Acetabular Impaction Grafting in Total Hip Replacement

Michael Rigby[1], Paddy J Kenny[2], Rob Sharp[3], Sarah L Whitehouse[4], Graham A Gie[5], A John Timperley[5]

1. Great Western Hospital, Swindon, UK
2. Cappagh Hospital, Dublin, Eire
3. North Shore Hospital, Auckland, New Zealand
4. Orthopaedic Research Unit, Institute of Health and Biomedical Innovation, Queensland University of Technology, The Prince Charles Hospital, Brisbane, Queensland, Australia
5. Exeter Hip Unit, Princess Elizabeth Orthopaedic Centre, Exeter, UK

Princess Elizabeth Orthopaedic Centre, Royal Devon & Exeter Hospital, Barrack Rd., Exeter, Devon, EX2 5DW UK

Corresponding Author:	AJ Timperley
email:	jtimperley@mac.com
Tel:	+44 (0)1392 406132
Fax:	+44(0)1392 403505

Running head: Acetabular Impaction Grafting in THR

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Abstract (242/250 words)

Background and purpose: Acetabular impaction grafting has been shown to have excellent results, but concerns regarding its suitability for larger defects have been highlighted. We report the use of this technique in a large cohort of patients with the aim of better understanding the limitations of the technique.

Methods: We investigated a consecutive group of 339 cases of impaction grafting of the cup with morcellised impacted allograft bone for survivorship and mechanisms for early failure.

Results: Kaplan Meier survival was 89.1% (95% CI 83.2 to 95.0%) at 5.8 years for revision for any reason, and 91.6% (95% CI 85.9 to 97.3%) for revision for aseptic loosening of the cup. Of the 15 cases revised for aseptic cup loosening, nine were large rim mesh reconstructions, two were fractured Kerboull-Postel plates, two were migrating cages, one medial wall mesh failure and one impaction alone failed.

Interpretation: In our series, results were disappointing where a large rim mesh or significant reconstruction was required. In light of these results, our technique has changed in that we now use predominantly larger chips of purely cancellous bone, 8-10 mm^3 in size, to fill the cavity and larger diameter cups to better fill the mouth of the reconstructed acetabulum. In addition we now make greater use of i) implants made of a highly porous in-growth surface to constrain allograft chips and ii) bulk allografts combined with cages and morcellised chips in cases with very large segmental and cavitary defects.

Keywords: cup, survivorship, morcellised impacted allograft

Introduction

The technique of impaction grafting in the socket was popularised by the Nijmegen group in a series of primary patients with acetabular protrusion (1) and revision cases (2). Ten year survival analysis of the cup with revision for any reason was 93% and 96% for aseptic loosening. Other authors have confirmed excellent results using impacted allograft in revision surgery in the shorter term (3-5). More recently, however, van Haaren (6) has drawn attention to a higher rate of failure in larger acetabular defects. The early series reported by the Nijmegen group did not contain large numbers of patients with significant segmental acetabular defects. The indications for the technique and the limitations for its use are not yet clear. Additionally, the most appropriate methods of reconstruction and use of hardware to reconstruct significant segmental defects have not yet been defined.

At our institution we have been using impaction in the socket since the late 1980s. The technique described by Slooff (1) was modified in order to use morcellised allograft material in the presence of significant segmental defects of the socket. Medial and lateral stainless steel meshes specifically designed to reconstruct segmental loss of bone became available in 1995. In a further extension of the original technique, acetabular rings and plates have been used in conjunction with impacted allograft bone where it was felt that a single mesh or indeed several meshes would give inadequate support or constraint to impacted allograft in the deficient acetabulum.

We report our use of impacted allograft in the acetabulum with these techniques. Our aim was to have a better understanding of the limitations of the technique with the various forms of reconstruction and the surgical factors important in determining an advantageous outcome.

Materials and Methods

A consecutive group of patients who underwent surgery using morcellised impacted allograft bone in the cup at our institution from July 1995 to July 1999 were reviewed in this prospective cohort study until the end of 2005.

Clinical data was collected prospectively including Charnley category (7), modified Charnley and D'Aubigne scores (7), Oxford hip scores (8) (0-48 worst to best scale as recommended by Murray (9)) and Harris pain and function scores (10). Pre and post-operative scores were recorded.

A total of 339 patients with impacted acetabular allograft were identified. The majority of patients were having their first revision (202), 46 patients the second, 9 the third and 4 patients the fourth. Forty four patients were undergoing a primary arthroplasty and there were 34 second-stage revisions for infection. The average age at surgery was 71 (range 23 – 96) with 218 (64%) females and 121 males. The average length of follow-up was 6.1 years (range 4.3 – 8.4 years) and no patient has been lost to follow up. There were 101 Charnley category A patients, 154 category B and 82 category C (unrecorded in 2 patients). This is a multi-surgeon series with 217 cases performed by consultants, 119 by fellows and 3 by specialist registrars.

The operative findings and reconstruction methods along with details of the graft preparation and sterilization methods were documented.

In cases with only a cavitary defect or where meshes were used to re-create the acetabulum (Figure 1), the impaction technique was standardised. The largest hemispherical X-Change packer (Stryker Orthopedics, Mahwah, NJ) that comfortably fitted into the mouth of the reconstructed socket rim was chosen for final packing. Morcellised graft was then placed in the socket and impacted firmly with multiple blows (milled bone chips were used in this series and were 3-4 mm^3 in size. We have since reverted to preparing all bone chips by hand, aiming for cancellous morsels, predominantly 8-10 mm^3 in size). Initially smaller diameter packers were used to ensure all areas of the cavity and cysts were soundly packed. Graft was repeatedly introduced into the socket until the largest packer would just fit flush within the mouth of the socket. Peripheral rim packers were then used to ensure the bone surrounding the edge of the packer was as tight as possible. The cavity achieved using this technique should be solid (Figure 2) and the surface should resist any further attempts to deform it; it should feel like cortical bone. The prepared surface was then washed with high pressure lavage through a sieve to prevent disruption of the graft. After drying with hydrogen peroxide swabs, cement (Antibiotic Simplex with Colistin and Erythromycin) was pressurised into the graft with the Exeter acetabular pressuriser (Stryker Orthopedics, Mahwah, NJ). The acetabular component was then inserted into the pre-rehearsed position of inclination and anteversion. There were 209 Exeter Contemporary cups, 125 Ogee, 3 Muller and 2 McKee Arden cups used.

Figure 1: A packer is held with its inferior edge at the level of the transverse ligament illustrating a large supero-lateral defect of the acetabular rim (a) and a large rim mesh screwed onto the pelvis to create a contained defect (b):

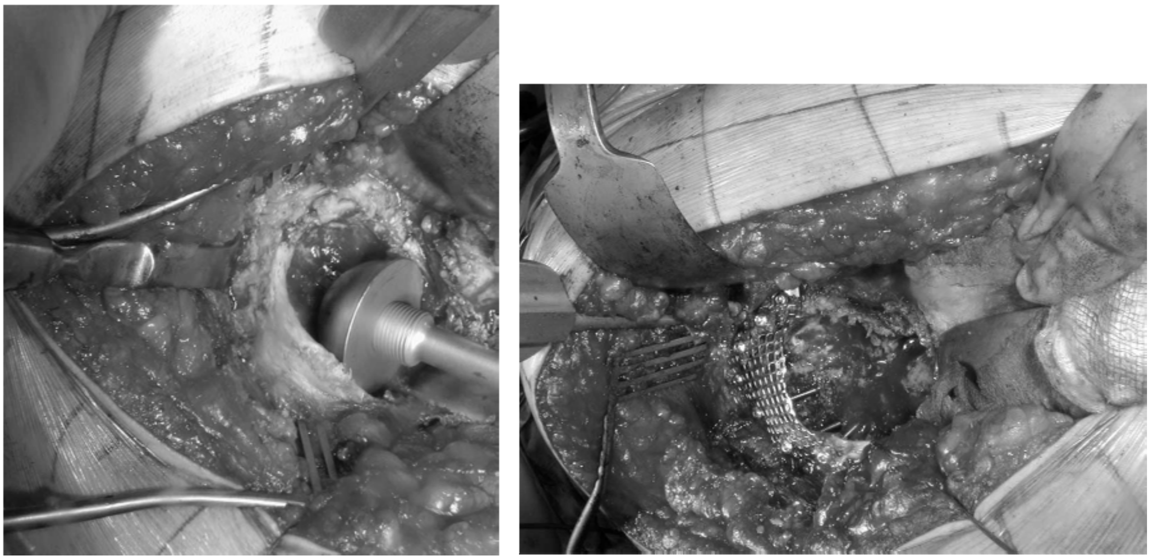


Figure 2: The impacted washed graft surface prior to application of cement:

Where a plate or cage was used, this metalwork was introduced onto a bed of impacted graft. With the Burch-Schneider reinforcement cage (Sulzer Medica, Swizerland), the inferior flange was usually introduced into a prepared slot in the ischium. The inferior hook of the Kerboull-Postel (K-P) plate was held under the teardrop. With both devices the supero-lateral flanges were applied to the iliac bone with several screws. If the cage was not supported by host bone at its dome then block allograft was used to support the metalwork. Cement was then introduced into the prepared cavity, pressurised and a polyethylene socket inserted.

Pre-operative radiographs were digitized and assessed (MR, AJT). The bony defect was classified using the Paprosky classification (11) (Table I), however some of the primary arthroplasty patients cannot be classified using this system and have been recorded as either ‘dysplastic’ or ‘protrusio’. Reconstruction methods are also summarised in Table I. The vast majority of patients required some form of metallic reconstruction of the socket.

Table I: Paprosky classification / acetabular defect and reconstruction methods used.

Paprosky grade	Impaction only	Medial mesh	Rim mesh	Rim and medial mesh	K-P plate	Reinforcemt ring/cage	TOTAL
1	5		5				10
2A	39	15	11	2	4		71
2B	16	6	55	2	9	2	90
2C	12	10	7	4	10	1	44
3A	4	5	24	5	17		55
3B	3	9	12	6	11	7	48
Discontinuity		1			1	1	3
Protrusio	9	2			1	1	13
Dysplasia	1		4				5
TOTAL	89	48	118	19	53	12	**339**

Post-operative radiographs were evaluated using a computerized Orthographics programme (Orthochart™, Ortho-Graphics Inc., 807 E S Temple, Suite 100, Salt Lake City, UT84102). The immediate post-operative films, 2-year and most recent films were scaled and analysed. Acetabular component position and abduction angle were measured and migration and change in angulation calculated. The inclination was measured from both the inter-teardrop line and inferior obturator foramen line. Graft thickness was measured in DeLee-Charnley zones 1, 2 and 3 (12) using digital analysis of the scaled images.

Survivorship analysis was performed using the Kaplan Meier method (13) to produce survival curves and 95% confidence intervals with both re-operation for aseptic loosening and re-operation for all reasons as the endpoints, with at least 40 cases remaining at risk (14, 15). No cases were lost to follow-up and so construction of a worst case curve (16) was not necessary. Cox proportional hazards regression analysis was also used (17) to determine if the method of graft sterilisation (fresh, pastuerised, irradiated or mix), reconstruction method (contained, uncontained or supplemental fixation), graft shape (chips, milled, chips and milled or chips and artificial/block), surgeon grade, gender or age at surgery significantly influenced failure (defined as revision for any reason – aseptic loosening, dislocation or infection). Paprosky classification could not be included in the model due the highly skewed nature of the data. Frequencies were compared using the chi-squared test or Fisher's Exact test where appropriate. Means and ranges are provided. Changes in clinical scores were examined using the Wilcoxon test for non-parametric data. Statistical analysis was performed using SPSS version 16.0 (SPSS Inc, Chicago, Il).

Results

In the 339 patients there were three peri-operative deaths – (myocardial infarction, stroke, pulmonary embolism). There have been 88 deaths to date in the group. There were six nerve injuries, two femoral and four sciatic - all but two have fully recovered. Deep infection was identified in 15 patients. Eight of these were new infections (8/305, 2.6%) and seven were recurrent infection after a two-stage revision (7/34, 20.6%). Dislocation occurred in 13 patients (3.8%) and four of these became recurrent, two requiring revision (Table II).

Table II: Complications and re-operations.

Complication	**Details**
3 peri-operative deaths	1 myocardial infarction 1 stroke 1 PE
6 nerve injuries	3 femoral 4 sciatic
15 deep infections	8 new 7 recurrent
13 dislocations	4 recurrent (2 required revision) 9 single
Re-operations (32)	**Details**
7 infection	
15 aseptic cup loosening	9/60 large rim mesh 2/53 K-P plates 1/48 medial wall mesh gave way 1/89 impaction failed
2 dislocation	
8 femoral revision	6 prosthetic fracture 1 loosening 1 wire removal

There have been 32 re-operations in total. Seven of these were for infection, and 15 for aseptic loosening (ACL) of the acetabular component (15/339 – 4.4%). Two were revised for dislocation and a further eight for femoral revision (six for prosthetic fractures, one loosening and one trochanteric wire removal). The overall survivorship at 5.8 years (with 40 cases remaining at risk) with cup revision for any reason (aseptic loosening, infection or dislocation) as the endpoint was 89.1% (95% CI 83.2 to 95.0%) (Figure 3). Cox regression analysis indicated that age at operation significantly influenced failure (p=0.013). Reconstruction method, surgeon grade, method of graft sterilisation and graft shape were not significant in the model (Table III).

Figure 3: Kaplan Meier survivorship curves.

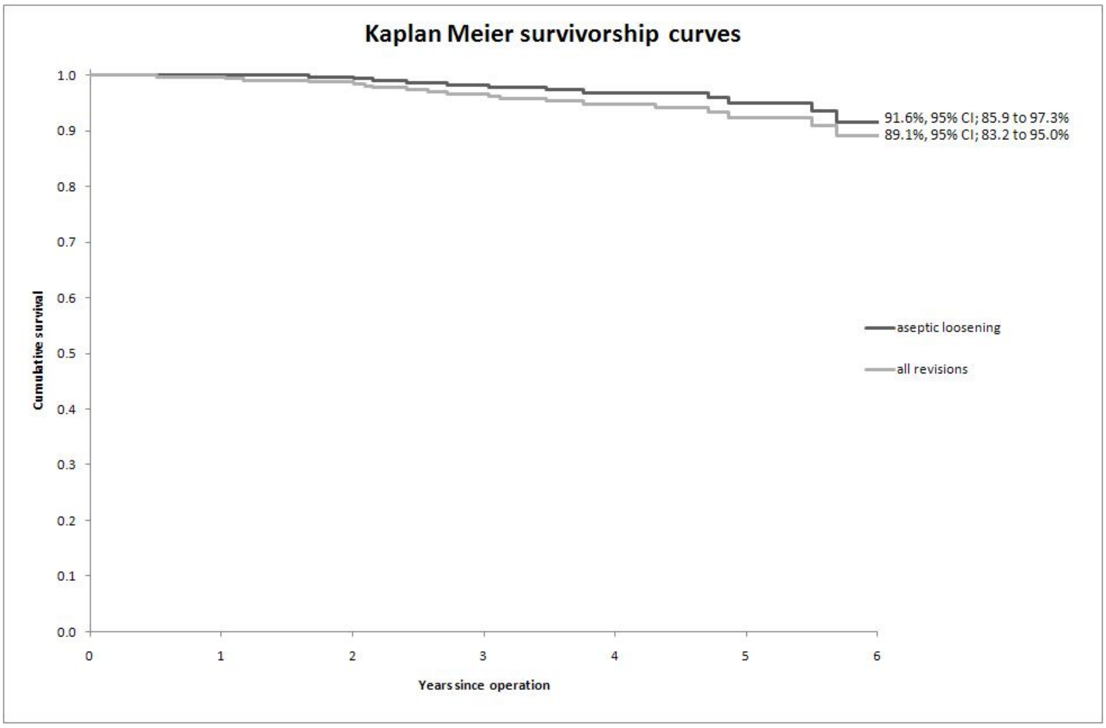
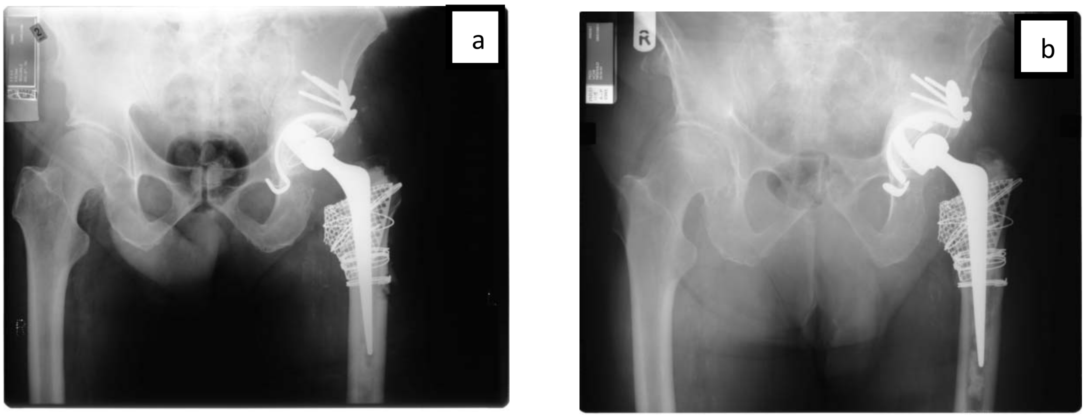


Table III: Odds ratios for failure for any reason and 95% confidence intervals for Cox regression.

Variable	**p-value**	**Odds ratio (95% confidence interval)**
Graft sterilisation method (overall)	0.93	
(pastuerised cf fresh)	0.66	1.29 (0.41 to 4.07)
irradiated cf fresh	0.98	0.0
mix cf fresh	0.50	1.52 (0.45 to 5.19)
Reconstruction method (overall)	0.14	
uncontained cf contained	0.05	9.42 (1.02 to 86.8)
supplementary fx cf contained	0.77	7.59 (0.81 to 71.6)
Graft shape (overall)	0.89	
milled cf chips	0.57	0.55 (0.07 to 4.47)
milled/chips cf chips	0.67	1.34 (0.36 to 5.06)
milled/chips/artificial/block cf chips	0.88	1.18 (0.15 to 9.31)
Grade of surgeon (Fellow/Specialist Registrar cf Consultant)	0.12	2.25 (0.81 to 6.25)
Gender (female cf male)	0.59	1.36 (0.45 to 4.09)
Age at op (odds ratio is increase in hazard ratio for each increasing year of age at op)	0.013*	0.96 (0.93 to 0.99)

Of the 15 revisions for aseptic loosening, there were nine of the 60 large rim mesh reconstructions (9/60 – 15%). Two of 53 Kerboull-Postel plates fractured (2/53 – 3.8%) (Figure 4) and allowed migration of the implant, two out of 12 cages migrated (2/12 – 16.7%), one of 48 medial wall meshes gave way (1/48 – 2.1%) and one impaction alone failed (1/89 – 0.01%). These cases were all revised. The overall survivorship for revision of socket for aseptic loosening at 5.8 years was 91.6% (95% CI 85.9 to 97.3%) (Figure 3).

Figure 4: Post-op (a) and 7 year (b) x-rays showing fractured Kerboull-Postel plate:



The average abduction angle was 43.5° (range 21 – 66°) and average migration was 1.8mm (0 – 4mm). Average angulation was 0.5° (0 – 4 °). The mean graft thickness was 1.6cm (range 0.4-6cm) in zone 1, 1.2cm (range 0.3-4.4cm) in zone 2 and 0.9cm (range 0.3-5cm) in zone 3.

Eight Kerboull-Postel plates have fractured (total number fractured 10/53 – 18.8%) but not been revised. Six of these migrated to a position of stability after the fracture occurred, and are giving no further cause for concern. The remaining two continue to migrate but as yet pain and function remain at a tolerable level and the patients do not need intervention. Eight large rim mesh reconstructions have migrated significantly (total number 17/60 – 28.3%). Four continue to migrate.

Charnley and D'Aubigne pain, function and range of movement scores all significantly improved, as did the Oxford and Harris hip scores (Table IV).

Table IV: Clinical scores with Wilcoxon p-values.

Charnley D'Aubigne	Pre-op	Latest FU	p-value
Pain (0-6 worst to best)	2.5	5.4	<0.001
Function (0-6 worst to best)	1.9	3.7	<0.001
ROM (0-6 worst to best)	3.9	5.4	<0.001
Oxford & Harris Hip Scores			
Oxford (0-48 worst to best)	42.1	24.7	<0.001
HHS – Pain (0-44 worst to best)	17.1	35.8	<0.001
HHS – Function (0-47 worst to best)	17.2	28.4	<0.001

The majority of operations were carried out using 100% fresh-frozen (134), pasteurised (80) or irradiated (40) graft. However in many cases different types of graft material were mixed together in different combinations. It is difficult therefore to prove the efficacy of these combinations or the influence on failure. Pasteurised bone fared worse with seven revisions for aseptic loosening. (7/80 cases with pasteurised bone – 8.8%). Fresh bone proved best with only four revisions for aseptic loosening (4/134 cases – 2.9%). Although this was not statistically significant (p=0.06), there is a clear trend (Table V).

Table V: Bone Graft Failures ACL (failures/total - %).

Pasteurised	7 (7/80 – 8.8%)
Fresh	4 (4/134 – 3.0%)
Fresh/Artificial	1 (1/9 – 11.1%)
Fresh/Pasteurised	2 (2/19 - 10.5%)
Unknown	1 (1/31 – 3.2%)

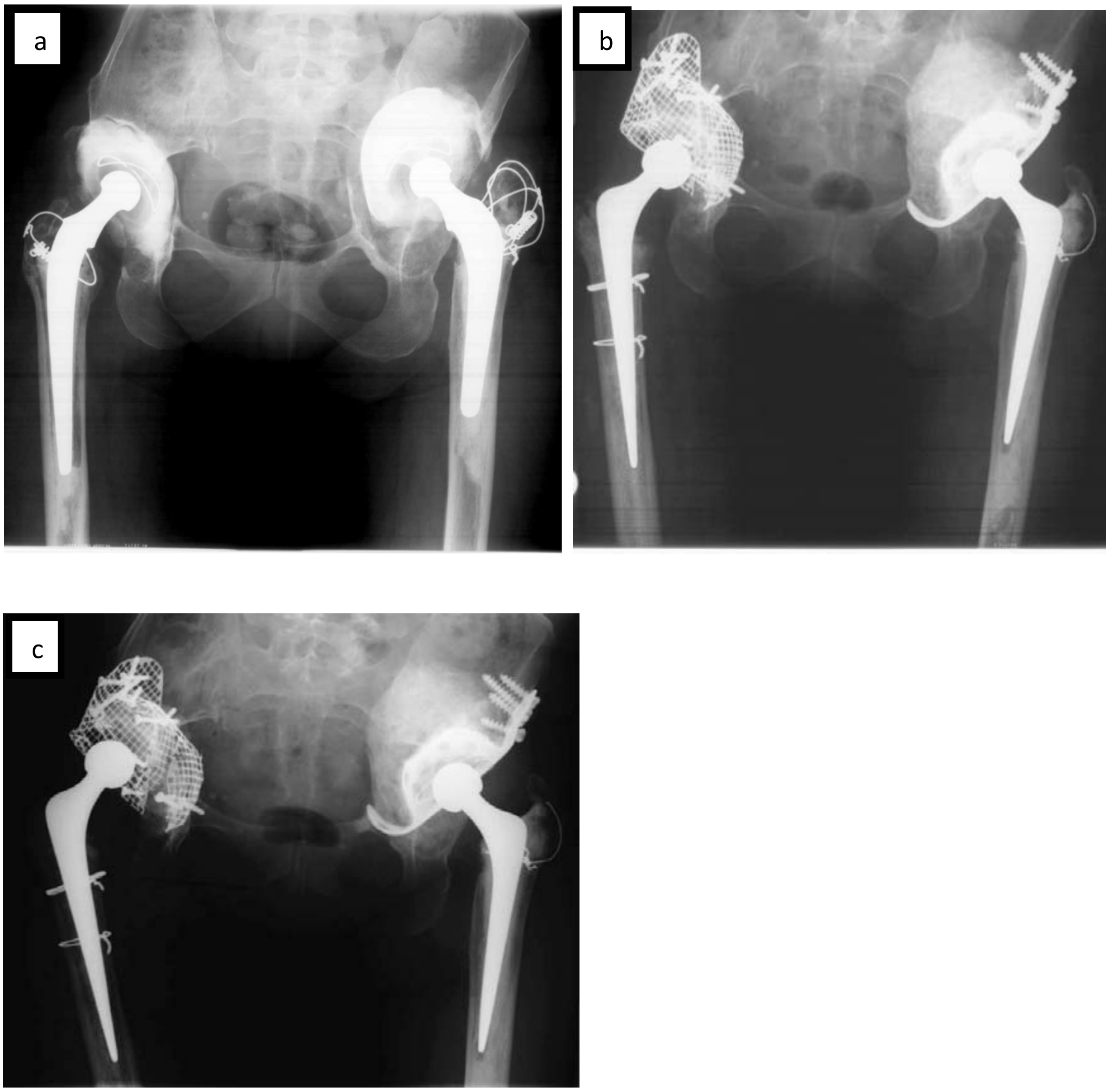
Discussion

The short to medium term results of using impacted allograft bone in the acetabulum in revision surgery in conjunction with a cemented cup have generally been good (3, 4). However, these series had few cases with severe segmental defects requiring reconstruction with mesh or block allograft prior to impaction. In a series reported by Garcia-Cimbrelo the survivorship for aseptic loosening of 70 acetabular revisions with Paprosky grade 3A or 3B defects at 5-9 year follow-up was 98%, with only one cup being revised for this indication (18). van Haaren (6) has shown a high rate of re-revision in AAOS type III or IV bone defects. The overall survivorship replanted in a series of 71 revisions was 72% at 7.2 years. Although the number of AAOS type III and IV defects was not significantly higher in the failed group (chi-squared test, p=0.19), there was a trend towards failure being associated with more severe defects. They concluded that in revisions with large bony deficiencies or pelvic discontinuity, the impaction grating technique carries with it a high risk of complications.

In our series, results were poorer with the larger defects and this was independent of the method of reconstruction.

Our results when a large rim mesh was used to repair a large segmental defect are disappointing. Nine of the 60 (15%) cases where a large rim mesh was used had been revised for aseptic loosening (Figure 5). The mechanism of failure of these cups was movement and rotation of the cup/cement composite within the graft followed, eventually, by the mesh being pulled off the reconstructed rim. Failure of the metalwork did not initiate the rotation and migration process. Our technique has since changed in that we now using predominantly larger chips to fill the cavity and larger diameter cups are now implanted, better filling the mouth of the reconstructed acetabulum. It is hoped, but not proven, that better initial stability of the cemented socket will reduce the incidence of significant migration of the cup and failure by cleavage within the graft material. With this aim, highly porous in-growth shapes are sometimes used against host bone, partially filling large defects.

Figure 5: Pre-operative x-ray (a) of bilateral failed sockets, each with massive cavitary and segmental bone stock loss. The right hip has been repaired with multiple meshes (b). In the left hip a cage has been used in combination with impacted allograft. The meshes have failed by 5 years (c) - the cage construct on the right has not moved and there is no evidence of resorption of the graft



First reported results with the use of the Kerboull acetabular re-enforcement device were encouraging (19) and other authors have reported their experience with this device (20, 21). Kawanabe reported their results with the use of morcellised and bulk graft. Graft in morcellised form fared less well and survivorship for clinical or radiological failure was 53% at ten years in this group compared with 82% when a structural graft was used to support the plate. In our series, ten of the 53 Kerboull plates fractured (19%). Two were revised and two showed a continuing pattern of painless migration. In six others the migration halted and the surrounding graft appeared satisfactory having presumably incorporated as it became stressed by the plate (Figure 4). We now believe that this design of plate should only be used with allograft chips when it is certain that the dome is supported by host bone or structural allograft.

Regis (22) reports 87.5% survivorship of Burch-Schneider cages at 11.7 years when used with supporting bulk allograft. Other authors have stressed the importance of using cages to protect structural allograft from collapse (23-25). They make the case that the cages off-load stress to the host bone of the pelvis. We believe there is a place for these cages in severe defects (Figure 5), but as with the Kerboull plates, they should be supported by direct contact with host bone or structural graft. The cage should not be suspended on a bed of cancellous bone and a few transverse screws, as any significant migration will inevitably lead to screw fracture. One could hypothesise that the inevitable stress-shielding behind the cages will delay graft incorporation and therefore increase the risk of early migration and failure of fixation. However, we support the use of impacted morcellised graft as a filler around the structural allograft and medially, where others have also found evidence that morcellised graft incorporates and remodels (26). The longer-term results of using these cages are uncertain but of significant interest since the limitation of these devices is that they are mechanically but not biologically fixed to the pelvis. They could survive in the longer term provided there is incorporation of, and therefore ultimately support from, the morcellised graft around the construct.

It has been shown that successful graft incorporation is essential for survival of the construct (6). Results and histology when fresh-frozen allograft has been used is widely reported in the literature and this material remains the “gold standard” when compared with treated bone or bone graft substitutes. However, in some regions fresh-frozen allograft heads are not available from local tissue banks or a decision has been taken to treat the bone in some way to reduce the risk of contamination of the graft or disease transmission. This is a cause for concern since the best published results have been with untreated graft and is a cause for much debate (27-30).

Thermal disinfection of bone has been advocated by some to reduce the risk of transmission of viral disease (31). The Marburg ‘Lobator sd-2’ system has been proven to be effective in inactivating viruses (32) and was used in our unit throughout the period under investigation although we have since reverted to using untreated fresh-frozen material.

Although our material of choice is fresh-frozen morcellised femoral heads we were not able to use this exclusively. As described we did use irradiated and pasteurised bone in some cases and in many there was a mixture of materials. Several types of man-made bone graft extender (tricalcium phosphate and hydroxyapatite) were also used in combination with other graft. The numbers did not allow meaningful statistical comparison of the type of graft used. It remains our policy to use washed, fresh-frozen femoral heads provided in compliance with European directives for banked bone.

RSA studies have shown that almost all impacted sockets migrate in the post-operative period although the rate of migration decreases with time. In one study 41% of sockets were still found to be migrating 18-24 months after surgery (33). The median migration was 2.5mm; range 0.2-8.1 mm. Restricted weight-bearing had no influence on the degree of subsidence.

There is no doubt that the best results will follow compaction of large allograft chips into a well-prepared and reconstructed acetabulum. In a synthetic model Arts (34) proved that from a mechanical standpoint, large bone allograft chips that had been washed prior to impaction are superior to small chips to obtain optimal cup stability using the impaction grafting technique. In practical terms, after final impaction the stability of the graft should be such that the impacted bed of allograft feels like cortical bone. The reversed reaming technique of slurry grafts cannot be recommended for bone grafting of acetabular defects (35). In another laboratory model the initial stability of cups reconstructed with slurry grafts and reversed reaming was significantly less than those carried out using the original impaction technique and relatively large-sized bone chips.

It is very difficult to assess the viability of grafted bone from plain radiographs, especially in the socket where the 3-D skeletal structure disguises the appearance of any orbicular remodelling that may be present. Histological studies in the socket humans have shown that the graft incorporates over a very long period and even in the long-term there may be incomplete incorporation of impacted allograft in to host bone (36, 37). It is quite probable that in some areas the impacted material may remain as a stable, low modulus layer.

The poorer results when a large rim mesh was used in this series have lead us to consider the use of i) implants made of a highly porous in-growth surface to constrain allograft chips and ii) bulk allografts combined with cages and morcellised chips. We believe these techniques should be considered in conjunction with impaction grafting in cases where a combined segmental and cavitary defect is too large or too complex to be reconstructed comfortably with a large rim mesh.

In summary, we report an overall survival rate for aseptic loosening of 91.6% at 5.8 years when impacted allograft chips are used in the reconstruction of deficient acetabular. Results were poorer in situations where a large segmental defect was reconstructed with a large rim mesh and where reconstruction rings were suspended within impacted chips unsupported at their dome by host bone or structural graft.

It is certain that there is a place for impaction grafting of the socket in the armamentarium of any revision hip surgeon. The unique advantage of this method of reconstruction is that if a further operation is required then there is almost always more living bone present as a result of healing of allograft bone to help with further reconstruction of the socket. In addition, the method of reconstruction almost always allows the surgeon to bring the centre of rotation back down to the anatomical position thus allowing more accurate recreation of the host biomechanics than is usually possible with other forms of acetabular reconstruction.

References

1. Slooff TJ, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Scand* 1984;55:593-6.
2. Schreurs BW, Luttjeboer J, Thien TM, de Waal Malefijt MC, Buma P, Veth RP, Slooff TJ. Acetabular revision with impacted morselized cancellous bone graft and a cemented cup in patients with rheumatoid arthritis. A concise follow-up, at eight to nineteen years, of a previous report. *J Bone Joint Surg [Am]* 2009;91:646-51.
3. Wang JW, Fong CY, Su YS, Yu HN. Acetabular revision with morsellised allogenic bone graft and a cemented metal-backed component. *J Bone Joint Surg [Br]* 2006;88:586-91.
4. Comba F, Buttaro M, Pusso R, Piccaluga F. Acetabular reconstruction with impacted bone allografts and cemented acetabular components: a 2- to 13-year follow-up study of 142 aseptic revisions. *J Bone Joint Surg [Br]* 2006;88:865-9.
5. Comba F, Buttaro M, Pusso R, Piccaluga F. Acetabular revision surgery with impacted bone allografts and cemented cups in patients younger than 55 years. *Int Orthop* 2009;33:611-6.
6. van Haaren EH, Heyligers IC, Alexander FG, Wuisman PI. High rate of failure of impaction grafting in large acetabular defects. *J Bone Joint Surg [Br]* 2007;89:296-300.
7. Charnley J. Numerical Grading of Clinical Results. In: Charnley J, ed. *Low Friction Arthroplasty of the Hip - Theory and Practice*. Berlin, Heidleberg, New York: Springer-Verlag; 1979:20-4.
8. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg [Br]* 1996;78:185-90.
9. Murray DW, Fitzpatrick R, Rogers K, Pandit H, Beard DJ, Carr AJ, Dawson J. The use of the Oxford hip and knee scores. *J Bone Joint Surg [Br]* 2007;89:1010-4.

10. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg [Am]* 1969;51:737-55.
11. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. *J Arthroplasty* 1994;9:33-44.
12. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976:20-32.
13. Kaplan EL, Meier P. Non-parametric estimation from incomplete observations. *J Am Stat Assoc* 1958;53:457-81.
14. Lettin AW, Ware HS, Morris RW. Survivorship analysis and confidence intervals. An assessment with reference to the Stanmore total knee replacement. *J Bone Joint Surg [Br]* 1991;73:729-31.
15. Bland M. *An introduction to medical statistics.* Oxford ; New York: Oxford University Press; 1995.
16. Murray DW, Carr AJ, Bulstrode C. Survival analysis of joint replacements. *J Bone Joint Surg [Br]* 1993;75:697-704.
17. Cox DR. Regression Models and Life-Tables. *J R Stat Soc Series B Stat Methodol* 1972;34:187-220.
18. Garcia-Cimbrelo E, Cordero J. Impacted morsellised allograft and cemented cup in acetabular revision surgery: a five to nine year follow-up study. *Hip International* 2002;12:281-8.
19. Kerboull M, Hamadouche M, Kerboull L. The Kerboull acetabular reinforcement device in major acetabular reconstructions. *Clin Orthop Relat Res* 2000:155-68.
20. Kawanabe K, Akiyama H, Onishi E, Nakamura T. Revision total hip replacement using the Kerboull acetabular reinforcement device with morsellised or bulk graft: results at a mean follow-up of 8.7 years. *J Bone Joint Surg [Br]* 2007;89:26-31.

21. Tanaka C, Shikata J, Ikenaga M, Takahashi M. Acetabular reconstruction using a Kerboull-type acetabular reinforcement device and hydroxyapatite granules: a 3- to 8-year follow-up study. *J Arthroplasty* 2003;18:719-25.

22. Regis D, Magnan B, Sandri A, Bartolozzi P. Long-term results of anti-protrusion cage and massive allografts for the management of periprosthetic acetabular bone loss. *J Arthroplasty* 2008;23:826-32.

23. Garbuz D, Morsi E, Gross AE. Revision of the acetabular component of a total hip arthroplasty with a massive structural allograft. Study with a minimum five-year follow-up. *J Bone Joint Surg [Am]* 1996;78:693-7.

24. Saleh KJ, Jaroszynski G, Woodgate I, Saleh L, Gross AE. Revision total hip arthroplasty with the use of structural acetabular allograft and reconstruction ring: a case series with a 10-year average follow-up. *J Arthroplasty* 2000;15:951-8.

25. van der Linde M, Tonino A. Acetabular revision with impacted grafting and a reinforcement ring: 42 patients followed for a mean of 10 years. *Acta Orthop Scand* 2001;72:221-7.

26. Peters CL, Curtain M, Samuelson KM. Acetabular revision with the Burch-Schnieder antiprotrusio cage and cancellous allograft bone. *J Arthroplasty* 1995;10:307-12.

27. Costain DJ, Crawford RW. Fresh-frozen vs. irradiated allograft bone in orthopaedic reconstructive surgery. *Injury* 2009;40:1260-4.

28. Buckley SC, Stockley I, Hamer AJ, Kerry RM. Irradiated allograft bone for acetabular revision surgery. Results at a mean of five years. *J Bone Joint Surg [Br]* 2005;87:310-3.

29. Robinson DE, Lee MB, Smith EJ, Learmonth ID. Femoral impaction grafting in revision hip arthroplasty with irradiated bone. *J Arthroplasty* 2002;17:834-40.

30. Deakin DE, Bannister GC. Graft incorporation after acetabular and femoral impaction grafting with washed irradiated allograft and autologous marrow. *J Arthroplasty* 2007;22:89-94.

31. von Garrel T, Knaepler H, Gurtler L. [Inactivation of HIV-1 in human femur heads using a heat disinfection system (Lobator SD-1)]. *Unfallchirurg* 1997;100:375-81.

32. Pruss A, Kao M, von Garrel T, Frommelt L, Gurtler L, Benedix F, Pauli G. Virus inactivation in bone tissue transplants (femoral heads) by moist heat with the 'Marburg bone bank system'. *Biologicals* 2003;31:75-82.

33. Ornstein E, Franzen H, Johnsson R, Stefansdottir A, Sundberg M, Tagil M. Hip revision with impacted morselized allografts: unrestricted weight-bearing and restricted weight-bearing have similar effect on migration. A radiostereometry analysis. *Arch Orthop Trauma Surg* 2003;123:261-7.

34. Arts JJ, Verdonschot N, Buma P, Schreurs BW. Larger bone graft size and washing of bone grafts prior to impaction enhances the initial stability of cemented cups: experiments using a synthetic acetabular model. *Acta Orthop* 2006;77:227-33.

35. Bolder SB, Verdonschot N, Schreurs BW. Technical factors affecting cup stability in bone impaction grafting. *Proc Inst Mech Eng [H]* 2007;221:81-6.

36. Heekin RD, Engh CA, Vinh T. Morselized allograft in acetabular reconstruction. A postmortem retrieval analysis. *Clin Orthop Relat Res* 1995:184-90.

37. Schreurs BW, Gardeniers JW, Slooff TJ. Acetabular reconstruction with bone impaction grafting: 20 years of experience. *Instr Course Lect* 2001;50:221-8.

Legends

Table I: Paprosky classification / acetabular defect and reconstruction methods used.

Table II: Complications and re-operations.

Table III: Odds ratios for failure for any reason and 95% confidence intervals for Cox regression.

Table IV: Clinical scores with Wilcoxon p-values.

Table V: Bone Graft Failures ACL (failures/total - %).

Figure 1a: A packer is held with its inferior edge at the level of the transverse ligament illustrating a large supero-lateral defect of the acetabular rim.

Figure 1b: A large rim mesh screwed onto the pelvis to create a contained defect.

Figure 2: The impacted washed graft surface prior to application of cement.

Figure 3: Kaplan Meier survivorship curves.

Figure 4: Post-op (a) and 7 year (b) x-rays showing fractured Kerboull-Postel plate:

Figure 5a: Pre-operative x-ray of bilateral failed sockets, each with massive cavitary and segmental bone stock loss.

Figure 5b: The right hip has been repaired with multiple meshes. In the left hip a cage has been used in combination with impacted allograft.

Figure 5c: The meshes have failed by 5 years. The cage construct on the right has not moved and there is no evidence of resorption of the graft.