ACETABULAR REVISION

The role of cages in the management of severe acetabular bone defects at revision arthroplasty

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The management of massive acetabular bone loss is one of the most challenging aspects of revision total hip arthroplasty (THA).1 Periacetabular bone loss can vary in degree and location and may be complicated by pelvic discontinuity. The outcome of the procedure is greatly affected by the extent of the associated acetabular bone loss. Several reconstruction options are available: the choice of which to use depends on the pattern of bone loss.2 An uncemented, hemispherical acetabular component secured with multiple screws and used in conjunction with morsellised allograft bone to fill any defects is the most commonly used technique and gives excellent long-term results.3,4 However, there are situations in which the acetabulum is so deficient that even a highly porous hemispherical component combined with metal augments or structural bone graft cannot provide sufficient mechanical stability when placed in the correct anatomical location. In these cases, there has been a growing interest in the use of reconstruction cages, mainly because of the encouraging midterm results of cup-cage reconstruction.5–7 The traditional indication for a reconstruction cage has been to protect major column structural allografts (Gross classification Type IV, Table I).8–10 Although structural allografts can restore deficient bone stock to a degree, their use has been declining because of the potential for allograft resorption and the technical complexity of the procedure.11 Nonetheless, structural allografts need to be considered for younger patients in whom further revisions are considered likely. Porous metal augments allow direct bone ingrowth and can be used as a substitute for structural allograft (Gross classification Type III and Type IV, Table I).12 Similarly, the larger column metal augments may need to be protected by a reconstruction cage. The presence of chronic pelvic discontinuity has resulted in poor outcomes from acetabular revision (Gross classification Type V, Table I).13 Cup-cage reconstruction addresses the need for biological ingrowth and mechanical stability required for the healing of a pelvic discontinuity.

Surgical technique of cage implantation

The basic principles of cage implantation are similar whether using a reconstruction cage with structural allograft, large metal augments or a cup-cage reconstruction (Fig. 1).14 An extensive surgical approach (i.e. a modified trochanteric
slide or extended trochanteric osteotomy) is often needed to expose the ischium, ilium and both columns without putting the superior gluteal and sciatic nerves at risk. After exposing the ischium, a small hole is drilled in a posterior-inferior direction and a depth gauge used to confirm its conformation. The depth gauge should advance at least 2.5 cm and have a solid endpoint. A small osteotome is impacted into the ischium to create a slot for the inferior flange of the cage and the ilium is exposed to allow fitting of the superior flange. The correct size of the flange and the degree of contouring needed are determined using cage trials. Usually, the inferior flange needs to be bent to accommodate the curve of the ischium and the superior flange needs to be bent towards the ilium to maximise the contact area. The definitive cage is slotted into the ischium and then impacted into the acetabulum. The superior flange is fixed to the ilium with at least three screws. It is imperative to use liner trials to determine the optimal orientation of the cup both for stability of the hip joint and to avoid possible neck impingement against the edge of the cage. The final liner usually needs to be cemented in a more horizontal and antverted orientation than the cage.

**Major column structural allografts and reconstructive cages**

Restoration of bone stock is one of the main goals when revising a deficient acetabulum, particularly in younger patients. Although true remodelling of structural allografts is controversial, it has been shown that the use of structural allograft usually restores or at least maintains the peri- acetabular bone stock and simplifies further revisions. In a recent study of 50 patients who underwent revision using minor or major column allograft, the bone stock in the subsequent revision had been restored in 31 patients, remained unchanged in ten and deteriorated in nine. In the revision, a hemispherical component could be used in a third of the patients without any allograft bone, metal augment, cage or ring. Structural allografts protected by a cage can also restore the centre of rotation to its correct anatomical position, thereby optimising the biomechanics of the reconstructed hip and maximising the strength of the abductor mechanism.

Uncontained defects of more than 50% of the acetabulum (major column defect, Gross classification Type IV, Table I) usually involve the dome and posterior column. If structural allograft is used, it needs to be offloaded with a reconstruction cage to prevent fracture and collapse of the graft. This clinical observation has been supported by finite element analysis which shows that the reconstruction cage reduces the stresses acting on the acetabulum by more than one half. Usually, allograft acetabular bone is used as a graft and shaped to fit the defect. The articular cartilage is reamed off the allograft leaving the subchondral bone intact. The major column graft is fixed with two 6.5 mm cancellous screws directed superiorly into the host bone: a reconstruction cage is implanted to protect it. (Figs 1 and 2).
The long-term results of using a major column structural allograft and protecting it with a reconstruction cage have been acceptable.\(^8,9\) Recently, Regis et al\(^{21}\) reported a survivorship of 72.2\% with a mean follow-up of 13.5 years (10.5 to 16.6) and Ilyas et al\(^{22}\) a survivorship of 84.9\% with a mean follow-up of 6.71 years (2 to 13.9). Overall, the results of using an acetabular cage to support the reconstruction of a massive acetabular bone defect with a major column structural graft are reasonable, although the technique is often considered to be a salvage procedure. The disadvantages of this technique are that the construct does not provide permanent biological fixation: the flanges will loosen or fracture with time if there is inadequate support from the host bone and allograft.\(^{23}\) There are also concerns about allograft resorption and infection. The availability and versatility of metal augments have reduced the use of structural allografts, although these should continue to be considered for patients in whom further revision is considered likely based on age and demand.

**Metal augments and reconstructive cages**

Over the last decade, the use of structural allografts in revision hip surgery has been decreasing. This is attributed to the midterm failure of the reconstruction because of an absence of true biological fixation and incorporation of the allograft.\(^8,9\) Consequently, alternative techniques using devices such as porous metal augments have been preferred. Currently, tantalum (trabecular metal) is the most commonly used material.\(^{12}\) It has a high volumetric porosity, a low modulus of elasticity and a high coefficient of friction. Experimental studies have shown rapid ingrowth of bone into its porous structure.\(^{24}\) The obvious benefits of a porous metal augment are the direct ingrowth of host bone, impossibility of resorption, avoidance of disease transmission, and easy availability.

The use of trabecular metal augments in conjunction with a trabecular metal shell has given excellent short- and mid-term results. Acetabular component survivorship of 91\% to 100\% has been reported with a follow-up of up to nine years using loosening as an endpoint.\(^{25-32}\) Survivorship of the tantalum augments has been even higher, as in some cases the augment has become solidly osseointegrated, despite loosening of the acetabular component. Interestingly, tantalum as a material seems to have the ability to resist the development of deep infection better than titanium.\(^{33}\) Metal augments must be implanted against bleeding host bone and secured with screws to allow ingrowth to occur. If implantation of a hemispherical acetabular component proves to be impossible because of limited contact with bleeding host bone, these large metal augments need to be protected with an acetabular cage in the same way as a major column structural allograft. The disadvantages of metal augments are that they do not restore bone stock and may produce debris by fretting if there is loosening of a cage or hemispherical acetabular component.

We have used the cage-augment technique in patients where cup-cage reconstruction has not been possible because there was insufficient bleeding host bone to stabilise a highly porous acetabular component but enough to stabilise an augment (major column defect, Gross classification Type IV, Table I). In this situation, the augment acts like a major column allograft and has to be protected with a cage (Fig. 3). At a minimum two-year follow-up of 16 patients (18 hips) with a maximum follow-up of four years, only one patient has undergone revision for loosening of the cage. In this challenging group of patients, other complications were relatively common: these consisted of one deep infection treated by irrigation and debridement, one dislocation treated by stem revision, one sciatic nerve injury, and one radiologically loose cage in a patient with minimal symptoms.

**Cup-cage reconstruction**

Chronic pelvic discontinuity is defined as a complete separation of the superior pelvis from the inferior pelvis through the acet-
Although the diagnosis of discontinuity is established intra-operatively, radiographs may show a visible fracture line through the anterior and posterior columns or medial translation and rotation of the inferior hemipelvis in relation to the superior hemipelvis. It has inherently poor healing potential and needs both a biological stimulus and mechanical stability to do so. Morsellised or structural allograft with posterior column plating, or a reconstruction cage have been associated with a failure rate of up to 50%. Cup-cage reconstruction addresses the requirements for healing by providing the mechanical stability to allow biological ingrowth to occur over a large porous surface, thereby bridging the inferior and superior hemipelvis. Although the technique has been mainly used to treat pelvic discontinuity, it can be used in patients with global bone loss without discontinuity when the porous acetabular component acts like a structural allograft.

In cup-cage reconstruction, the deficient acetabulum is packed with morsellised allograft bone. A highly porous hemispherical trabecular metal component oversized by 2 mm is impacted against bleeding host bone and secured with multiple screws which bridge the discontinuity (Fig. 4). The acetabular component is offloaded using a titanium cage which spans ischium to ilium and allows biological ingrowth and stabilisation of the hemispherical shell. A polyethylene liner is cemented inside the cage in the desired position. The cage usually guides the centre of rotation into the correct anatomical position if the inferior flange can be secured to the ischium. The titanium cage used in cup-cage reconstruction is more malleable than a conventional rigid cage and should not be used in isolation. Once ingrowth has occurred into the trabecular metal, the stress on the malleable cage is relieved.

The cup-cage reconstruction has been shown to outperform structural allografts and rigid cages in cases of pelvic discontinuity. Recently, Amenabar et al reported the results of 67 cup-cage reconstructions with a mean follow-up of 74 months (24 to 135). The bone defects were classified as Gross type IV in 39% of the patients and Gross type V in 61%. The five and ten-year survivorship figures...
were 93% and 85%, respectively when failure was defined as revision for any cause. Initially, four patients showed radiological signs of migration of the ischial flange of the cage, but the constructs stabilised with time, suggesting ingrowth into the hemispherical acetabular component. Other complications included deep infection in three patients, dislocation in three and sciatic nerve injury in two patients.

The excellent long-term results of uncemented hemispherical acetabular components in revision THA have changed the indications for cage reconstruction of the acetabulum. There has also been a significant reduction in the use of massive structural allografts which have generally been replaced by porous metal augments. However, little is known about the long-term consequences of augments and their impact on subsequent revision. Currently, cages are used to reconstruct the most deficient acetabula which have global bone loss preventing adequate rim fit for a hemispherical component. Major structural column allografts which are used to reconstruct an uncontained defect involving more than half the acetabulum should be protected with an acetabular cage to prevent graft collapse. Cup-cage reconstruction is an efficient technique and addresses the prerequisites of biology and stability to allow healing of chronic pelvic discontinuity. Recently, porous metal augmentations have been used in conjunction with acetabular cages to address segmental bone defects as an alternative to structural allografts. Reconstruction cages still have a definite role to play in the management of complex acetabular revision with severe bone loss.

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T. J. Mäkinen: Data collection, Data analysis, Writing the paper.
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D. P. R. T. Kuzyk: Performed the surgeries.
A. E. Gross: Data analysis, Performed the surgeries, Writing the paper.

References