemi-pelvis and acetabular defect is performed. Using stereolithography, a hemipelvis matching this is produced from which a clay model component can be made. In consultation with the medical engineer the size and shape of the flanges, the height, abduction angle and version of the component are decided upon by the surgeon and a plastic trial component is manufactured. The flanges are made large enough to allow multiple screw fixation options into both ilium and ischium. This trial can be sterilised and used intraoperatively.

The definitive component is then manufactured usually from titanium and can be coated it with hydroxyapatite to improve the osseous integration potential. After extensile exposure and acetabular preparation, including debride-ment and bone grafting, the ilial flanges are slid up underneath the abductor muscles and then the component is fixed with screws into first the ilium and then the ischium. A trochanteric osteotomy may be valuable to assist exposure, component placement and protect the abductor and superior gluteal neurovascular bundle. As the ischial area is usually the one most commonly associated with loss of fixation, multiple screw holes should be available in this part of the component.

Short-term results reported with the use of these components have been encouraging with 89% survival at 4.5 years in this complicated patient population.¹⁴

Trabecular metal components

Trabecular metal is a relatively new material made of the element tantalum from which acetabular components can be made. Trabecular metal consists of interconnecting pores resulting in a structural biomaterial that is 80% porous, allowing approximately 2–3 times greater bone ingrowth compared to conventional porous coatings. This material has been shown to have a substantially higher coefficient of friction on cancellous bone, when compared to other commonly used prosthetic materials, and a higher bone interface shear strength compared to other fixation surfaces.¹⁵ This metal, due to its reduced stiffness, may also provide a more favourable environment for the remodelling of morsellised or structural bone graft in comparison with other materials (Fig. 5).

Trabecular metal acetabular components come both with modular liners or as revision shells into which a cemented cup is implanted. Our own clinical experience with the trabecular metal at revision surgery is of excellent initial bony stability and scratch fit, even in clinical situations with very limited or poor quality bone stock. Traditionally, the use of an uncemented cup has required greater than 50% of host bone contact. However, some authors have described the use of trabecular metal with less than 50% bone contact and have found that its use has decreased the requirement for the use of reconstruction cages.¹⁵ One recent paper reported the use of a monoblock trabecular shell without screws for 55 of 60 acetabular revisions which would seem perilous with other implants.¹⁶ The porous nature of this material also allows additional screw holes to be burred through a revision component in whatever position is required to gain fixation (Fig. 6).

The trabecular metal revision shell has been used for the technique of the cup-cage construct. In this construct morsellised or structural bone graft can be implanted into
acetabular defects and then a trabecular shell fixed into the defect with multiple screws. To protect the trabecular metal shell until the bone graft has incorporated a reconstruction cage is then inserted into the cup and fixed through the holes in the flanges to the pelvis superiorly and inferiorly. Screws can also be drilled from the cage into the cup itself providing improved strength of construct. A liner is then cemented into the reconstruction cage. In this construct, the reconstruction cage functions to protect the trabecular cup in the short term until cup ingrowth and bone graft incorporation has occurred after which the trabecular cup provides added support for the cage in the longer term, holding promise for greater survivorship.

Cup cage construct for massive pelvic defects

Another recent advance is the development of trabecular metal augments used primarily for superior bone defects where a hemispheric cup will gain less than 50% host bone contact. Early results of this technique appear promising. Trabecular metal augments are available in various sizes and shapes to fill required bone defects. These can be screwed into position independent of the trabecular metal cup and then connected to the trabecular hemispheric cup with a small amount of bone cement at the time of cup impaction (Fig. 7).

Recently, a series of transverse acetabular fractures leading to pelvic discontinuity were reported with the use of trabecular metal shells presenting at an average of 8-month post-revision THA. The authors stated that the acetabular components were all well fixed and thus surmised that this may represent an insufficiency fracture where the trabecular shells gain fixation in acetabuli with

![Figure 6 Trabecular metal revision shell with augment. (Zimmer, Warsaw, IN, USA.)](image)

![Figure 7 Cup cage construct. Massive acetabular defect (left) treated with cancellous bone graft, a trabecular revision shell with a reconstruction cage and cemented polyethylene cup.](image)
less bone stock than previously possible, thus predisposing the acetabulum to later stress fracture.

While no long-term results have been published in the literature, the short term results for trabecular metal technology are encouraging. In the future, the possibility of combining trabecular metal into reconstruction cages may provide both excellent biological fixation with the advantages of a reconstruction cage.

Osteo-inductive materials in acetabular revision

Recent research interest has concentrated on the use of osteo-inductive materials such as osteogenic proteins (OP) or bone morphogenic proteins (BMP) to aid in the healing of bone. Advances in cloning and genetic expression have allowed the production of recombinant human OP-1 in large quantities. OP-1 (BMP-7) has been shown in preclinical canine models, either alone or in combination with autograft or allograft bone, to improve healing in models of both morcellised graft, cortical strut allografts, and acetalular bone defects.

Autologous platelet concentrate, which contains multiple growth factors (PDGF, TGF-β, IGF) has also been shown to be efficacious in reconstructive surgery. It is therefore possible that osteo-inductive proteins could improve the amount of bone ongrowth to components as well as improving the restoration of bone stock.

Currently, these substances are very expensive, and theoretical complications exist with respect to the formation of heterotopic ossification. In addition, some patients may develop antibodies after implantation of OP, and the effect of these antibodies on future bone induction and healing is unknown. Until proper clinical evaluation is performed, these substances should be used with caution. However, they definitely hold promise for the future of reconstructive arthroplasty surgery.

Role of bisphosphonates in managing osteolysis

Particle induced osteolysis, leading to aseptic loosening, is a major problem affecting the long-term survivorship of total joint replacements. Osteoclasts have been implicated in the pathophysiology of particle induced osteolysis. Bisphosphonates have well-described effects on the inhibition of osteoclastic action. In particular the third-generation substances (alendronate) appear to have a more specific action on osteoclasts with limited effects on osteoblasts.

Alendronate has been shown in animal models to inhibit the osteolysis caused by polyethylene wear debris. An increase in bone volume and the reversal of particle induced bone loss has been shown following the administration of alendronate. Similarly, a recent study has shown an improvement in the mechanical stability of bisphosphonate-coated implants inserted into osteoporotic rats. Currently, there are no clinical trials to support this intervention; however, the widespread use of bisphosphonates for the prevention of osteoporosis has demonstrated the safety and efficacy of these medications with few complications. Therefore, a future role for these medica-

Summary and conclusions

Acetabular component revision is a challenging part of revision THA surgery which requires a systematic approach with meticulous pre-operative planning, advanced reconstructive surgical techniques and careful post-operative supervision. Bone defects can be large and often underestimated and thus the revision surgeon must be skilled in bone grafting techniques. The majority of acetabular revisions can be accomplished with uncemented "jumbo" components. Massive defects may require structural allografts, protected by reconstruction cages where less than 50% host bone contact exists. In the future, the use of trabecular metal technology, modular reconstruction rings and cages, coupled with the use of bone induction and osteoclast inhibitor substances, may improve the outcomes and simplify complex acetabular reconstruction problems.

Practice points

- Meticulous pre-operative planning and imaging
- Thorough knowledge of extensive exposure to the hip joint and pelvis
- Inventory to deal with implant removal, manage bone defects, prosthesis re-implantation and other eventualities
- Development of skill with advanced bone grafting techniques
- Careful post-operative care and radiographic evaluation

Future directions

- Use of trabecular metal in reconstruction rings and cages
- Modularity in reconstruction rings and cages
- Locking screw technology in shells of revision acetabular components
- Bone induction substances and HA coating to improve ingrowth
- Bisphosphonate use to limit osteolysis progression

Reference


