SUBSIDENCE OF THE FEMORAL COMPONENT
RELATED TO LONG-TERM OUTCOME OF HIP REPLACEMENT

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From King Edward VII Hospital, Midhurst

We compared the clinical outcome with femoral subsidence and radiographic changes in 102 patients at 9 to 13 years after low friction arthroplasty.

In 92 cases with a satisfactory outcome there was an average of 2.3 radiological signs and mean subsidence of less than 5 mm. An unsatisfactory outcome was associated with 3.4 signs per film and with subsidence of more than 5 mm. The radiological signs we describe are often the hallmark of successful load transmission, but if they increase with time or are associated with subsidence of over 5 mm, then clinical failure is likely. Fracture of the cement tip is associated with increased subsidence and adversely affects the long-term clinical outcome.

Some cemented prostheses with smooth tapered stems are designed to subside within the cement mantle if this is necessary to take up a more optimal position for load transmission. In fact, in the first year after implantation, small amounts of prosthetic subsidence do occur (Loudon and Charnley 1980; Chafetz et al 1985), and in increased amounts if associated with the development of radiological signs in the proximal femur and at the bone-cement interface. The sign which is associated with the greatest amount of subsidence (an average of 4 mm at one year) is fracture of the cement tip (Loudon 1986). After one year, subsidence may continue, but usually at a reduced 'stable' rate; this is not necessarily a cause of symptoms at five years. Breakage of the prosthetic stem is also associated with subsidence (Loudon 1986).

We report a study of 102 primary low friction arthroplasties, inserted at the King Edward VII Hospital, Midhurst by the late Professor Sir John Charnley between 1969 and 1972. The series includes only the patients surviving at 9 to 13 years and reports the relationship between measured subsidence, radiological signs and clinical outcome in this group.

Table 1. Radiological signs recorded in the survey

1. Fracture of cement at the tip of the prosthesis
2. Resorption of the medial femoral neck (rounding-off osteoporosis)
3. Destruction of the medial femoral neck (full thickness loss of height)
4. Demarcation at the bone-cement interface
5. Gap between the convex prosthesis border and the cement
6. Femoral shaft hypertrophy

METHODS

The clinical outcome was assessed by one author (MWJO), using the Charnley modification of the Merle d'Aubigné and Postel (1954) grading for pain, function and range of movement. Radiographs were taken and studied to assess the presence or absence of one or more of six radiological signs (Table I; Figs 1 to 3). A single exposure was made with the beam centred on the pubic symphysis and the leg in neutral rotation. The films were assessed by the other author (JRL) and compared with films taken at hospital discharge about two weeks after operation, and at one year. Where revision had been performed the last available film before revision was also examined. In the four cases of stem breakage the last available radiograph was the one-year film.

Subsidence. Subsidence of the femoral prosthesis was

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measured as described by Loudon and Charnley (1980). The method measures the level of the tip of the prosthesis within the femoral canal relative to the entry point of the double longitudinal wires used for trochanteric reattachment. Comparison of sequential films gives the amount of subsidence in relation to the two-week ‘hospital discharge’ film.

Radiological loosening was defined as an obvious change in the position of the prosthesis, relative to the cement or bone, associated with increasing radiological signs and especially widening, demarcation, or the appearance of cement fractures (Fig. 1b).

**Clinical outcome.** The clinical outcome was deemed *satisfactory* when the patient had minimal or no pain (grade 5 or 6) with function satisfactory to the patient (usually grades 5 or 6) and with the prosthesis in situ. An *unsatisfactory* result was recorded when the prosthesis had been revised or removed, or when it was unacceptably painful, or had unsatisfactory function, but was still in situ because the patient’s general health did not allow revision.

**RESULTS**

**Clinical outcome.** At one year, all 102 prostheses had been functioning satisfactorily. By 9 to 13 years, 10 had become unsatisfactory. Of these, seven had been revised (four for stem breakage and three for loosening) and three were radiologically loose and unacceptably painful, but in patients who were medically unfit for revision.

**Cement tip fracture.** Fracture of the cement at the tip of the prosthesis (Fig. 1a) appeared within a year of operation in 29 cases, and after this in a further 13, giving a total of 42. The presence of such a fracture had an adverse influence on the clinical result at 10 years (Table II). Thus, of the 42 cases, six had been revised (stem breakage 3, loosening 3), and two were symptomatically loose. This left 34 prostheses with cement tip fracture and a satisfactory long-term clinical result, but 10 of these showed full thickness loss of the medial femoral neck (destruction), with corresponding loss of support for the local cement and prosthesis (Fig. 2b).

By contrast, where no cement tip fracture was seen (60 cases), only one hip had been revised for breakage and one was symptomatically loose, leaving 58 of the 60 prostheses functioning well. Six of these, however, showed destruction of the medial femoral neck (Table II).

In summary, at 9 to 13 years, outright clinical failure had occurred in 19% of patients with cement tip fracture and there was apparent loss of support for the proximal part of the prosthesis in a further 30% of the clinically satisfactory results. By comparison, only 3% of the prostheses without cement tip fracture showed clinical failure, with only 10% of the clinically satisfactory hips showing radiological loss of medial support for the prosthesis.

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**Table II.** Fracture of the cement tip related to clinical outcome

<table>
<thead>
<tr>
<th></th>
<th>Fracture</th>
<th>No fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>42</td>
<td>60</td>
</tr>
<tr>
<td>Revised</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Symptomatically loose*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>34</td>
<td>58</td>
</tr>
<tr>
<td>Destruction of the medial femoral neck</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

*see text
**Subsidence.** The measured subsidence in relation to the long-term clinical outcome is shown in Figure 4, with mean values in Table III. There are three groups:

A) Satisfactory, without cement tip fracture (58)
B) Satisfactory, with cement tip fracture (34)
C) Unsatisfactory (revised or loose) (10)

Statistical analysis, using the t-test, showed highly significant differences in subsidence between the clinically unsatisfactory group (C), and the satisfactory group without cement tip fracture (A) \(p < 0.001\), the satisfactory group with cement tip fracture (B) \(p < 0.001\), and both combined (A + B) \(p < 0.001\).

Subsidence of over 5 mm was seen in 14 of the 92 clinically satisfactory prostheses compared with 8 of the 10 unsatisfactory prostheses. Fisher’s exact test showed a very highly significant statistical difference \(p < 0.0001\). The pattern of long-term mean subsidence is shown in Figure 5.

**Radiological signs.** The radiological signs recorded are shown in Table IV in relation to the clinical outcome. By 9 to 13 years every prosthesis had one or more of the six radiological signs, irrespective of the outcome. More signs were seen on the films of those with an unsatisfactory clinical result, but the numbers in the clinically unsatisfactory group (10) were too small to show a statistical difference.

**DISCUSSION**

We have not reported a consecutive clinical series, but attempted to correlate the long-term clinical result in relation to the subsidence of the femoral component and the radiological signs. It should be pointed out that all the replacements used the original thin ‘roundback’ prosthesis without a dorsal flange.

Scrutiny of postoperative films can be helpful to the clinician, but the radiological signs have to be interpreted with care. All of the 92 implants surviving 9 to 13 years showed some of our radiological signs, the average being 2.3 per film. These signs can therefore be compatible with satisfactory long-term function, although the ‘unsatisfactory’ prostheses tended to show a higher number of signs (3.4 per film). Any implant which shows an increasing number of these signs is best viewed with suspicion.

Prosthetic subsidence needs separate consideration. The ‘male’ prosthesis is designed to slip or subside within the ‘female’ cement mantle and only a small amount of subsidence may be needed for load transmission (McLeish 1977). Such small amounts, of the order of 1 to 2 mm, are known to occur (Loudon 1986). There is evidence to suggest that radiological signs develop because the prosthesis subsides, so it can be argued that in the absence of infection these signs are simply a reflection of successful load transmission. At one year after implantation, prostheses associated with radiological signs have been shown to have subsided by signifi-
cantly more than prostheses without such signs: the mean subsidence in 80 prostheses with signs was 2.27 mm and in 20 without 0.54 mm (p < 0.01) (Loudon 1986).

An indication that the load transmission may be imperfect, though still functioning, is the appearance of fracture of the cement tip, seen in 40% of our series by 9 to 13 years. This sign shows ‘end-bearing’: the load is transmitted mainly through the length of the prosthesis to its tip. The load is then received predominantly by the cement and bone around the tip of the prosthesis, leading not only to cement tip fracture but also to ‘physiological’ hypertrophy of bone in this area (Table IV, Fig. 3b) (Blacker and Charnley 1978). Meanwhile, the defunctioned upper femur develops osteoporotic resorption (Table IV, Fig. 3a) (Bocco, Langan and Charnley 1977).

Fracture of the cement tip is associated with subsidence of 4 mm or more (Loudon and Charnley 1980). This brings the prosthesis into more intimate contact with the cement sheath proximal to the tip; in about 80% of cases this is enough to impede further progress (Fig. 4). However, this subsidence also allows the possibility of contact between the concave undersurface of the femoral prosthesis (with its sharp ‘minicollar’) and the osteoporotic medial femoral neck (Fig. 2a). The result is an increased rate (threelfold in our series) of destruction of the medial femoral neck (Fig. 2b). Therefore, the possibility that the prosthetic stem may break is higher in the patient with satisfactory function, but with cement tip fracture.

In 20% of cases with cement tip fracture, subsidence appears to continue, presumably at the expense of the proximal cement. Our study indicates that the risk of an unsatisfactory result, due to stem breakage or loosening, is greatly increased by subsidence beyond 5 mm (Table III) though this is not inevitable (Fig. 4). Thus, while small amounts of subsidence are inevitable, indeed

**Table III.** Subsidence related to clinical outcome at 9 to 13 years

<table>
<thead>
<tr>
<th>No cement tip fracture</th>
<th>Cement tip fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfactory</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>Number</td>
<td>58</td>
</tr>
<tr>
<td>Subsidence in mm</td>
<td>2.01 (1.30)</td>
</tr>
<tr>
<td>Number with subsidence</td>
<td>1</td>
</tr>
<tr>
<td>over 5 mm</td>
<td>13</td>
</tr>
</tbody>
</table>

**Table IV.** Radiological signs related to clinical outcome at 9 to 13 years

<table>
<thead>
<tr>
<th>Number of hips</th>
<th>Satisfactory</th>
<th>Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>No signs</td>
<td>92</td>
<td>10</td>
</tr>
<tr>
<td>Cement tip fracture</td>
<td>34</td>
<td>8</td>
</tr>
<tr>
<td>Gap at convex border</td>
<td>34</td>
<td>7</td>
</tr>
<tr>
<td>Resorption of medial femoral neck</td>
<td>58</td>
<td>3</td>
</tr>
<tr>
<td>Destruction of medial femoral neck</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Demarcation</td>
<td>44</td>
<td>8</td>
</tr>
<tr>
<td>Femoral shaft hypertrophy</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>Number of signs</td>
<td>231</td>
<td>34</td>
</tr>
<tr>
<td>Average number per hip</td>
<td>2.3</td>
<td>3.4</td>
</tr>
</tbody>
</table>

necessary for this system, movement beyond about 5 mm is at the expense of the cement column, which is split, or fractured from within, producing either loosening, or damage to the medial femoral neck which may lead to stem breakage due to loss of support.

The prostheses we studied were inserted between 1969 and 1972 and were the ‘roundback’ model. Since then, the design has been modified to include a dorsal flange along the convex border of the prosthesis. This flange sits outside and on top of the cement and engages the whole column under load. A previous study of 75 flanged prostheses, showed no cases of cement tip fracture at one year (Loudon and Charnley 1980); subsidence was reduced compared with the roundback models. We therefore await the 10-year clinical results for the flanged prosthesis with considerable interest.
Conclusions. All prostheses which employ a tapered male-female system subside a little (2 mm) and develop one or more radiological signs, but this is compatible with a long-term satisfactory result. However, if end-bearing causes cement tip fracture, there will be increased subsidence (4 mm) bringing the prosthesis into contact with the proximal cement. If there is no further progress, the clinical result is likely to be satisfactory, although there will be an increased incidence of medial femoral neck damage. Subsidence of more than 5 mm indicates that the remaining cement proximal to the tip cannot resist the load; an unsatisfactory long-term outcome is likely from stem breakage or loosening.

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REFERENCES