Gilbody, Julian, Taylor, Clare, Bartlett, Gavin, Whitehouse, Sarah, Hubble, Matthew, Timperley, A. John, Howell, Jonathon, & Wilson, Matthew
(2014)
Clinical and radiographic outcomes of acetabular impaction grafting without cage reinforcement for revision hip replacement: a minimum ten-year follow-up study.
Bone and Joint Journal, *96-B*(2), pp. 188-194.

https://doi.org/10.1302/0301-620X.96B2.32121

Clinical and radiographic outcomes of acetabular impaction grafting without cage reinforcement for revision hip arthroplasty. A minimum 10-year follow-up study.

Julian Gilbody MSc FRCS (Tr&Orth)[1]

Clare Taylor MRCS[1]

Gavin E Bartlett MD FRCS (Tr&Orth)[2]

Sarah L Whitehouse PhD[3]

Matthew JW Hubble FRCS (Tr&Orth)[1]

A John Timperley FRCS DPhil[1]

Jonathan R Howell MSc FRCS (Tr&Orth)[1]

Matthew J Wilson FRCS (Tr&Orth)[1]

1. Princess Elizabeth Orthopaedic Centre, Royal Devon and Exeter Hospital, Exeter, UK
2. Trauma & Orthopaedic Department, Royal Cornwall Hospital, Truro, UK
3. Orthopaedic Research Unit, Institute of Health and Biomedical Innovation, Queensland University of Technology, The Prince Charles Hospital, Chermside, Queensland, Australia

Corresponding author: MJ Wilson
Princess Elizabeth Orthopaedic Centre
Royal Devon and Exeter Hospital
Barrack Road, Exeter, EX2 5DW, UK.
Tel: 01392 403588
Fax: 01392 403505
Email: matthewwilson@nhs.net

Abstract

Impaction bone grafting for reconstitution of bone stock in revision hip surgery has been used for nearly 30 years. We used this technique, in combination with a cemented acetabular component, in the acetabula of 304 hips in 292 patients revised for aseptic loosening between 1995 and 2001. The only additional supports used were stainless steel meshes placed against the medial wall or laterally around the acetabular rim to contain the graft. All Paprosky grades of defect were included. Clinical and radiographic outcomes were collected in surviving patients at a minimum of 10 years following the index operation. Mean follow-up was 12.4 years (SD 1.5; range 10.0-16.0). Kaplan-Meier survivorship with revision for aseptic loosening as the endpoint was 85.9% (95% CI 81.0 to 90.8%) at 13.5 years. Clinical scores for pain relief remained satisfactory, and there was no difference in clinical scores between cups that appeared stable and those that appeared loose radiographically.

Key words: Bone grafting; joint revision; arthroplasty; replacement; hip

Running title: Acetabular impaction grafting 10-year results

Introduction

The use of impacted, morcellised bone allograft for the reconstruction of cavitary and segmental bony defects in revision hip surgery has been employed for nearly 30 years. It relies on the successful vascularisation and incorporation by creeping substitution of cancellous bone chips,[1] whose initial mechanical stability is achieved with the use of retaining meshes and firm impaction to achieve a substratum similar to that of normal bone. Early results from the Nijmegen centre showed the technique to be successful in small series of patients,[2] and it was adopted in our institution in the mid-1980s following collaboration with the Nijmegen group.[3] In 1995, medial and lateral stainless steel meshes became available which were specifically designed for the reconstruction of segmental defects. Schreurs et al have reported survivorship of 75% at 20 years; subsequent series from other centres have shown impaction bone grafting to have survivorship of between 72 and 90% at 5-8 years.[4-6] However these are generally small series or have only a few years of follow-up and the results are conflicting. Alternative techniques in revision cases have used uncemented implants, including more recently trabecular metal implants.[7,8] However these techniques do not allow for restoration of bone stock in the same way as impaction grafting with a cemented socket. We now have a substantial series of patients who have more than ten years follow-up since their index operation with impaction grafting and a cemented socket, and the aim of this study is to determine survivorship and clinical and radiographic outcomes for this large group of patients in the longer term.

Methods

This is a consecutive series comprising 304 hips in 292 patients who underwent acetabular impaction grafting (AIG) with a cemented cup, for revision of an acetabular component which had failed due to aseptic loosening, at our institution between 1st October 1995 and 31st December 2001. No cases were excluded. The detailed surgical technique has been described previously by Rigby et al[9]. All grafts were secured with impaction alone or in combination with reconstruction of segmental defects using mesh and screws (X-change, Stryker Orthopedics, Mahwah, NJ). Cases involving the use of uncemented acetular components, support rings or cages to augment cup fixation to host bone were not included in this series.

All of the cups implanted were cemented cups. There were 186 Exeter Concentric cups, 75 Ogee, 39 Exeter Contemporary, 3 McKee-Arden and 1 Muller. There were 204 cases where Simplex P was used, 99 with Simplex RO and 1 with CMW cement. Of the 304 revision cases, 286 (94.1%) underwent both stem and socket revision. All stems that were not revised remained well fixed.

Bone allograft from donated femoral heads was prepared by removing all cartilage and soft tissue before being morcellised with rongeurs or a bone mill (Noviomagus Bone Mill, Spierings Medische Techniek, Nijmegen, Netherlands). In 128 cases the bone was prepared by hand with rongeurs alone, in 69 cases by mill and hand and in 101 by bone mill alone. In one case bone chips were mixed with artificial graft expander. The preparation technique was not recorded in five cases. The different graft preparation techniques represent an evolution of the technique rather than active choice in which methods were most appropriate, as techniques changed from chips to milled or a mixture of both over time.

Allograft storage techniques changed over the course of the cohort. From 1995 until 1998 the graft was pasteurised (57 cases); during 1998 it was sterilised by irradiation (29 cases) whilst a fresh-frozen bone bank was set up; subsequently, retrieved femoral heads were fresh-frozen (144 cases). In 48 cases a mixture of techniques was used. The preservation technique was not recorded for 26 cases.

Clinical scores were collected prospectively comprising the Oxford Hip Score[10] (OHS) from December 1996 when it became included as a routine measure (and hence is missing for the first 40 cases), transformed to the 0 (worst) to 48 (best) scale as recommended by Murray et al[11]; the Harris Hip Score[12] (HHS), subdivided into pain and function scales; and the Charnley modification of the Merle d'Aubigne and Postel score[13] (CS) which gives separate scores for pain, function and range of motion. Plain radiographs (AP pelvis and lateral of operated hip) were also obtained where possible. When the patient's general health prevented them from attending out-patient clinics, clinical scores were obtained by postal questionnaire or telephone. In these patients, the Range of Motion section of the CS, which requires examination by a physician, was omitted and treated as a missing value. This was the case for 38 patients. The deformity and range of motion sections of the HHS were not recorded for any patient.

In addition to basic demographics (patient age and gender), data were collected on factors considered to be possibly implicated in graft failure: number of previous operations, grade of lead surgeon, use of mesh and its position, graft thickness, Paprosky grade[14] of acetabular defect, graft preparation (rongeurs, bone mill or both) and graft preservation technique (fresh frozen, pasteurised, irradiated or a mixture). Radiographic assessment was performed on all surviving cups, comparing the immediate post-operative radiographs with the most recent. The radiographs were either plain films that had been digitised using a scanner (Vidar Systems Corp, Diagnostic Proadvantage) or stored in an original digital format (Webpacs, GE Centricity). The radiographs were analysed using Orthoview™ software

(Meridian Technique Ltd., Southampton, Hampshire). Accurate scaling was performed using the femoral head as a marker. The anatomical reference points used were the teardrops; if these could not be identified the infero-lateral margins of the obturator foramina were used. The cup inclination angle was measured from a horizontal line drawn between these points, and horizontal and vertical displacement of the cup was measured from a vertical reference line drawn perpendicular to the horizontal at the reference points to the centre of the cups. The cup centre was used rather than the centre of the femoral head as the latter could be affected by polyethylene wear over the time period of the series, possibly more than 2mm over ten years.[15] Cup inclination and displacement measured in this way have previously been used by other groups for measuring migration of sockets following AIG, with a cut-off of more than 5° change in cup inclination angle or more than 5mm change in cup position in the vertical and horizontal planes taken to indicate cup migration.[4,16,17] Demarcation at the cement-bone interface was graded using a modification of the criteria previously published by Hodgkinson et al[18] (Table 1).

The cut-offs of 5° change in cup inclination angle and 5mm displacement would appear to be reasonable parameters for a retrospective review of plain radiographs where changes in hip position between consecutive images, variability in quality of radiographs (e.g. exposure, centring) and difficulty in defining precise anatomical landmarks could not be controlled. In order to assess the reproducibility of our measurement technique, two of the assessors (MJW and GEB) independently measured 19 randomly selected radiographs, and then repeated the measurements two days later, so that intraclass correlation coefficients (ICCs) could be calculated for inter- and intra-observor error. Both showed high levels of agreement with ICCs of 0.9. The cut-off thresholds used were not informed by reliability assessment, but rather from previous publications in this area,[4,16,17] although a recent paper by Del Gaizo et al used more generous limits.[19]

Assessment was also made of whether the position of the pelvis was the same on each radiograph. Loss of the lumbar lordosis can occur with ageing;[20] causing the pelvis to flex and may contribute to an apparent change in cup position. Using these assessment criteria, the surviving cups were classified as stable, probably stable, probably unstable and definitely unstable (Table 2).

In addition, an assessment of graft thickness was made on the immediate post-operative film for all patients where possible. The measurement was made at the mid-point of each of the three zones described by DeLee and Charnley[21] and averaged to give a single measurement. Radiographic measurements were made by four assessors (JG, GEB, MJW and CT).

Kaplan-Meier survivorship curves[22] (with 95% confidence intervals) were calculated using the endpoints of revision for any cause and revision for aseptic loosening. Cox proportional hazards regression analysis,[23] using the forward conditional method of variable entry, was performed to determine if any of the factors considered to be implicated in graft failure significantly influenced rates of revision. Statistical analysis was performed using SPSS for Windows version 18.0 (SPSS Inc, IBM Corporation, New York).

Results

Between October 1995 and December 2001, 304 hips in 292 patients underwent acetabular revision according to the criteria described above. There were 107 male and 185 female patients, with 12 bilateral procedures (none simultaneously). The average age at time of surgery was 70.3 (range 34-95) years. There were 181 operations performed on patients aged 70 years or over at the time of surgery. It was the first revision procedure in 237 cases, the second in 60, third in four cases and the fourth in three cases. Consultant surgeons performed 189 of the procedures with the remaining 115 by fellows and trainees.

Patients were reviewed at a mean of 12.4 years (SD 1.5; range 10.0-16.0). At the time of review, 123 patients (128 cups) had not required revision for any reason, and had completed some form of follow-up (clinical, radiographic or both). One patient had revision of a well-fixed cup to a constrained cup, using an in-cement technique[24] at the time of revision of a femoral component, and was censored at the date of this revision for the purposes of survivorship analysis. One hundred and thirty patients (136 cups) had died without requiring revision of their acetabular components – of these, there were 84 completed Oxford and Harris Hip scores available for analysis and 98 Charnley scores and mean time to death was 6.7 years (range 0-15.1 years). Thirty-six patients (37 cups) have had their cups revised: 33 for aseptic loosening at mean 6.4 years (range 0.2-14.7 years); 3 for dislocation (mean 6.0 years, range 1.9-13.1 years) and 1 for infection at 10.1 years. Two patients (2 cups) were lost to follow-up despite extensive efforts to locate them, having last been seen at 4.6 and 11.8 years. Paprosky grades for all patients are shown in Table 3, along with revisions for aseptic loosening according to Paprosky grade.

Complications

There were three (1%) peri-operative deaths; one pulmonary embolism, one cerebrovascular accident and one myocardial infarction. There were two (0.7%) cases of deep vein thrombosis. There was one (0.3%) femoral nerve palsy, which fully recovered, and two (0.7%) sciatic nerve palsies, one of which recovered fully and one partially. Two (0.7%) patients developed post-operative haematomas. There were three (1%) trochanteric fractures, one (0.3%) calcar fracture, four (1.3%) femoral shaft fractures and four (1.3%) femoral perforations intra-operatively, all but one of which were identified and managed during the index operation; the exception was a femoral perforation which was identified post-operatively and re-operated on five days after the initial operation. The femoral perforations were all in patients undergoing simultaneous revision of the femoral component. There was one (0.3%) case of pelvic penetration in which the medial wall gave way during impaction. This was managed with placement of a large medial mesh and further impaction grafting. Only one (0.3%) patient developed heterotopic ossification. There were ten (3.3%) cases of dislocation, of which six were managed non-operatively; three were managed with revision of the acetabular component, and one with insertion of a posterior lip augmentation device. One patient (0.3%) developed a deep infection, which was managed with a revision ten years after the index operation. The overall complication rate was 11.5%. In addition, seven patients sustained late femoral peri-prosthetic fractures; three of these were managed with stem revisions, two with internal fixation and two were successfully managed non-operatively.

Clinical outcomes

The pre-operative and latest clinical outcome scores for the entire series are shown in Table 4. This includes the most recent scores for all survivors, and the last scores collected pre-mortem on those who died without revision. The time interval at which these post-operative outcomes were collected ranges from 3 months to 16 years. Patients were also classified according to Charnley's categories for quality of walking.[25] Pre-operatively, the number of patients who were classified as category A (unilateral hip disease) was 83 (27%), category B (bilateral hip disease) 135 (44%) and category C (hip disease plus other comorbidity limiting ambulation) 82 (27%), with four not recorded. At last follow-up, these numbers were 33 (11%), 92 (30%) and 110 (36%); in addition 69 (23%) were not recorded.

Clinical outcome scores are also presented according to degree of bone loss, expressed as the Paprosky grade, in Table 5; for this and subsequent outcomes analyses (Tables 5 to 8) only the results on surviving patients have been used. This comprises 128 patients and the time interval for these ranges from 10 years 4 months to 16 years.

Survivorship

Kaplan-Meier survivorship curves were calculated with a minimum of 40 cases remaining at risk[26] at 13.5 years (Figure 1). Survivorship with revision for aseptic loosening as the endpoint was 85.9% (95% confidence interval (CI) 81.0 to 90.8%). Survivorship with revision for any reason as the endpoint was 82.8% (95% CI 76.9 to 88.7%); taking the worst-case scenario, with revision for any cause and including the two patients lost to follow-up, survivorship was 81.6% (95% CI 75.5 to 87.7%).

Cox regression analysis

Unfortunately, the number of cases with missing data for graft thickness limited the inclusion of a significant number of cases. So as not to introduce unnecessary bias to the model, and after confirmation that it did not influence the survival model (p=0.43), the model was formed without this variable. Owing to incomplete data, the number of events (revision for any reason) in our model was 36, with 30 missing values (where one or more variables were missing). The only factor found to be significantly associated with revision was the use of mesh – the use of any kind of mesh other than medial mesh significantly influenced the model (Table 6). This model remained constant when the variable with the next highest number of missing values (sterilisation method) was also omitted, confirming the validity of the model. Variables not significant in the model were age (p=0.165), gender (p=0.077), number of previous surgeries (p=0.900), surgeon grade (p=0.108), Paprosky grade (p=0.219), graft preparation method (p=0.136) and sterilisation method (p=0.169). Hazard ratios (HR), 95% confidence intervals (CI) and significance are shown in Table 5. Inclusion of cup type and cement used also did not influence the model (p=0.560 and p=0.909 respectively).

Radiographic assessment

Of the surviving 128 patients who had at least ten years of follow-up, three did not have an immediate post-operative and subsequent film available for comparison. This was either because the original films had been destroyed prior to being digitised or the patient had not attended for radiographic review following discharge from hospital, but had been able to complete the questionnaires necessary for the clinical review. Of the remaining 125 patients, 33 were unable to complete radiographic evaluation at the same time as their clinical evaluation, so their last available films were used for measurement. In these patients the radiographic follow-up ranged from 2.5–9.9 (mean 7.4) years. Seventy-seven had cups which appeared stable according to the criteria described above on the most recent available radiograph, 20 had cups which were probably stable, 13 had cups which were probably unstable and 15 had cups which were definitely unstable. Clinical outcome scores for each of the groups are shown in Table 7. Radiographic outcomes according to bone loss, expressed as Paprosky grade, are shown in Table 8.

Discussion

This series shows that after a minimum of ten years, for cases initially revised for aseptic loosening, the overall incidence of revision in our series was 12.2 %. The overall complication rate was 11.5%, including a peri-operative mortality rate of 1%, which compares favourably to other published data on complications following revision hip arthroplasty.[27,28] It is perhaps notable that there was only case of heterotopic ossification (HO) in this series. We do not routinely give prophylaxis for HO unless the patient has a prior history of this problem. Our standard DVT prophylaxis is a six week course of 150mg O.D. of aspirin and this may go some way to explain the low rate of HO in this series.

Although many of the patients in the series had died, there were only three deaths which occurred in the peri-operative period and the mortality rate is most probably a reflection of the age and morbidity of the majority of patients at the time of surgery.[29] Of the surviving cups, 22.4% were judged probably or definitely unstable using our radiographic criteria, but the clinical results of these patients were very similar to the patients whose cups were probably or definitely stable. It may be that after initial migration, these cups settle into a stable position and do not cause symptoms, or may simply reflect a group of patients with very low functional demands, or both. The most recent post-operative clinical scores shows that most patients experienced good pain relief and range of motion but poor function; however, the increase in the proportion of patients in Charnley category C suggests that factors other than hip pathology contributed to lower post-operative functional scores.

Multiple radiographic parameters were used in this study to try to improve the accuracy of the assessment; however any assessment in such a series is difficult because of metalwork obscuring anatomical features (as previously noted[4]), obliteration of landmarks by osteolysis and/or surgery, inconsistent radiographic quality and changes in pelvic position between films. Demarcation is an inconsistent sign, even after primary arthroplasty,[30] and graft resorption following impaction bone grafting is also difficult to assess.[4] Consequently there is no consistently reliable method for retrospectively assessing subtle changes in cup position, osteolysis or graft resorption following impaction bone grafting. Even to assess it prospectively using Roentgen Stereophotogrammetric Analysis (RSA) techniques would be difficult as the metal marker beads used in this technique may be obscured by metalwork. As is always the case, correlation of radiographic findings with clinical assessment of the patient is paramount in deciding whether the operation has succeeded or failed, and it is the practice in our unit to simply observe, albeit more frequently than usual, patients whose cups appear to be migrating but who maintain good clinical function.

The Cox regression analysis in our study shows that the use of any mesh other than medial mesh was associated with an increased risk of revision. Bone allograft is incorporated into the host skeleton by a process of creeping substitution[1,3] and until this process has been completed the integrity of the graft is dependent on the inherent mechanical stability of the impacted chips. For this reason it is recommended to use washed bone chips at least $1cm^3$ in size and hemispherical acetabular impactors to create a graft bed with the consistency of cortical bone.[3,9,27] This bed is contained by the remaining viable host bone, augmented where necessary by flexible meshes attached with multiple screws. An explanation for the findings of the Cox regression analysis may be that where the defect is particularly large, these thin meshes are not adequate to provide the initial support necessary until graft incorporation has been achieved. The results of the regression analysis suggest that this technique is particularly suited to type 1, type 2A and 2C defects, where bone loss is either minimal or medial. However, the proportion of grade 2b deficiencies revised for aseptic loosening is about the same as grade 2a and 2b (Table 3). Therefore this technique appears to work well for grade 1 and all grade 2 deficiencies. Grade 3 deficiencies, of course, involve considerable bone loss and are very challenging to treat by any method.

In Garcia-Cimbrelo's paper looking at impaction bone grafting and cemented cups,[4] 4 out of 94 (4.1%) grade 3A sockets and 7 out of 83 (8.4%) grade 3B sockets were re-revised for aseptic loosening. During the time period this study covers, the principal alternative to impaction bone grafting for replacement of bone stock was bulk allograft. Morsi et al[31] reported survivorship of 86% at a mean follow-up of 7.1 years in a series of 29 patients, but Sporer at al[32] reported a 78% survival for revision due to aseptic loosening in their series of 23 grade 3A acetabula at 10 years. Lewallen's group[33] reported an overall survival rate at 15 years of 69% with acetabular revisions using uncemented acetabular components, with uniform fall-off in results in to the second decade. They also report a positive correlation between bone loss and implant failure. More recently, Del Gaizo et al have shown very low rates of aseptic loosening using tantalum augments in a series of 37 hips with a mean follow-up of five years, only one of which required revision for aseptic loosening.[19] One significant modification of the practice in our unit in recent years has been the increased use of Trabecular Metal™ augments (Zimmer, Warsaw, IN) to fill large voids and rim defects, rather than relying solely on allograft impacted onto mesh; these have shown very promising early results.[34]

This is the largest series of medium- to long-term results of revision of acetabular components using impaction bone grafting with a cemented cup currently in the literature. Most series reported on using this technique give short-term results for small series of patients. Schreurs et al[35] reported survivorship of 75% at 20 years with revision for any cause as the endpoint in a small series of 62 hips. In that series, 39 of the acetabular bone deficiencies were cavitary and the remaining 23 were combined cavitary and segmental deficiencies. Comba et al[36] reported a survival rate of 98% at a mean 51.7 months in 131 patients using revision for aseptic loosening as the endpoint. Buckley et al[5] reported survival of 88.7% at a mean of 5 years in a series of 123 acetabular revisions using irradiated allograft bone. Garcia-Cimbrelo et al[4] reported their use of the technique on a series of 208 hips in 188 patients with Paprosky type 3 defects and reported survivorship rates of 83.9% for type 3A defects and 81.6% for type 3B defects at eight years. In contrast, van Haaren et al[6] reported 72% survival at a mean of 7.2 years, using revision for aseptic loosening as the endpoint in their series of 71 revisions. Schreurs speculated that this may be attributable to the use of very small milled bone chips in that series.[35] Our series adds to this growing body of evidence that impaction bone grafting is a viable and durable option for restoring lost bone stock when total hip replacements require revision for aseptic loosening, with acceptable rates of long-term survivorship particularly for grade 1 and 2 deficiencies. Although the results of our regression analysis do not demonstrate an association between the use of bone mills to prepare the graft and aseptic loosening, we support the use of graft preparation by rongeurs to produce allograft chips as detailed above. We also favour the fresh frozen method of graft storage as being most likely to preserve the integrity of the bony architecture, and thereby provide the best environment for graft support, neovascularization and creeping substitution. We have confirmed that during the period covered by this study, impaction bone grafting was the best available method for treating grade 3 deficiencies, but in the future trabecular metal implants may well prove to be superior.

This is a retrospective review using prospectively collected data. As with many retrospective series, the biggest failing of this study is the number of missing values. Our unit has always been rigorous in prospective data collection but it is perhaps inevitable that outcome scores will never be 100% complete, either because forms are not distributed or collected or more often because patients decline to complete them. Radiographs are lost or destroyed. A retrospective review, even when the data have been collected prospectively, is a less powerful research tool as the data are not being collected with a view to achieving a primary outcome measure. Also, a prospective study design would have precluded some of the heterogeneity in our methodology, such as the use of different methods in graft preparation. Other sources of heterogeneity were a consequence of new technology becoming available, such as the change in different graft storage methods. However, we hope that with such a large series, the results that are available are representative of the population as a whole.

Conclusion

This retrospective review of prospectively collected data shows good long-term results for impaction bone grafting in combination with cemented sockets for acetabular deficiencies in revision hip surgery, with survivorship of 86% for aseptic loosening at 13.5 years and satisfactory clinical outcomes. The findings of this paper suggest that larger Paprosky grade 3 defects may be better managed with alternative techniques including the use of uncemented implants. However, for Paprosky grade 1 and 2 defects, we believe that impaction grafting with a cemented socket allows for restoration of anatomy and bone stock and should be considered the gold standard.

Tables

Table 1: Grading of demarcation at bone-cement interface

Grade 0	No demarcation
Grade 1	Demarcation in one zone only
Grade 2	Demarcation in two zones
Grade 3	Demarcation in all three zones
Grade 4	Socket migration

Table 2: Classification of radiographic cup stability

Stable	No radiographic failure on any parameters
Probably stable	Exceeds 5°/ 5mm criteria but 0/1 on demarcation grading AND pelvic flexion; within 5°/ 5mm criteria but grade 2 on demarcation WITHOUT pelvic flexion
Probably unstable	Exceeds 5°/ 5mm criteria with no flexion OR exceeds 5°/ 5mm criteria plus grade 2/3 with flexion
Definitely unstable	Grade 4

Table 3: Paprosky classification of acetabular defect

Grade	1	2a	2b	2c	3a	3b
N (%)	7 (2)	82 (27)	93 (31)	49 (16)	49 (16)	24 (8)
Revision for aseptic loosening (% for that grade)	0 (0)	6 (7.3)	5 (5.4)	3 (6.1)	9 (18.4)	4 (16.7)

Table 4: Clinical outcome scores

	Pre-op		Post-op		p-value (Wilcoxon)
Score (possible score)	n	Mean (range)	n	Mean (range)	
OHS (0-48)	241	20.4 (0-47)	216	32.9 (2-48)	p<0.001
CS pain (0-6)	279	2.6 (0-6)	236	5.2 (1-6)	p<0.001
CS function (0-6)	283	2.1 (0-6)	236	3.1 (0-6)	p<0.001
CS range of motion (0-6)	265	4.5 (1-6)	190	4.9 (2-6)	p<0.001
HHS pain (0-44)	268	18.8 (0-44)	220	36.6 (0-44)	p<0.001
HHS function (0-47)	268	19.2 (0-45)	220	25.6 (0-47)	p<0.001

CS: Charnley modification of the Merle d'Aubigne score
HHS: Harris Hip Score

Table 5: Mean (range) clinical outcome scores according to Paprosky grade

Paprosky grade	OHS	HHS pain	HHS function	CS pain	CS function	CS range of motion
1 n = 2	34.5 (33-36)	44.0 (44-44)	21.5 (20-23)	6.0 (6-6)	2.0 (2-2)	5.0 (5-5)
2a n = 40	34.0 (4-48)	36.4 (10-44)	29 (3-47)	5.1 (3-6)	3.5 (1-6)	5.0 (3-6)
2b n = 44	32.2 (7-48)	34.5 (0-44)	25.8 (0-47)	5.0 (2-6)	3.2 (1-6)	4.7 (3-6)
2c n = 22	34.7 (20-48)	38.8 (20-44)	27.6 (8-47)	5.5 (4-6)	3.3 (1-6)	4.8 (3-6)
3a n – 15	33.3 (2-46)	40 (20-44)	28.2 (0-42)	5.6 (3-6)	3.4 (1-6)	5.3 (4-6)
3b n = 6	31.5 (24-41)	40.3 (20-44)	26.7 (19-36)	5.0 (3-6)	3.0 (1-5)	4.8 (4-5)

Table 6. Results of Cox regression analysis

Variable (reference variable)	HR (95% CI)	p-value
Mesh (impaction only)		0.002
medial mesh	0.77 (0.15 to 3.85)	0.745
rim mesh	3.74 (1.42 to 9.86)	0.008
wall mesh	5.11 (1.72 to 15.19)	0.003
combination	3.54 (1.11 to 11.28)	0.033

Table 7: Clinical outcome scores according to radiographic stability

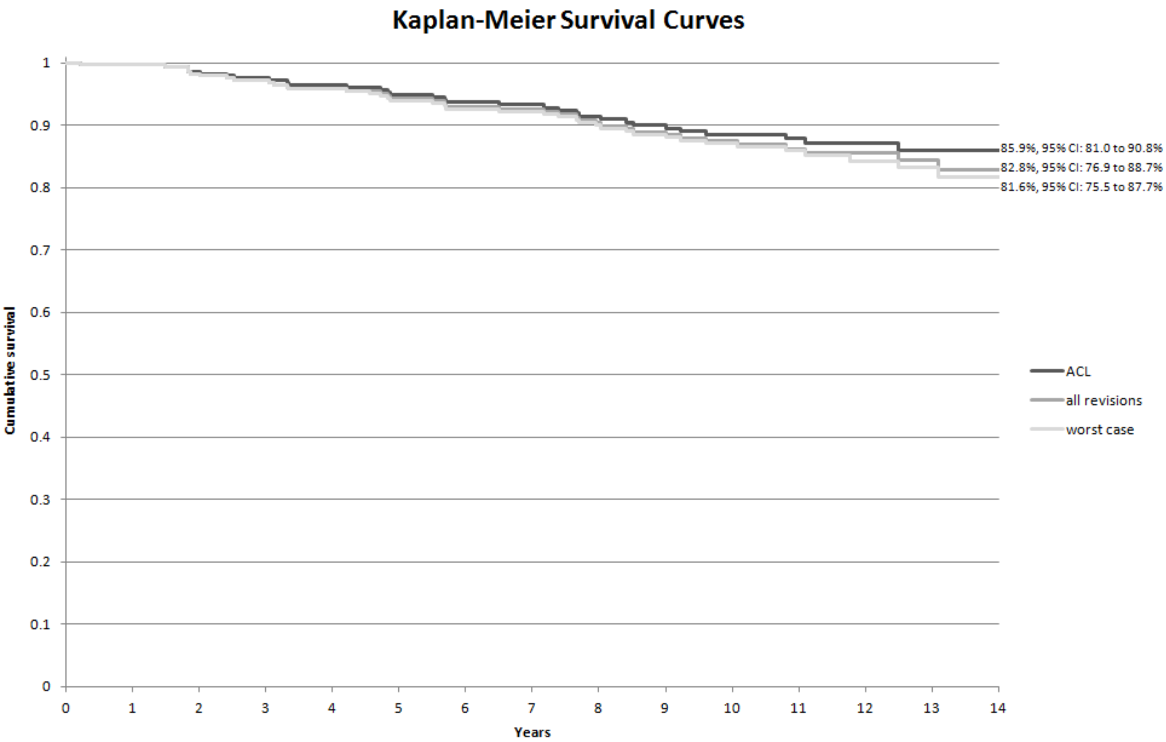
	OHS	HHS pain	HHS function	CS pain	CS function	CS range of motion
Stable (range) n = 77	33.8 (2-48)	36.7 (20-44)	28.6 (3-47)	5.2 (3-6)	3.6 (0-6)	5.0 (3-6)
Probably stable (range) n = 20	32.5 (11-45)	33.8 (10-44)	24.9 (7-39)	5.1 (2-6)	2.8 (0-5)	4.7 (4-6)
Probably unstable (range) n = 13	31.6 (21-46)	41.5 (30-44)	25.8 (9-44)	5.8 (4-6)	3.2 (1-6)	4.5 (3-6)
Definitely unstable (range) n = 15	32.5 (26-41)	35.9 (20-44)	24.7 (7-36)	5.0 (3-6)	2.9 (1-5)	5.1 (4-6)

Table 8 Radiographic outcomes according to Paprosky grade

Paprosky grade	Stable	Probably stable	Probably unstable	Definitely unstable
1 (%) n=2	1 (50)	1 (50)	0	0
2a (%) n=38	26 (68.4)	7 (18.4)	4 (10.5)	1 (2.6)
2b (%) n=43	23 (53.5)	8 (18.6)	4 (9.3)	8 (18.6)
2c (%) n=22	14 (63.6)	3 (13.6)	2 (9.1)	3 (13.6)
3a (%) n=14	9 (64.3)	1 (7.1)	2 (14.3)	2 (14.3)
3b (%) n=6	4 (66.7)	0	1 (16.7)	1 (16.7)

Figure legends

Figure 1: Kaplan-Meier survival curve for revision for aseptic cup loosening (ACL), revision for all reasons and revision for all reasons including patients lost to follow-up (worst-case)



Acknowledgements

The authors are grateful to Ros Schulpher, Sandy Wraight and Leo Collett of the Exeter Hip Research Team for their assiduous work in data collection and validation. We would also like to thank Mr Graham Gie for his invaluable contribution to this work.

References

1. van der Donk S, Buma P, Slooff TJ, Gardeniers JW, Schreurs BW. Incorporation of morselized bone grafts: a study of 24 acetabular biopsy specimens. *Clin Orthop Relat Res 2002-396:131-41.*

2. Slooff TJ, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. *Acta Orthop Scand 1984;55-6:593-6.*

3. Slooff TJ, Buma P, Schreurs BW, Schimmel JW, Huiskes R, Gardeniers J. Acetabular and femoral reconstruction with impacted graft and cement. *Clin Orthop Relat Res 1996-324:108-15.*

4. Garcia-Cimbrelo E, Cruz-Pardos A, Garcia-Rey E, Ortega-Chamarro J. The survival and fate of acetabular reconstruction with impaction grafting for large defects. *Clin Orthop Relat Res 2010;468-12:3304-13.*

5. 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;87-3:310-3.*

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;89-3:296-300.*

7. Pulido L, Rachala SR, Cabanela ME. Cementless acetabular revision: past, present, and future. Revision total hip arthroplasty: the acetabular side using cementless implants. *Int Orthop 2011;35-2:289-98.*

8. Abolghasemian M, Tangsataporn S, Sternheim A, Backstein D, Safir O, Gross AE. Combined trabecular metal acetabular shell and augment for acetabular revision with substantial bone loss: A mid-term review. *Bone Joint J 2013;95-B-2:166-72.*

9. Rigby M, Kenny PJ, Sharp R, Whitehouse SL, Gie GA, Timperley JA. Acetabular impaction grafting in total hip replacement. *Hip Int 2011;21-4:399-408.*

10. Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg [Br] 1996;78-2:185-90.*

11. 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;89-8:1010-4.*

12. 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;51-4:737-55.*

13. 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.

14. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. *J Arthroplasty 1994;9-1:33-44.*

15. Eggli S, z'Brun S, Gerber C, Ganz R. Comparison of polyethylene wear with femoral heads of 22 mm and 32 mm. A prospective, randomised study. *J Bone Joint Surg [Br] 2002;84-3:447-51.*

16. Garbuz D, Morsi E, Mohamed N, Gross AE. Classification and reconstruction in revision acetabular arthroplasty with bone stock deficiency. *Clin Orthop Relat Res 1996-324:98-107.*

17. Schreurs BW, Bolder SB, Gardeniers JW, Verdonschot N, Slooff TJ, Veth RP. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented cup. A 15- to 20-year follow-up. *J Bone Joint Surg [Br] 2004;86-4:492-7.*

18. Hodgkinson JP, Shelley P, Wroblewski BM. The correlation between the roentgenographic appearance and operative findings at the bone-cement junction of the socket in Charnley low friction arthroplasties. *Clin Orthop Relat Res 1988-228:105-9.*

19. Del Gaizo DJ, Kancherla V, Sporer SM, Paprosky WG. Tantalum augments for Paprosky IIIA defects remain stable at midterm followup. *Clin Orthop Relat Res 2012;470-2:395-401.*

20. Gelb DE, Lenke LG, Bridwell KH, Blanke K, McEnery KW. An analysis of sagittal spinal alignment in 100 asymptomatic middle and older aged volunteers. *Spine 1995;20-12:1351-8.*

21. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res 1976;121:20-32.*

22. Kaplan EL, Meier P. Non-parametric estimation from incomplete observations. *J Am Stat Assoc 1958;53:457-81.*

23. Cox DR. Regression Models and Life-Tables. *J R Stat Soc Series B Stat Methodol 1972;34-2:187-220.*

24. Brogan K, Charity J, Sheeraz A, Whitehouse SL, Timperley AJ, Howell JR, Hubble MJ. Revision total hip replacement using the cement-in-cement technique for the acetabular component: Technique and results for 60 hips. *J Bone Joint Surg [Br] 2012;94-11:1482-6.*

25. Charnley J. The long-term results of low-friction arthroplasty of the hip performed as a primary intervention. *J Bone Joint Surg [Br] 1972;54-1:61-76.*

26. 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;73-5:729-31.*

27. Mahomed NN, Barrett JA, Katz JN, Phillips CB, Losina E, Lew RA, Guadagnoli E, Harris WH, Poss R, Baron JA. Rates and outcomes of primary and revision total hip replacement in the United States medicare population. *J Bone Joint Surg [Am] 2003;85-A-1:27-32.*

28. Wolf BR, Lu X, Li Y, Callaghan JJ, Cram P. Adverse outcomes in hip arthroplasty: long-term trends. *J Bone Joint Surg [Am] 2012;94-14:e103.*

29. Ramiah RD, Ashmore AM, Whitley E, Bannister GC. Ten-year life expectancy after primary total hip replacement. *J Bone Joint Surg [Br] 2007;89-10:1299-302.*

30. Nunn D, Freeman MA, Hill PF, Evans SJ. The measurement of migration of the acetabular component of hip prostheses. *J Bone Joint Surg [Br] 1989;71-4:629-31.*

31. Morsi E, Garbuz D, Gross AE. Revision total hip arthroplasty with shelf bulk allografts. A long-term follow-up study. *J Arthroplasty 1996;11-1:86-90.*

32. Sporer SM, O'Rourke M, Chong P, Paprosky WG. The use of structural distal femoral allografts for acetabular reconstruction. Average ten-year follow-up. *J Bone Joint Surg [Am] 2005;87-4:760-5.*

33. Kremers HM, Howard JL, Loechler Y, Schleck CD, Harmsen WS, Berry DJ, Cabanela ME, Hanssen AD, Pagnano MW, Trousdale RT, Lewallen DG. Comparative long-term survivorship of uncemented acetabular components in revision total hip arthroplasty. *J Bone Joint Surg [Am] 2012;94-12:e82.*

34. Wilson MJ, Whitehouse SL, Howell JR, Hubble MJW, Timperley AJ, Gie GA. The results of acetabular impaction grafting in 129 primary cemented total hip replacements. *J Arthroplasty 2013;In Press.*

35. Schreurs BW, Keurentjes JC, Gardeniers JW, Verdonschot N, Slooff TJ, Veth RP. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented acetabular component: a 20- to 25-year follow-up. *J Bone Joint Surg [Br] 2009;91-9:1148-53.*

36. 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;88-7:865-9.*