Acetabular reconstruction with impacted bone allografts and cemented acetabular components

A 2- TO 13-YEAR FOLLOW-UP STUDY OF 142 ASEPTIC REVISIONS

We reviewed the clinical and radiological results of 131 patients who underwent acetabular revision for aseptic loosening with impacted bone allograft and a cemented acetabular component. The mean follow-up was 51.7 months (24 to 156).

The mean post-operative Merle D’Aubigné and Postel scores were 5.7 points (4 to 6) for pain, 5.2 (3 to 6) for gait and 4.5 (2 to 6) for mobility. Radiological evaluation revealed migration greater than 5 mm in four acetabular components. Radiological failure matched clinical failure. Asymptomatic radiolucent lines were observed in 31 of 426 areas assessed (7%). Further revision was required in six patients (4.5%), this was due to infection in three and mechanical failure in three. The survival rate for the reconstruction was 95.8% (95% confidence interval 92.3 to 99.1) overall, and 98%, excluding revision due to sepsis.

Our study, from an independent centre, has reproduced the results of the originators of the method.

Several different approaches have been described to manage acetabular bone loss at revision hip arthroplasty. Impaction bone allografting is philosophically attractive as an option because it enables a biological reconstruction of the bone defect.

Based on previous reports of bone grafting in complex primary hip surgery, Slooff, Schimmel and Buma were the first to apply impaction bone grafting in acetabular revision. They reported favourable results at short-, medium- and long-term follow-up. However, they describe this method as technically demanding and other authors have reported less satisfactory outcomes. In view of these problems one review described the technique as having a low reproducibility and limited indications.

We have analysed the clinical and radiological results of a series of patients who underwent acetabular revision for aseptic loosening with impacted bone allograft and a cemented acetabular component.

Table I. Diagnosis at primary replacement

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of cases</th>
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</thead>
<tbody>
<tr>
<td>Osteoarthritis</td>
<td>98</td>
</tr>
<tr>
<td>Trauma</td>
<td>18</td>
</tr>
<tr>
<td>Hip dysplasia</td>
<td>12</td>
</tr>
<tr>
<td>Avascular osteonecrosis</td>
<td>6</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>5</td>
</tr>
<tr>
<td>Ankylosing spondylitis</td>
<td>3</td>
</tr>
</tbody>
</table>

Table II. Indications for revision

<table>
<thead>
<tr>
<th>Indication</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aseptic loosening</td>
<td>130</td>
</tr>
<tr>
<td>Hemiarthroplasty with acetabular protrusion</td>
<td>6</td>
</tr>
<tr>
<td>Peri-prosthetic femoral fracture</td>
<td>3</td>
</tr>
<tr>
<td>Femoral stem fracture</td>
<td>2</td>
</tr>
<tr>
<td>Failed resurfacing arthroplasty</td>
<td>1</td>
</tr>
</tbody>
</table>

Patients and Methods

Between March 1986 and December 2001, 149 acetabular reconstructions were performed in 137 patients with aseptic failure of their primary replacement using the impacted bone allograft technique. The operations were performed by the senior author (FP) or under his supervision. A total of six patients (seven reconstructions) were lost to follow-up. Therefore, 142 reconstructions in 131 patients (11 bilateral) were included in the study of whom 90 were female and 41 male. The mean pre-operative Merle D’Aubigné and Postel functional score was 2.5 points (1 to 3) for pain, 2.2 (1 to 3) for gait and 2.5 (1 to 4) for mobility. The mean age at revision was 66 years (31 to 90). There were 80 right-sided reconstructions and 62 left. Table I shows the primary diagnosis and Table II the indications for revi-
Table III. Classification of acetabular bone defects according to the AAOS' classification system

<table>
<thead>
<tr>
<th>Type of defect</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segmental</td>
<td>12</td>
</tr>
<tr>
<td>Cavitary</td>
<td>61</td>
</tr>
<tr>
<td>Combined</td>
<td>69</td>
</tr>
</tbody>
</table>

* AAOS, American Academy of Orthopaedic Surgeons

In all cases the absence of infection was based on clinical history, radiological appearances, macroscopic intra-operative findings, intra-operative frozen section according to the Mirra criteria, negative cultures of intra-operative biopsies and histopathological findings. It was the first revision procedure in 116 cases, the second in 20 and the third in six. In 110 of the 116 first revisions we could determine the date of the primary arthroplasty. The mean time to revision for this group of 110 patients was 11.4 years (1 to 26).

In order to classify acetabular bone defects according to the American Academy of Orthopedic Surgeons (AAOS) classification system, we compared pre- and post-operative radiographs, as well as obtaining information from the operative records. Table III shows the distribution of the bone defects.

**Surgical technique.** All operations were performed under epidural hypotensive anaesthesia. Intravenous antibiotic prophylaxis with a first-generation cephalosporin was given during anaesthetic induction and for the first 24 post-operative hours. Routine prophylaxis for thromboembolic disease was continued for the first post-operative month. This consisted of intravenous of heparin during surgery, early post-operative mobilisation, enoxaparin in patients with a high clinical risk of thromboembolic disease, and aspirin in patients with a low clinical risk. Prophylaxis against heterotopic calcification was not routinely prescribed.

A transtrochanteric approach was used in 98 cases, a posterolateral approach without trochanteric osteotomy in 42 and a transgluteal approach in two cases. Wide exposure was required to obtain a complete view of the acetabular margins as well as the bone defects. Neurolysis of the sciatic nerve was not performed in any case. The components and the remaining cement were carefully removed. The transverse ligament or the tear-drop was identified. These landmarks allowed the reconstruction of the centre of rotation in an anatomical position, an essential condition to achieve optimal biomechanical balance for the hip. Intervertebral soft tissue was carefully removed, avoiding disruption of the medial cortex of the acetabulum. This step was essential to expose underlying bone in order to permit direct contact between the graft and host bone, thereby avoiding early acetabular radiolucencies in the post-operative radiographs. Bone allografts were obtained from frozen femoral heads in our own bank following the protocol of the American Association of Tissue Banks for the harvesting and processing of grafts. We used a mean of 2.4 femoral heads (1 to 5) per case. For the revision of a failed resurfacing arthroplasty, we combined allograft with femoral head autograft. In 11 cases, with cavity defects combined with severe segmental defects, we used supplementary metallic meshes in six and femoral head structural allografts attached to the ilium with screws in five to contain the impacted grafts.

Routinely, cancellous bone chips (7 mm to 10 mm diameter) were impacted according to the original Slooff technique using dedicated instruments (Exchange Revision Instruments System, Stryker Howmedica Osteonics, Allendale, New Jersey and Primary Impaction Grafting Instruments, DePuy International, Leeds, United Kingdom), consisting of increasing diameter impactors, placed in the desired acetabular position and impacted vigorously. The diameter of the last impactor was 4 mm greater than the definitive acetabular implant. The intention was to obtain a thickness of graft of at least 5 mm. Care was also taken to avoid accumulation of the allograft medially to prevent lateralisation of the acetabular component. In 69 cases 1 g of Vancomycin was added per femoral head used, in accordance with our reported local experience. Once the defects had been satisfactorily grafted to create a hemispherical cavity, an acetabular trial was performed, followed by cement preparation. A wet gauze was placed in the cavity, soaked in adrenalin 1/500 000 or hydrogen peroxide if necessary, to avoid the pooling of blood in the graft. Finally, the cement was pressurised for four seconds before implanting the acetabular component.

We used 142 cemented polyethylene acetabular components: 11 Osteonics (Stryker Howmedica Osteonics), eight CH (Stratec Medical, Umkirch, Germany), and 123 Ogee (De Puy, Warsaw, Indiana). The internal diameter of the acetabular component was 22 mm in all cases. We used three types of polymethylmethacrylate: Palacos (Smith and Nephew Richards, Memphis, Tennessee), CMW (De Puy) and Simplex (Stryker Howmedica Osteonics). We used antibiotic-laden cement in 38 cases only. Revision of the femoral component was also performed in 124 patients. In 98 cases we used the impaction grafting technique with cemented stems and in 26 we performed a cemented revision of the femoral stem without bone grafting. We implanted eight CMK femoral stems (Stratec Medical), 11 Exeter femoral stems (Stryker Howmedica Osteonics) and 105 Charnley stems (De Puy).

The rehabilitation protocol involved early mobilisation using a walking frame and toe-touch weight-bearing on the operated side for six weeks. After that, progressive weight-bearing was allowed as tolerated.

Clinical and radiological follow-up was performed in all cases. For clinical evaluation we used the Merle D’Aubigné and Postel scoring system. All patients had anteroposte-
rior pelvic radiographs and lateral views of the operated hip. The final radiographs were compared with those performed in the immediate post-operative period. Heterotopic calcification was described according to Brooker et al’s classification. In order to determine allograft incorporation, we followed the radiological criteria described by Slooff et al, and evaluated graft consolidation, migration of the acetabular component and the presence of radiographic lines at the cement-graft interface. Consolidation was defined by the presence of trabecular bone crossing the graft-host junction. Migration of the acetabular component was determined according to the initial position of the implants using the marking wires relative to the Köhler line and a horizontal line between the tear-drop image. The distribution of radiolucent lines was described according to DeLee and Charnley. Acetabular components with continuous radiolucent lines greater than 2 mm in thickness were considered loose.

Clinical failure was defined as the need for further acetabular revision, irrespective of the aetiology. Radiological failure was defined as progression of radiolucent lines in the three acetabular areas, or migration in excess of 5 mm. Survival analysis was performed using the Kaplan-Meier method.

Results
The mean follow-up period was 51.7 months (24 to 156). Functional. A total of six reconstructions had been excluded due to failure. The post-operative Merle D’Aubigné and Postel scores were available for the remaining 136 successful reconstructions. The mean score for pain was 5.7 points (4 to 6), 5.2 (3 to 6) for gait and 4.5 (2 to 6) for mobility.

Further revisions. The revision rate was 4.2% (six cases) overall. In three cases (2.1%) this was due to aseptic loosening, presenting clinically with pain, and radiographs confirmed migration of the component during the first two months after surgery. These three cases had combined acetabular defects with severe segmental defects involving the medial wall and suffered intrapelvic migration of the acetabular component. Of these three cases, two were second revisions. In two cases, a new acetabular reconstruction with allograft was performed, using a Kerboull reconstruction ring in one and a metal mesh in the other. In the third the prosthesis was removed and the patient refused to undergo another revision.

The other three revisions (2.1%) were due to deep infection. The mean delay before detecting infection was 34 months (17 to 50). These patients presented with disabling pain and one of the acetabular reconstructions showed radiological migration. There were two patients who had undergone revision before the routine use of a laminar-flow operating theatre. One of the patients had a history of recurrent dental abscesses. These three patients underwent removal of the component and one had a further revision after appropriate antibiotic treatment.

The survival rate of the reconstructions with the need for further revision as the end-point was 95.8% (95% confidence interval 92.3 to 99.1) (Fig. 1). Excluding failure due to infection, survival with a follow-up period of two to 13 years rose to 97.9%. Other complications. A total of nine patients (6.3%) had one or more dislocations, three of which had been operated on via a posterolateral approach and six through a trans-trochanteric approach. Among the latter, four had non-union of the greater trochanteric osteotomy. All these patients had Charnley femoral components. Closed reduction was performed and no further operative treatment was required.

No patient had a sciatic nerve palsy.

Other re-operations. Further surgery was required in four other patients. Of these, two had peri-prosthetic fractures; one with a broken femoral component and one an unrecognised intra-operative femoral perforation.

Radiological. Radiological evidence of graft incorporation and a stable acetabular component was observed in most cases. The host bone and graft had a similar bone density with continuity of the trabecular pattern and some remodelling of the medial wall of the acetabulum (Fig. 2). Migration of the acetabular component greater than 5 mm was seen in four cases (2.8%), these required further revision as previously described.

Heterotopic ossification was noted in 72 cases (50.7%). Of these, 43 (30.3%) were Brooker grade I, 19 (13.4%) grade II, nine (6.3%) grade III and one (0.7%) grade IV. None underwent further surgery for this reason.

Of the 426 DeLee and Charnley areas radiologically evaluated in the 142 reconstructions, 31 (7%) had radiolucent lines at the cement-graft interface. These lines were non-progressive and were not associated with failures or reduced functional scores.
Discussion

Our results support the use of impaction bone allografting in acetabular reconstruction at revision arthroplasty.

In this series 142 acetabular reconstructions were evaluated at a minimum follow-up of two years and maximum of 13.1 years. The survival rate of the reconstruction was 95.8% overall and 97.9% excluding infected cases. Only six patients (seven reconstructions) were lost to follow-up. In the worst-case scenario, the overall survival rate would decrease to 91.3%.

The main objectives of acetabular reconstruction surgery are to achieve adequate fixation of the new component, to restore the centre of rotation of the hip and replace lost bone. Slooff et al11 have reported their results at a follow-up period of 2 years, 5.7 years,12 11.8 years13 and 15 to 20 years,14 with a favourable outcome.

In three cases (2.1%) there was failure of the reconstruction due to mechanical factors. The acetabular bone defect combined with a severe segmental defect on the medial wall would probably have been better managed with a graft supporting device, such as a metal mesh or an acetabular reconstruction ring. Although 69 patients (48.6%) presented with a combined AAOS type III acetabular defect, only 11 (7.7%) required a mesh or structural femoral head allograft for the reconstruction, in addition to the impacted chips. This might be due in part to our use of Ogee acetabular components in many cases. This design has a continuous flange that may support the impacted bone grafts as well as improving the cement pressurisation.29,30 However, the three aseptic failures described were also combined defects managed with Ogee components.

Schreurs et al12 reported an overall rate of re-revision of 4.5% in 88 reconstructions, with a mean follow-up similar to our series of 5.7 years. Garcia-Cimbrelo and Cordero31 described 70 reconstructions, with a minimum follow-up of five years and maximum of nine years with a 98% survival rate due to aseptic loosening.

Uncemented components are widely used for acetabular reconstruction. Few studies are available with results greater than ten years. Leopold, Rosenberg and Bhatt32 reported an 11% re-revision rate in 138 cases, with a mean follow-up of 11.8 years, but with no aseptic loosening of the acetabular component. However, other complications were seen such as pelvic osteolysis (17%) or release of metal particles,33 which might have an adverse effect at longer follow-up.

Acetabular reconstruction with impacted bone allografts is a demanding technique requiring access to banked bone. The impaction of grafts of a certain size should be vigorous in order to provide early stability.34 Even though the reconstruction is stable, the post-operative period should include restricted loading, which in our series was complete for six weeks and partial for approximately six additional weeks.

Fig. 2a
Fig. 2b
Fig. 2c

Radiographs showing a) aseptic loosening (American Academy of Orthopaedic Surgeons classification defect type II), b) the hip one month after acetabular reconstruction and c) remodelling (arrow) of the acetabulum medial wall three years after revision.
Radiological assessment of consolidation of the graft is difficult and perhaps unreliable. However, incorporation appeared not to be the determinant for a successful outcome based on the histological evidence described in the literature. Unfortunately, histological studies performed in our six cases of further revision examination only for evidence of infection. In our series, massive migration was a radiological sign consistent with clinical failure. It is not clear whether minor migration could be an initial sign of late failure. We did not undertake radiostereometric studies which have been shown to detect minimal displacement.

The reconstruction of acetabular bone defects using impacted bone allografts is a biological technique allowing restoration of bone stock. As in primary surgery, conventional components are used, with consequent reduction in costs. Except for the septic failures found in our series, only three patients required further revision due to failure of the reconstruction and these were associated with a technical error in the management of the bone defect. Our clinical and radiological medium-term results support the use of this reconstructive technique in acetabular revision surgery.

We are grateful to Gabriela Rodriguez, MD for her assistance in statistical analysis. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References