Radiological factors influencing femoral and acetabular failure in cemented Charnley total hip arthroplasties


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We have made a retrospective review of 185 cemented Charnley total hip arthroplasties performed between 1970 and 1974 to determine the relationships between radiological variables and failure of the femoral and acetabular components. We measured the acetabular wear, the orientation of the cup, the thickness and consistency of acetabular and femoral cement mantles, radiolucency and femoral alignment. The mean follow-up was for 11.7 years. Femoral loosening was demonstrable radiologically in 15 hips (8.1%), ten (5.4%) of which were revised during the period of follow-up. Only when the first postoperative radiograph showed a thin cement mantle in Gruen zone 5 was there a significant association with failure of the femoral component. There were 12 loose acetabular components (6.5%), nine (4.8%) of which were revised. When the initial radiograph after operation showed radiolucency in DeLee and Charnley zone 1, the incidence of acetabular loosening was 28.21%. If such radiolucency was not present, the incidence of acetabular loosening was only 0.69%. Our findings emphasise the importance of careful cementing.

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In total hip arthroplasty (THA), failure of the cemented femoral and acetabular components has always been a problem. With time, there has been better understanding of the variables associated with failure and improvements in techniques of cementing and of prosthetic design have increased the survival of THAs.

Star et al showed that failure of the femoral component occurred when the cement mantle in Gruen zones 5 and 6 was too thin. After analysing the mantle surrounding both femoral and acetabular components, Ebramzadeh et al also concluded that careful cementing was an important factor in the success of THA.

Beckenbaugh and Ilstrup noted that patients had increasing pain when loosening led to movement of 2 mm or more. Although Blacker and Charnley believed that if loosening had not taken place within the first four years it was unlikely to occur, Gruen et al found that it did progress with time. Factors influencing loosening include alignment of the stem in varus, residual cancellous bone at the level of the calcar, the amount of cement around the distal portion of the stem, an inadequate cement mantle at the calcar, poor packing of cement around the prosthesis, and a wide femoral canal.

Improvements in techniques of cementing have reduced the incidence of loosening of the femoral stem. Harris suggested that precoating the metal surface proximally with polymethylmethacrylate, roughening selected areas of the rest of the stem and using a collar further increased the chances that the femoral stem would remain stable. Improvements in cementing, however, have not noticeably decreased the rate of failure of acetabular components.

Although Olsson, Jernberger and Trygg found that the age, weight and preoperative diagnosis of the patient influenced failure of the acetabular component, neither Blacker and Charnley nor Ranawat et al established a correlation between loosening and age, weight and gender.

Ranawat et al, who noted a correlation between failure of the socket and radiolucency in the acetabulum on the first postoperative radiograph, found that inflammatory arthritis and dysplastic acetabula were the only conditions which correlated with acetabular loosening. Other authors have reported a higher incidence in patients with protrusio acetabuli, possibly because of bony biological constraints. Schmalzried et al believe that biological rather than mechanical factors influence loosening while Ritter attributes aseptic loosening of the acetabular component to poor initial fixation and positioning, the presence of a metal backing, and sepsis. Radiolucency which first appears ten years after surgery probably indicates a biological response to polyethylene wear debris, but that seen on the first
postoperative radiograph may reflect the preoperative state of the bony bed and/or technical faults.

In a retrospective analysis of the reasons for failure of the femoral and acetabular components, we attempted to determine which radiologically demonstrable variables were associated with failure of a Charnley THA.

Patients and Methods

Between 1970 and 1974, we performed 247 consecutive Charnley THAs in 192 patients. Of these, 62 hips were excluded, 41 because of total radiolucency of the cement, 15 because of inadequate follow-up, three as a result of infection and three because of a fractured femoral stem. This left 185 hips (144 patients) in the study. The mean time of follow-up was for 11.7 years (SD 7.1). In 45 hips the follow-up was for 20 years or more and in 32 for 15 to 20 years. Table I gives the clinical details of the patients.

Radiological analysis. We examined the anteroposterior (AP) and lateral radiographs taken after operation and at the subsequent follow-ups. From the initial radiograph we evaluated the alignment of the femoral component, the acetabular angle, and the thickness and consistency of the cement mantle. We measured polyethylene wear at one year and on the most recent film. We measured acetabular and femoral cement mantles. We measured polyethylene wear at one year and on the most recent film.

Alignment. The alignment of the coronal plane of the femoral component had failed, the mean thickness of the cement mantle in Gruen zone 5 was associated with failure of the acetabular and femoral components to determine whether they were associated with failure. We used the chi-squared test on the categoric variables and independent logistic regression analysis to evaluate the relationship between acetabular radiolucency and loosening of the cup.

Results

Femoral component. Table I shows that there were 15 loose femoral stems (8.1%), ten of which were revised. The mean time to failure of the stems was 11.3 years. Both backward and step-wise logistic regression analysis was performed on the continuous variables of the femoral component to determine whether any single variable or combination of variables was associated with failure. Neither alignment (p = 0.262) nor cement voids (p = 0.286) were associated with failure (Tables II and III).

Cement mantle. The femoral component was divided into the 14 standard Gruen zones on the AP and lateral radiographs. We examined the thickness of the femoral cement mantle and counted the number of voids. We took measurements at the same place on each femur. Similar zonal acetabular analysis was performed in each of the three zones of DeLee and Charnley.

Failure. We considered the procedure to have failed if the prosthesis had migrated 3 mm or more, and/or revision was necessary. At the time of the study, 83 patients had died. The operation was considered to be a success if the prosthesis was still functioning at the time of death.

Table I. Details of the 144 patients in the study who received Charnley total hip arthroplasties (THAs)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Femur</th>
<th>Acetabular cup</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not loose</td>
<td>Loose</td>
</tr>
<tr>
<td>Number of hips</td>
<td>170</td>
<td>15</td>
</tr>
<tr>
<td>Number of patients</td>
<td>130</td>
<td>14</td>
</tr>
<tr>
<td>Mean age in years (SD; range)</td>
<td>62.95</td>
<td>61.21</td>
</tr>
<tr>
<td>Gender</td>
<td>Male (%)</td>
<td>67(51.5)</td>
</tr>
<tr>
<td></td>
<td>Female (%)</td>
<td>63(48.5)</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>Osteoarthritis (%)</td>
<td>106(62.4)</td>
</tr>
<tr>
<td></td>
<td>Rheumatoid arthritis (%)</td>
<td>10(7)</td>
</tr>
<tr>
<td></td>
<td>Osteonecrosis (%)</td>
<td>24(14.1)</td>
</tr>
<tr>
<td></td>
<td>Previous failure</td>
<td>17(10)</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>15(8.8)</td>
</tr>
<tr>
<td>Radiolucency Zone</td>
<td>1</td>
<td>28(16.2)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>16(9.2)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>13(7.5)</td>
</tr>
</tbody>
</table>

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was 2.64 mm (SD 1.38), compared with an overall mean thickness of 3.26 mm (SD 2.52).

**Acetabular component.** There were 12 failures of the acetabular cup (6.5%) (Table I), of which nine (4.8%) were revised. Of 185 cups, 41 showed radiolucency at one year. There were 39 with radiolucency in DeLee and Charnley zone 1, 20 in zone 2, and 15 in zone 3. Failure occurred in 11 patients with radiolucency in zone 1, in four with radiolucency in zone 2, and in two with radiolucency in zone 3. Table V gives the combinations of radiolucencies.

Treating the acetabular radiolucencies as independent variables, we used logistic regression analysis to test whether they were associated with loosening of the acetabular component. We used regression analysis to deter-
mine the relationship between radiolucencies and acetabular wear. Table VI shows that radiolucency in zone 1 (Fig. 2) was evident in 99.5% of failed implants (p = 0.0001). Wear independent of other variables was not statistically associated with loosening, except when radiolucency was present in zone 1 on the initial radiographs. The relationship between acetabular wear and radiolucency in zone 1 was significant (p = 0.0339). When there is radiolucency in zone 1, an acetabular component has 38.8 times more chance of loosening than when no radiolucency is present.

Neither the acetabular angle (mean 39.42°, SD 6.53) nor the thickness of the cement mantle was statistically associated with acetabular loosening or revision (Table VII).

Discussion

In our study of the Charnley THA there was a survival rate of 93.6% at ten years, and 45 hips lasted for more than 20 years. Although the cement mantles were thinnest in Gruen zones 8 and 12, a thin mantle in Gruen zone 5 was the most significant predictor of loosening of the femoral component. This suggests that increasing the thickness of the cement mantle along the distal medial portion of the stem may reduce the incidence of failure. At this stage, we cannot give a reason for this association. Star et al, using DF-80 prostheses (Zimmer, Warsaw, Indiana), also found that loosening was associated with a thin cement mantle in Gruen zones 5 and 6. Finite element analysis shows that stress is concentrated at the distal cement-metal interface. Peak loading at the tip remain unchanged before and after debonding, but after debonding the greatest increase in stress occurs in the distal cement-metal interface medially near the tip of the stem. Further, stress at the tip of the stem can cause disruption of the cement-metal interface. Peak loading at the tip remain unchanged before and after debonding, but after debonding the greatest increase in stress occurs in the distal cement-metal interface medially near the tip of the stem. To minimise this problem, we suggest using distal spacers to centre the prosthesis within the canal.

The cement voids often seen with first-generation cementing techniques had no effect on femoral failure in this series.

We found that when radiolucency in acetabular zone 1 was evident on the first postoperative radiograph, the probability of loosening was 38.8 times greater than when no radiolucency was present. Ranawat et al and Star et al also
found that radiolucenty in femoral zone 5 or acetabular zone 1 reliably predicted failure. THAs which have cemented acetabular components have a higher rate of failure than that of cementless procedures. This may be due simply to imperfect surgical technique. It is possible to reduce the risk of acetabular radiolucenty in zone 1 by careful cementing.

Wear is increased in cementless and cemented metal-backed acetabular components. The relationship between acetabular wear and radiolucenty in DeLee and Charnley zone 1 (p = 0.0339) suggests that patients with radiolucenty are more likely to develop wear associated with loosening. Garcia-Cimbrelo et al. have shown that wear is related to loosening of the acetabular component and radiolucenty. In our study, however, acetabular wear was associated neither with increased radiolucenty in zone 1 nor with loosening when considered as an independent variable. In zone 1, there was a correlation between early radiolucenty, acetabular wear and loosening. In the presence of radiolucenty, especially at the periphery of the cup, an increase in wear will promote the likelihood of loosening.

Our findings confirm that the polyethylene wear associated with inadequate cementing can lead to early loosening probably because wear particles come into direct contact with the cement-bone interface. We agree with Ranawat et al. that careful selection of patients and preparation of the acetabular bed are important. Patients with protrusio acetabuli or medial osteoarthritis have a high incidence of early loosening of cemented acetabular components. Their sclerotic acetabular bone stock often leads to development of radiolucenty at the cement-bone interface. Despite the recognised limitations of first-generation cementing techniques, the Charnley prosthesis is an excellent device. Centring the distal stem, careful preparation of the acetabular bed and meticulous cementing, especially medially and distally in zone 5, may increase the chances of survival of the femoral and acetabular components.

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


