We reviewed the results of 71 revisions of the acetabular component in total hip replacement, using impaction of bone allograft. The mean follow-up was 7.2 years (1.6 to 9.7). All patients were assessed according to the American Academy of Orthopedic Surgeons (AAOS) classification of bone loss, the amount of bone graft required, thickness of the graft layer, signs of graft incorporation and use of augmentation.

A total of 20 acetabular components required re-revision for aseptic loosening, giving an overall survival of 72% (95% CI, 54.4 to 80.5). Of these failures, 14 (70%) had an AAOS type III or IV bone defect. In the failed group, poor radiological and histological graft incorporation was seen.

These results suggest that impaction allografting in acetabular revision with severe bone defects may have poorer results than have previously been reported.

The number of total hip replacements (THR) requiring revision for aseptic loosening continues to increase.1 The associated loss of bone stock, either in the femur or in the acetabulum, presents a major challenge. Various techniques have been described to manage this effectively, including large uncemented acetabular components, reinforcement rings and cages, and structural bone allografts.2-4 These techniques provide a biomechanical solution to address the loss of bone, but not all of them contribute to restoration of the bone stock. Impacted morsellised allografts provide an effective and widely-accepted method to restore bone stock and have shown good clinical and radiological results.5-9 However, some studies have reported problems with the technique as applied to femoral bone loss.10-12

The clinical results of impaction allografting at the acetabulum are generally encouraging,5,6,8,9,13,14 with favourable results extending into the mid- and long-term.5,6,8 Comba et al13 reported a 95.8% (95% confidence interval (CI) 92.3 to 99.1) survival rate at 51.7 months after impaction grafting with cemented acetabular components.

We have reviewed a consecutive series of 76 impaction allograft acetabular revisions and studied the clinical, radiological and histological outcomes to identify factors associated with failure of the reconstruction.

Patients and Methods
Between February 1994 and March 2002, 76 impaction allograft reconstructions of the acetabulum were performed on 73 patients. Pre- and post-operative radiological and clinical data of 71 hips were available for review.

The mean follow-up was 7.2 years (1.6 to 9.7). The reason for primary revision was aseptic loosening in 59 hips and septic loosening in 12. In all cases with septic loosening, a two-stage procedure was performed.

In 32 patients (45%) an isolated acetabular revision was undertaken, and in 39 (55%) both components were revised. The mean age of the patients at operation was 69.1 years (32.8 to 91.4). All acetabular revisions were performed according to the principles established by Schreurs et al15 and Slooff et al16,14 with Exeter X-change revision instrumentation (Stryker Howmedica Osteonics, Allendale, New Jersey) via a posterolateral approach. Peri-operatively, all patients were screened for infection using blood tests, bone scans and intra-operative cultures. Two experienced surgeons (ICH and PIJMW) performed the operations. Cemented polyethylene acetabular components (Stryker Howmedica Osteonics) were used. All grafts consisted of fresh frozen bone, harvested, processed and stored at -80°C until required, in accordance with existing bone bank protocols.15,16 Before impaction the allograft bone was thawed at room temperature and prepared by hand with a rongeur to...
produce bone chips of approximately 0.7 cm to 1 cm in diameter. All cartilage was removed first. The acetabular host bone was reamed until a bleeding bone bed was created. If necessary, small drill holes were made for revascularisation of the host bone. The bone graft was forcefully impacted until a solid new bone bed was created using Stryker impaction instrumentation (Stryker Howmedica Osteonics). The acetabular components were cemented with Simplex cement containing gentamicin (Stryker Howmedica Osteonics) using a pressurising technique recommended by the manufacturer in order to produce a cement mantle at least 2 mm thick. When necessary, segmental and/or cavitary defects were reconstructed with metal meshes (Stryker Howmedica Osteonics) which were secured to the pelvis with screws to contain the defects. The caudal rim of the component was positioned at the level of the transverse ligament.

Post-operatively all patients remained on bed rest for five days, followed by a three-month period of minimal weight-bearing, after which full weight-bearing was allowed in most cases. Based on the pre- and first post-operative radiograph and record of the operation, the acetabular bone defects were classified according to the American Academy of Orthopaedic Surgeons (AAOS) classification.17 Per-operatively the amount of bone graft needed to restore the bone defects and the use of augmentation was recorded.

The immediate post-operative and the most recent radiographs were used for analysis. All radiographs were taken with the patient supine. The thickness of the graft layer for each De Lee and Charnley zone was measured on the radiograph and then corrected for magnification. To be able to describe the thickness of the graft layer in more detail, the DeLee and Charnley zone II was subdivided into four segments of equal size. For each segment separate measurements were performed, with correction for magnification taken into account by calibrating from the known acetabular diameter. Further radiological analyses included inclination of the acetabular component, the presence of radiolucent lines, and signs of graft incorporation or trabecularisation. The inclination angle was measured from the acute angle created by the intersection of a line drawn between both ischial tuberosities and a line constructed through the apices of the radiological orientation ring of the acetabular component. A radiolucent line of 2 mm or more was considered indicative of loosening.19 Graft incorporation, as a measure of bone remodelling, was categorised from the most recent radiograph by applying the method of Burssens et al20 as either complete incorporation, partial or early incorporation, no incorporation, or indistinct. Graft incorporation was considered certain when its radiodensity was equal to that of the host bone, and trabecular bridging could be identified between the host and graft as described by Conn et al.21 Radiological analysis was performed by two authors (EHvH, ICH) reaching a consensus. Failure was defined as the need for re-revision of the acetabular component for any reason, except infection.

Statistical analyses were performed using Kaplan-Meier survival analysis with 95% CI. For comparisons within the groups, chi-squared tests and Student’s t-tests were used. A p-value of ≤ 0.05 was considered significant.

**Results**

Of the 71 revised hips (68 patients), 25 (24 patients) needed to be re-revised and were considered failures. In five hips the reason for the re-operation was infection although none was from the original septic loosening group. These patients were excluded from the analysis of failures, leaving 20 hips in the failed group. Taking aseptic loosening as an end-point, the overall survival was 72% (95% CI, 54.4% to 80.5%) (51 of 71 hips) (Fig. 1). In seven hips re-revision was necessary within a year of the first operation. Of these, failure occurred in two hips following trauma. In 12 hips the acetabular component failed between one and five years after revision, and in one the failure was after seven years.
A total of 14 hips (70%) in the failed group had an AAOS type III or IV bone defect, whereas in the successful group 27 (53%) had a type III or IV defect. This difference was not significant (chi-squared test, \( p = 0.19 \)). There were five (25%) type IV defects in the failed group, whereas in the successful group there was only one (chi-squared test, \( p = 0.02 \)) (Table I).

In the failed group seven hips (35%) needed one femoral head to reconstruct the bone defects, in 12 (60%) two femoral heads were necessary and in one (5%) three were used. In the successful group one femoral head was used for the reconstruction in 23 hips (45%), in 19 (37%) two femoral heads were used, and in nine (18%) three were used (Table II). The overall mean thickness of the graft layer as measured on the direct post-operative radiograph, broken down into the DeLee and Charnley zones was, in both groups, greatest in zone IIA (failed, 1.63 cm; successful, 1.53 cm). The mean overall thickness of the graft layer in all zones was higher in the failed group (1.38 cm vs 1.25 cm), although this difference was not statistically significant (Student’s \( t \)-test, \( p = 0.08 \)) (Table III).

The mean acetabular inclination angle was 45˚ (31˚ to 60˚) in the failed group and in the successful group 41˚ (22˚ to 65˚). The use of rim meshes, or a combination of rim and medial wall meshes, was more frequent in the failed (15; 75%) than in the successful group (29; 57%) (Table IV).

On the latest post-operative radiograph good radiological graft incorporation was seen in 66% of hips (34) in the successful group, whereas in the failed group only 20% (4) showed good graft incorporation. This difference was statistically significant (chi-squared test, \( p < 0.001 \)). In the failed group, 30% (6) showed no graft incorporation, and in 45% (9) the graft incorporation was partial or early. In the successful group, only 8% (4) showed no radiological evidence of graft incorporation and 16% (8) had partial incorporation (Table V).

In 13 of the hips (65%) who required a re-operation after failure of their impaction graft reconstruction of the acetabulum, a biopsy of the impacted bone bed was taken for histological analysis. Applying the classification of van der Donk et al.,\(^3\) three groups of graft incorporation were identified: group 1 consisted of non-vascularised graft remnants, including fragments with dead fibrous tissue; group 2 showed revascularisation and bone graft incorporation, including fibrous tissue infiltration, dynamic bone resorption and new bone apposition, in group 3 the graft incorporation was complete and a new lamellar bone structure formed; group 4 consisted of biopsies showing only necrotic or fibrous tissue.

A total of 13 histological biopsies in 13 patients was available for analysis. Of these, two biopsies (one at 9 weeks and one at 6 months) were categorised as group 1 with non-vascularised graft remnants. Four biopsies were classified in group 2 showing some evidence of revascularisation and bone graft incorporation at a mean follow-up of 10 months (1 month to 2 years). Four biopsies were categorised in group 3 with complete incorporation at a mean follow-up of 39.5 (20 months to 4.5 years), and six biopsies at a mean follow-up of 42 months (2 years to 7 years) were allocated to group 4 with only necrotic or fibrous tissue to find.

### Discussion

Impaction allografting of morsellised bone combined with cemented fixation of primary implants is commonly used in revision hip surgery because it offers the opportunity for regeneration of bone stock. Although initial studies have shown good results,\(^5\)–\(^9\) other studies have identified potential problems with this technique.\(^10\)–\(^11\),\(^23\)–\(^25\) Most of the complications reported have been related to the femoral component.
In this study we found a high rate of failure of impaction grafting for acetabular revision. Of the 71 revisions available for review, 20 needed to be re-revised, producing a survival rate of only 72%, (95% CI, 54.5 to 80.5) which is considerably lower than in other series.5–9

Our series commenced with the introduction of the impaction grafting technique in our hospital. As the technique is demanding, it might be considered that the high rate of failure was due to lack of experience. However, this cannot be the complete explanation because 11 of the 20 failures occurred in patients operated on three years or more after the technique was introduced in our clinic. Also, an experienced visiting surgeon (JWMG), familiar with the technique, frequently assisted during the operation, thereby ensuring proper application of the method.

The proportion of large, uncontained defects in our study is relatively high. In the total group 49% (35) had an AAOS type III defect. Pelvic discontinuity (AAOS type IV defects) was also significantly present in the failed group. It is notable that 65% of the patients (2.3 hips) in the second half of the series had an AAOS type III or IV defect, suggesting that there was an increasing complexity in the bone defects referred for treatment and a broadening of the indications for this technique over time.

In a large proportion of our revisions (31 hips, 44%) two femoral heads were necessary to reconstruct the bone defects, and in ten hips (14%) three femoral heads were necessary. A direct comparison of our results with other studies is difficult, owing to the lack of comparable data. Schreurs et al9 found a 94% survival rate at 11.8 years. Although an AAOS classification of the bone defects was given, the exact extent of the defects managed and the amount of bone graft needed was not specified. Welten et al10 reported a 94% survival after 12.3 years. However, this study does not report the amount of bone graft inserted or the use of metal meshes to contain the graft. In another study by Schreurs et al16 a 90% survival at eight years was achieved after acetabular revision in patients with rheumatoid arthritis. In their study no correlation was found between the extent of bone loss and the survival of the implants.

In femoral revision with impaction allografting, Pekkarinen et al25 reported a high incidence of complications, mostly in patients with more severe defects. They found that their series contained a higher proportion of more severe defects than in the series described by Gie et al.7 It was concluded that impaction grafting revision of the femoral component in patients with large defects carried a high complication rate and can only be useful as an adjunct to other reinforcement techniques. Our acetabular results seem to reflect these findings. Although the number of AAOS type III and IV defects was not significantly higher in the failed group, there was a trend towards failure being associated with more severe defects.

It is questionable whether a direct comparison can be made between failure mechanisms in the femoral and acetabular components. However, we believe that the underlying mechanism is the same, being primary micromovement leading to mechanical instability and graft resorption.22

Unsurprisingly, graft incorporation was worst in the failed group: in only four of the 13 histological biopsies was complete graft incorporation seen, and radiological graft incorporation was significantly worse. This indicates that successful graft incorporation is essential for survival of the construct. This view was also put forward by van der Donk et al,22 who found large necrotic areas in long-term biopsies of failed impaction graft revisions.

Another possible explanation for the high failure rate in our series might be the high prevalence of segmental acetabular defects, which is illustrated by the frequent use of rim meshes, especially in the failed group (12; 60%, Table IV). In these types of defect the absence of superior bony support leads to a large amount of bone graft being placed at the most loaded area above the acetabular component. Owing to insufficient support for the bone graft, it is likely that micromovement of the prosthesis results in implant failure.27

It is now recognised that large bone grafts that have been washed before impaction may be preferable for optimal mechanical stability of the acetabular component, because of an increase in shear strength of the impacted bone.28–30 None of our grafts were prepared in this way. Although this step might have improved our results, it cannot be the only reason for the high failure rate.

We found a worryingly high rate of failure for cemented impaction grafting in acetabular revision. This was associated with the extent of the bone defect, and in particular the lack of bony support behind the graft in cases of large segmental defects. Other studies also identified the size of the bone defect as a major determinant of failure.1,12,25 We conclude that in revisions with large acetabular bone defects or pelvic discontinuity, the impaction grafting technique carries with it a high risk of complications.

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