Although the technique of autogenous acetabular bone grafting has been widely used to augment containment of the acetabulum in total hip arthroplasty (THA) for developmental dysplasia, the role of this technique in improving long-term results remains controversial.

We present the long-term results of cemented THA with acetabular bone grafting in 112 patients (133 hips) in order to clarify the factors which affect the outcome. The mean follow-up was for 12.3 years (8 to 24). Kaplan-Meier survivalship analysis predicted a rate of survival of the acetabular component at 15 years of 96% (95% confidence interval (CI) 92 to 99) with revision for aseptic loosening as the endpoint, and of 75% (95% CI 65 to 85) when radiological loosening was used. Parametric survivorship analysis using the Cox proportional-hazards model indicated that trochanteric nonunion, lateral placement of the socket, and delayed trabecular reorientation of the bone graft were risk factors for loosening of the acetabular component.

Our findings have shown that autologous acetabular bone grafting is of value for long-term success provided that the risk factors are reduced.

**Patients and Methods**

Between 1974 and 1988 we performed 148 consecutive, primary cemented THAs with acetabular bone grafting on 124 patients. Of these, nine (12 hips) died within eight years of operation, two (two hips) were lost to follow-up and one (one hip) had an excision arthroplasty for infection. This left 112 patients (133 hips) in the study.

There were four men and 108 women with a mean age at the time of the operation of 53 years (33 to 72), a mean height of 1.50 m (1.34 to 1.66) and a mean weight of 51 kg (29 to 78). The mean duration of follow-up was 12.3 years (8 to 24). The diagnosis for all hips at the time of operation was secondary osteoarthritis due to developmental dysplasia or dislocation. The degree of subluxation was categorized according to the classification of Crowe et al.¹

All operations were performed through a lateral approach with trochanteric osteotomy, using the femoral head for the graft, as described by Wolfgang.¹⁹ The grafts were screwed to the superolateral aspect of the acetabular roof, except for two in which internal fixation was not used. Single crystalline alumina-ceramic screws (Kyocera, Kyoto, Japan) were used in 122 hips and metal cancellous screws in nine.

We used three types of implant: the original Charnley prosthesis (Thackray, Leeds, UK) in 51 hips, the modified Charnley (Howmedica, Rutherford, New Jersey) in nine and the Bioceram implant (Kyocera, Kyoto, Japan) with a 28 mm alumina-ceramic head in 73 (Fig. 1). All the sockets were fixed with CMW1 radiopaque cement (CMW Laboratories, Devon, UK).
The femoral component was inserted with CMW1 cement using the double-thumb technique in 49 procedures and with CMW3 cement and a cement gun in 84.

Standard radiographs were taken after operation and at 2, 4, 6 and 8 weeks, at 3, 6 and 12 months, and then 6-monthly or yearly thereafter.

The initial postoperative radiographs were measured to define the centre of the socket and the approximate centre of the femoral head according to the method of Pagnano et al.\(^{34}\) The degree of initial abduction of the socket was measured and the centre-edge (CE) angle, as described by Sugano et al.\(^{35}\) Lengthening of the limb was also recorded.

The remodelling process of the grafted bone was analysed according to the method described by Knight et al.\(^{6}\) Radiological analysis was performed on 124 hips and the presence of a radiolucent line at the cement-bone interface in the three zones of DeLee and Charnley\(^{36}\) was recorded. Loosening of the acetabular component was classified according to the criteria of Hodgkinson, Shelley and Wroblewski.\(^{37}\) The presence of a radiolucent line around the femoral component was recorded for the seven zones described by Gruen, McNeice and Amstutz.\(^{38}\) The criteria of Harris, McCarthy and O’Neill\(^{39}\) were used to assess radiological evidence of loosening and hip function was also evaluated according to the scoring system of Merle d’Aubigné and Postel.\(^{40}\)

**Statistical analysis**

We used the Kaplan-Meier product-limit method to estimate the cumulative probabilities of revision and loosening. The survivorship curves for various subgroups were compared by the log-rank test. The Cox proportional-hazards model was used for parametric survivorship analysis (Statview software; Abacus Concepts, Berkeley, California) to detect the risk factors which affect the outcome.

**Results**

Early postoperative complications included a dislocation in one hip which required closed reduction; there was no recurrence. One patient had a transient partial palsy of the peroneal nerve. There were long-term complications in 26 patients; 25 had nonunion of the trochanteric osteotomy and one sustained a fracture of the femoral component (Kyocera type 5 straight, made of SUS316L) 13 years after operation.

The mean Merle d’Aubigné and Postel hip score improved from 9.1 before operation to 15.6 at the final follow-up.

Ten hips required reoperation; six for aseptic loosening of the socket, two for aseptic loosening of the femoral component, one for aseptic loosening of both components and one for a fracture of the femoral stem.

The Kaplan-Meier survivorship analysis, with revision for aseptic loosening as the endpoint, predicted a rate of survival of the socket of 97% (95% confidence interval (CI) 94 to 100) at ten years, and of 96% (95% CI 92 to 99) at 15 years (Fig. 2). For the femoral component the rate of survival was 99% (95% CI 97 to 100) at ten years and 94% (95% CI 88 to 100) at 15 years (Fig. 3).

**Radiological analysis**

**Acetabular components.** At the most recent follow-up, six sockets had been revised for loosening and an additional 20 showed radiological evidence of this. According to the criteria of Hodgkinson et al.,\(^{37}\) 16 sockets were type 4 and ten were type 3. Kaplan-Meier survivorship analysis,
with radiological loosening as the endpoint, predicted a rate of survival for the socket of 83% (95% CI 76 to 89) at ten years and of 75% (95% CI 65 to 85) at 15 years (Fig. 4).

Non-parametric survivorship analysis with the use of the log-rank test was applied to 12 variables: the type of component, the age of the patient, body-weight, the size of the socket, neck offset, horizontal positioning of the socket, initial abduction of the socket, CE angle, limb lengthening, Crowe type, trochanteric nonunion and the time to trabecular reorientation (Table I).

Radiological loosening was seen in 17 Bioceram sockets and nine Charnley cups with no statistical significance in

**Fig. 2**
Kaplan-Meier cumulative probability of an acetabular component not having revision for loosening. The dotted lines indicate 95% confidence intervals.

**Fig. 3**
Kaplan-Meier cumulative probability of a femoral component not having revision for loosening. The dotted lines indicate 95% confidence intervals.

**Fig. 4**
Kaplan-Meier cumulative probability of an acetabular component not becoming radiologically loose. The dotted lines indicate 95% confidence intervals.
the rate of loosening (log-rank test, p = 0.20) or the rate of revision (log-rank test, p = 0.12) between the two types.

We recorded the offset of the femoral component which is the horizontal distance from the centre of the femoral head of the prosthesis to the longitudinal axis of the stem. The mean offset of all components was 32 mm (19 to 40). The rate of loosening of the socket when the offset of the femoral components was less than 35 mm, was relatively higher than the others but was not statistically significant (log-rank test, p = 0.07) with no significant difference in the rate of revision (log-rank test, p = 0.07).

The positions of the centre of the socket on the initial postoperative radiographs were assessed using the four-zone classification. Three sockets were placed superiorly and 37 laterally. Comparison of the laterally-placed sockets with all others (Fig. 5) showed a significant difference in the rate of loosening (log-rank test, p < 0.019), but no significant difference in the rate of revision (log-rank test, p = 0.96).

The degree of initial abduction of the socket had a mean value of 38° (23 to 51). The rate of loosening of 19 sockets with an initial abduction of more than 45° was relatively higher than that of all other components, but was not statistically significant (log-rank test, p = 0.07). There was no significant difference in the rate of revision (log-rank test, p = 0.68).

The mean CE angle was -1° (-40 to +40). Sixty-six sockets were classified as a subgroup in which the CE angle was negative and the rate of loosening of these was higher than that of all other components, but was not statistically significant (log-rank test, p = 0.09). Six of seven sockets

---

Table I. Variables to which non-parametric survivorship analysis was applied for possible risk factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of component</td>
<td></td>
</tr>
<tr>
<td>Charnley</td>
<td>60</td>
</tr>
<tr>
<td>Bioceram</td>
<td>73</td>
</tr>
<tr>
<td>Mean (sd) age at operation (years)</td>
<td>52.8 ± 7.7</td>
</tr>
<tr>
<td>Mean (sd) body-weight (kg)</td>
<td>50.7 ± 8.6</td>
</tr>
<tr>
<td>Mean (sd) socket size (mm)</td>
<td>42.3 ± 2.0</td>
</tr>
<tr>
<td>Mean (sd) neck offset of femoral component (mm)</td>
<td>32.0 ± 5.0</td>
</tr>
<tr>
<td>Mean (sd) horizontal positioning of the socket (mm)</td>
<td>30.1 ± 4.5</td>
</tr>
<tr>
<td>Mean (sd) initial abduction of the socket (degrees)</td>
<td>38.3 ± 6.4</td>
</tr>
<tr>
<td>Mean (sd) socket CE angle (degrees)</td>
<td>-1.0 ± 13.8</td>
</tr>
<tr>
<td>Mean (sd) limb lengthening (mm)</td>
<td>18.2 ± 9.9</td>
</tr>
<tr>
<td>Crowe type</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>58</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Trochanteric nonunion</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>108</td>
</tr>
<tr>
<td>No</td>
<td>25</td>
</tr>
<tr>
<td>Mean (sd) trabecular reorientation (months)</td>
<td>32.5 ± 10.0</td>
</tr>
</tbody>
</table>

---

Fig. 5
Comparison of radiological survival between 37 sockets which were laterally placed (L) and 96 which were medially placed (M). The 95% confidence intervals are shown on only one side of each curve.

Fig. 6
Comparison of radiological survival between 14 sockets with a CE angle of less than -20° and all others. The 95% confidence intervals are shown on only one side of each curve.
Comparison of radiological survival between 25 sockets with radiological evidence of trochanteric nonunion (N) and all other sockets (U). The 95% confidence intervals are shown on only one side of each curve.

Radiographs of a 67-year-old woman with Crowe type-II congenital dysplasia. Figure 8a – Before operation. Figure 8b – After Charnley low-friction arthroplasty, showing the combined acetabular bone graft fixed by two alumina-ceramic screws. Figure 8c – Three months after operation showing bridging trabeculation across the graft-host interface which represents bony union. This was present when the interface could no longer be clearly identified. Figure 8d – Twelve months after operation, showing graft remodelling which is an indicator of revascularisation and was defined as a rounding-off of the protruding edge of a graft beyond the cup or as a change in density of the graft in areas where it was not stressed. Figure 8e – Three years and six months after operation showing trabecular reorientation in the graft to match the normal trabecular orientation of the acetabular dome. Figure 8f – Fourteen years after operation showing no evidence of loosening of the acetabular component and complete incorporation of the bone graft.
which had been revised for loosening had a negative CE angle, but this was not statistically significant (log-rank test, \( p = 0.053 \)). In 14 sockets the CE angle was less than \(-20^\circ\) and these had a higher rate of loosening (log-rank test, \( p < 0.003 \); Fig. 6).

There were 25 hips with trochanteric nonunion, and 11 of these were associated with loosening of the socket. Comparison of the sockets with trochanteric nonunion with all other hips showed a significant difference in the rate of loosening (log-rank test, \( p < 0.0001 \); Fig. 7), but not in the rate of revision (log-rank test, \( p = 0.75 \)).

The remodelling process of the grafted bone was analysed according to the method of Knight et al. and the results are shown in Figure 8. Bridging trabeculation across the graft-host interface was seen in all cases at a mean of three months after operation (2 to 12). Remodelling of the graft was seen in 122 of 124 hips (98%) at a mean of nine months after operation (4 to 19). Trabecular reorientation was seen in 111 of 124 hips (89%) at a mean of 32.5 months after operation (18 to 77); in the other 13 it was incomplete or absent (Fig. 9). The rate of loosening of the sockets with a delay in trabecular reorientation of more than 36 months after operation was higher than that of components showing early reorientation, but the difference was not statistically significant (log-rank test, \( p = 0.06 \); Fig. 10). There was, however, a significant difference in the rate of revision (log-rank test, \( p = 0.03 \)).

Surviviorship analysis using the log-rank test showed that age at operation, body-weight, the size of the socket, limb lengthening and Crowe type did not significantly affect the rate of loosening.

Parametric survivorship analysis using the Cox proportional-hazards model was applied to the 12 variables used in the log-rank tests (Table I). When each of these was screened separately, four were found to affect loosening: horizontal positioning of the socket (\( p = 0.03 \)), CE angle (\( p = 0.02 \)), trochanteric nonunion (\( p = 0.0004 \)) and duration of trabecular reorientation (\( p = 0.005 \)). These were analysed together, and three, namely lateral positioning of the socket (\( p = 0.015 \)), trochanteric nonunion (\( p = 0.0002 \)) and delayed trabecular reorientation (\( p = 0.005 \)), were found to be risk factors for loosening of the socket.

**Femoral components.** At the most recent follow-up, four femoral components had been revised for loosening,
including one fracture of the stem, and one which was radiologically loose. Kaplan-Meier survivorship analysis, with radiological loosening as the endpoint, predicted a rate of survival of the femoral component of 97% (95% CI 94 to 100) at ten years, and of 94% (95% CI 88 to 100) at 15 years (Fig. 11).

Discussion

Various techniques to deal with the lack of acetabular bone stock in developmental dysplasia have been described including a cemented socket with structural bone graft,\(^3\),\(^4\),\(^15\),\(^16\),\(^20\)-\(^29\) a small socket with cement,\(^8\),\(^41\) a medial-wall fracture technique,\(^14\),\(^42\) and uncemented sockets with\(^19\),\(^43\)-\(^49\) or without\(^17\),\(^50\),\(^51\) bone graft.

There are only a few studies which have followed patients with cemented arthroplasty and a bone graft for more than ten years.\(^5\),\(^7\),\(^9\),\(^31\)-\(^33\),\(^52\) Harris et al\(^15\) reported a series of 27 dysplastic hips which had been treated by grafting of the femoral head in conjunction with THA. Follow-up studies showed rates of loosening and revision of 46% and 20%, respectively, after a mean of 11.8 years. Others\(^5\),\(^16\),\(^30\)-\(^33\) have had more favourable results. Good results have been reported 10 and 16 years after Charnley low-friction arthroplasty and acetabular bone grafting.\(^5\),\(^33\)

In the past the number of patients studied has not been large enough to allow comparisons based on survivorship analysis. In our series, survivorship analysis using the log-rank test showed that lateral placement of the socket, the CE angle and trochanteric nonunion significantly affected the rate of loosening of the socket, and although the type of component, neck offset and trabecular reorientation were also possible factors, these were not statistically significant.

Inadequate medialisation of the socket increases the incidence of loosening\(^9\),\(^53\)-\(^55\) and there are a number of reports which suggest that a large acetabular bone graft should be avoided.\(^29\),\(^31\),\(^32\),\(^43\),\(^46\),\(^52\) Some authors have suggested that proximal positioning of the acetabular compon-
Five femoral components (4%) showed radiological evidence of loosening. Kaplan-Meier survivorship analysis, with radiological loosening as the endpoint, predicted a rate of survival of the femoral component of 97% at ten years. This is similar to that reported for the Charnley prosthesis in reconstruction of degenerative dysplasia. Other authors have reported a higher rate for femoral loosening. 10

In the surgical treatment of the degenerative dysplastic hip, THA without acetabular bone graft can give acceptable results, but some studies have shown that acetabular reconstruction using graft from the femoral head gives a better outcome. We believe that acetabular bone grafting may improve the long-term results and our data indicate that trochanteric nonunion, lateral placement of the socket and delay of trabecular reorientation are all risk factors for loosening of the socket.

More recently, we have used the direct lateral approach, and have improved our preoperative planning by using computer simulation. We have also used more sophisticated techniques of bone grafting.

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


