HYDROXYAPATITE COATING OF AN ACETABULAR PROSTHESIS

EFFECT ON STABILITY


From the Royal London Hospital, London, England

We report the radiological and clinical outcome of a press-fit (SLF) acetabular component at two to three years in two groups of patients having primary total hip replacement. In 69 the implant was coated with hydroxyapatite (HA) and in 40 it was uncoated. The stability of the cup was assessed by measurement of proximal migration and change in the angle of inclination.

The clinical results in the two groups did not differ significantly, and the mean proximal linear wear was similar in both. Fewer radiolucent lines (RLLs) were seen on the radiographs of cups coated with HA.

The mean proximal migration was studied by calculating regression lines for each patient using migration measurements: for the SLF+HA group the mean slope was 0.06 mm/year and for the SLF–HA group 0.20 mm/year (p = 0.22). The change in the angle of inclination during follow-up was also consistently smaller in HA–coated cups. Using regression methods the SLF+HA group had a mean slope of 0.08°/year and the SLF–HA group 0.44°/year (p = 0.023).

Partial HA coating appeared to have no effect on the clinical outcome or on the rate of wear of polyethylene, but there was a trend towards a reduced rate of proximal migration, and a significant reduction in rotational migration and the number of radiolucent lines. This suggests that HA coating enhances the stability of this acetabular component.

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There is controversy about the use of hydroxyapatite (HA) coating on the acetabular component of a hip prosthesis. Its osteoconductive properties are well documented (Geesink, de Groot and Klein 1988; Furlong and Osborn 1991) and it has been found to increase contact with host bone in a stable implant by stimulating bone to close gaps of up to 3 mm (Søballe et al 1991; Stephenson et al 1991). In an animal model HA coating of an initially unstable implant allowed conversion of a fibrous tissue membrane to bone when controlled micromotion was discontinued (Søballe et al 1993a). These potential benefits of HA coating must be weighed against the possible hazards: these include separation causing third-body wear and subsequent accelerated osteolysis and aseptic loosening (Bloebaum and Dupont 1993; Bloebaum et al 1994). The use of HA coating is more expensive.

Several authors have reported satisfactory early clinical results with HA-coated hip prostheses (Geesink 1990; D’Antonio, Capello and Jaffe 1992). HA coating has been found to decrease subsidence of the femoral stem at one (Kroon and Freeman 1992; Søballe et al 1993b) and two years (Scott and Freeman 1993). These short-term studies have shown that increased early prosthetic migration correlates with an increased rate of aseptic loosening for both the femoral component of replaced hips (Freeman and Plante-Bordeneuve 1994; Karrholm et al 1994) and the acetabular prosthesis (Freeman and Plante-Bordeneuve 1993; Stocks, Freeman and Evans 1995).

Our aim was to determine the effect of HA coating on the clinical result, radiolucent lines, change in the angle of inclination and the proximal migration of an acetabular component at a follow-up of up to three years.

PATIENTS AND METHODS

We first implanted the SLF acetabular cup, which is manufactured in cobalt chrome as a press-fit prosthesis (Corin
Medical, Cirencester, UK), in November 1988. The same cup became available with HA coating in March 1990 (Fig. 1). Between May 1989 and October 1992 we implanted SLF cups in 111 patients undergoing total hip replacement (THR), 40 without (SLF–HA) and 71 with HA coating (SLF+HA). From March 1990 to March 1991 the two types of component were used contemporaneously and the allocation of patients to either group was determined by the availability of different sizes of component and other random variables.

Two cups were revised from the HA-coated group, one for infection at four months after the operation and one at seven months for recurrent dislocation. These hips were excluded leaving 69 for review in the HA-coated group. Table I gives the details of the two groups.

The HA coating is applied by plasma spray to the shot-blasted roughened surface of the outer face of the cup (Plasma Biotal Ltd, Tideswell, UK) in a thickness of 80 to 120 μm. The characteristics of the HA coating (as determined by the Division of Physics, Staffordshire Polytechnic, UK) are as follows: purity >98% hydroxyapatite; crystallinity >75%; shear strength (in vitro) 20 to 40 MPa.

The SLF cup has an ultra-high-molecular-weight polyethylene liner with an internal diameter of 28 mm, which articulates with a cemented or uncemented Freeman stem (Corin Medical). This stem allows the retention of some of the femoral neck (Albrektsson et al 1987). In 27 of the 69 HA-coated cups and in nine of the 40 non-coated cups we used an alumina ceramic head instead of the standard cobalt-chromium head. In patients over 60 years of age a cemented femoral stem was usually preferred, but the choice of stem was independent of the type of acetabular component.

The acetabulum was approached by the anterolateral route (Stephenson and Freeman 1991). The technique of implantation was the same as that used for other similar prostheses since 1978. The approach, the indications for operation and the postoperative management were the same for both groups and were unchanged throughout the period of the study. After operation patients with cemented stems were mobilised on crutches fully weight-bearing as tolerated for six weeks and those with uncemented stems were on crutches partially weight-bearing for six weeks and then fully weight-bearing for another six weeks.

Follow-up examinations at six months and at one, two and three years postoperatively were performed by orthopaedic surgeons other than the authors. These included assessment of pain and walking ability using standard proformas for data collection. Standard radiographs were taken and analysed for vertical migration using the method.
of Nunn et al (1989). These measurements were made by a technician blinded to the presence of HA coating and to prior results (Stocks et al 1995). The angle of inclination of the acetabular component was determined from each radiograph in an inverse manner by drawing a line through the central peg and the centre of the hemisphere of the component, then using the inter-teardrop line as a horizon (Fig. 1b). The angle formed by these lines was subtracted from 90° to give the inclination angle. The accuracy of this measurement is influenced by differences in projection, as is vertical migration, but is not changed by differences in magnification. On the basis of repeated radiographs with varying projections, the reproducibility of the measurement of the angle of inclination was estimated to be approximately 3°.

Analysis of the radiolucent lines (RLL) about the acetabulum was performed by two of the authors (GWS and TM) using the three zones described by DeLee and Charnley (1976), and also the parallel surfaces of the peg. Initially, all available radiographs were analysed for RLLs, but since the width of an RLL is difficult to establish accurately before a sclerotic line appears, the results of the follow-up examinations up to one year were regarded as unreliable. The RLL results are therefore recorded only for radiographs taken between two and three years after operation.

Polyethylene wear was measured by comparing the postoperative radiograph with that taken three years later, using a digitiser to record the vertical distance from the centre of the prosthetic head to the top of the cup. This wear analysis of patients with three-year radiographs included 28 with SLF–HA and 15 with SLF+HA.

**Statistical methods.** Migration data were analysed as described by Stocks et al (1995). The difference in migration and the change in the angle of inclination between the two groups were compared by calculating regression lines fitted to each hip and then recording the means of these slopes of migration and changes in angle. The six-month value was taken as the starting point to discount the known increased migration during the immediate postoperative period caused by bedding-in of the implant.

**RESULTS**

**Clinical outcome.** No cups have been revised for aseptic loosening. The clinical results did not differ significantly between the two groups as judged by the requirement of analgesics for pain and the ability to walk continuously for at least 30 minutes (Table II).

**Stability.** Table III gives the mean vertical migration for each group at each follow-up calculated using regression lines derived from the straight line fitted to each hip with at least three migration measurements (Fig. 2). The mean migration rate of the SLF–HA group was 0.20 mm/year and of the SLF+HA group 0.06 mm/year; this difference was not statistically significant (t-test, p = 0.22). The 95% confidence interval (CI) for the difference between the groups is −0.36 to +0.09 mm/year. The inclusion of the length of follow-up or the migration level at six months did not affect the results nor were they statistically significant predictors of the rate of the migration. The choice of bearing surface, whether a metal or ceramic femoral head, also made no difference to the migration rates of either group.

The mean immediate postoperative angle of inclination of the cups was 37.8 ± 6.8° (SD) for the SLF+HA cups and 202 T. MOILANEN, G. W. STOCKS, M. A. R. FREEMAN, ET AL

![Fig. 2](image_url)

The mean vertical migration (mm ± SEM) for the SLF–HA and SLF+HA groups as calculated from the mean slopes of the straight lines fitted to each hip (t-test, p = 0.22).

<table>
<thead>
<tr>
<th>Follow-up time</th>
<th>SLF-HA</th>
<th>SLF+HA</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mth</td>
<td>0.09 ± 1.02</td>
<td>0.07 ± 0.96</td>
</tr>
<tr>
<td>1 yr</td>
<td>0.26 ± 1.15</td>
<td>0.12 ± 1.09</td>
</tr>
<tr>
<td>2 yr</td>
<td>0.58 ± 1.30</td>
<td>0.31 ± 1.42</td>
</tr>
<tr>
<td>3 yr</td>
<td>0.51 ± 1.47</td>
<td>0.24 ± 1.62</td>
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</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>36</th>
<th>38</th>
<th>29</th>
<th>30</th>
</tr>
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<tbody>
<tr>
<td>SLF-HA</td>
<td>36</td>
<td>63</td>
<td>52</td>
<td>28</td>
</tr>
</tbody>
</table>

**Table III.** The mean vertical migration (mm ± so) for both groups over three years.
38.5 ± 6.2° for the SLF–HA cups. At follow-up the angle had changed by more than 3°, which we considered to be the reproducibility of our measurements, in 13 of the 40 SLF–HA cups; in all but one the change was towards a more open position. Of the 69 HA-coated cups, eight had a change of more than 3°, in seven towards an increasing angle. The two cups which changed their position towards a more closed position were both initially placed at an angle of inclination of 31°.

The mean change in inclination angle (degrees ± SD) from the postoperative value in both groups over three years is shown in Table IV.

Table IV. The change in inclination angle (degrees ± SD) from the postoperative value in both groups over three years.

<table>
<thead>
<tr>
<th></th>
<th>Postop value</th>
<th>6 mth</th>
<th>1 yr</th>
<th>2 yr</th>
<th>3 yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLF-HA</td>
<td>38.5 ± 6.2</td>
<td>1.1 ± 1.6</td>
<td>1.5 ± 2.1</td>
<td>2.3 ± 2.1</td>
<td>2.3 ± 2.9</td>
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<tr>
<td>Number</td>
<td>40</td>
<td>36</td>
<td>38</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>SLF+HA</td>
<td>37.8 ± 6.8</td>
<td>0.4 ± 1.4</td>
<td>0.2 ± 1.7</td>
<td>0.6 ± 2.3</td>
<td>0.3 ± 2.0</td>
</tr>
<tr>
<td>Number</td>
<td>69</td>
<td>65</td>
<td>63</td>
<td>54</td>
<td>29</td>
</tr>
</tbody>
</table>

The mean change in the angle of inclination (degrees ± SEM) for the SLF–HA and SLF+HA groups as calculated from the mean slopes of the straight lines fitted to each hip (t-test, p = 0.023) is shown in Fig. 3.

Wear. Vertical linear wear was measured in 28 hips of the SLF–HA and in 15 of the SLF+HA group at three years. We found no statistically significant difference between the two groups; 0.10 ± 0.17 mm for the SLF–HA group and 0.07 ± 0.19 mm for the SLF+HA group (t-test, p = 0.61). The 95% CI was –0.87 to 0.15 mm.

Radiolucent lines. The interpretation of the RLL data is modified by the fact that the SLF component subtends an angle less than a hemisphere (140°) and that it has two superolateral flanges and a central peg. Zones 1 and 3 are narrower than in conventional cups and zone 1 is partly obscured by flanges (Fig. 1b). Zone 2 has the peg in it, but the RLL appearance around the peg was recorded separately. Table V gives details of RLLs greater than 1 mm on two-year or three-year radiographs, few of which were detectable on the postoperative films. After they had appeared at between six months to two years, we saw no progression during the remaining short period of follow-up. In the SLF–HA group there were eight patients with RLLs; three had lines in zones 2 and 3, four had lines in zone 3 only and one had an RLL along one side of the peg. In the SLF+HA group only three patients had RLLs, all in zone 3. The difference between the groups was significant for the total number of hips with RLLs and for RLLs in zones 2 and 3 (Fisher’s exact test, p < 0.05).

DISCUSSION

Our study was not a prospective randomised trial but a retrospective review of data collected prospectively on two groups which, for the most part, did not have the prosthesis implanted contemporaneously. The strength of a cohort comparison tends to be inferior to that of a prospectively randomised trial, and a strict review of the study cohorts is essential before any conclusions can be drawn. Table I shows that the patients in the SLF+HA group were slightly younger and that there was a significantly larger proportion

Table V. The number of radiolucent lines (RLL) >1 mm at two or three years in both groups.

<table>
<thead>
<tr>
<th>RLL</th>
<th>Number of patients</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Peg wake</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLF-HA (n = 30)</td>
<td>8</td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>SLF+HA (n = 52)</td>
<td>3*</td>
<td>0</td>
<td>0*</td>
<td>3*</td>
<td>0</td>
</tr>
</tbody>
</table>

* p < 0.05, Fisher’s exact test
with post-traumatic and other conditions as an underlying diagnosis. We used no other cementless implants during the time of this study and the one-year overlap in the period of implantation can therefore be used to study the possibility of patient selection between the groups. During the 13 months from March 1990 to March 1991, 34 cementless cups were implanted, 17 in each group. All 17 in the SLF–HA group were in patients with osteoarthritis with a mean age of 65.5 years. The SLF+HA patients had a mean age of 57.9; 13 had osteoarthritis, three rheumatoid arthritis and one a hip problem after injury. The higher proportion of post-traumatic and other disorders in SLF+HA patients was not due to patient selection but to a higher incidence of patients with such diagnoses during the period of implantation of SLF+HA. We believe, however, that this difference in underlying diagnosis and age does not prevent a clinical or radiological comparison of the groups.

The short-term clinical outcome as measured by the absence of pain requiring analgesia and the ability to walk continuously for at least 30 minutes is similar in the two groups. The outcome is satisfactory, unremarkable and comparable with other studies on similar implants (Geesink 1990; Soballe et al 1993b). We do not use hip scores because the quantification of non-numerical data has little meaning (Johnston et al 1990; Bryant et al 1993) and we have not described the range of movement since this is not relevant to prosthetic fixation and has little to do with patient satisfaction (Levack et al 1988; Wright, Rudical and Feinstein 1994).

Radiologically, HA-coated cups had fewer RLLs in zones 2 and 3 than non-coated cups. Huracek and Spirig (1994) also found that HA coating markedly reduced the number of RLLs around an acetabular implant. We did not observe any progression of the RLLs but this may be due to the shortness of follow-up. The narrow, non-progressive RLLs are not necessarily associated with loosening of the implant, but probably indicate fibrous rather than bony union between the implant and bone. Thus, the fewer RLLs in HA-coated implants may indicate better bonding to bone.

In contrast to the presence of partial non-progressive RLLs, early migration has been shown to predict later aseptic loosening of the acetabulum (Stocks et al 1995) and has been associated with a worse clinical outcome (Krismer et al 1994). Roentgen stereophotogrammetric analysis (RSA) has the best accuracy (0.15 mm) for measurement of the vertical migration of the acetabulum (Mjöberg et al 1986), but cannot be used for large series of patients because of its complexity and cost. Our information on vertical migration was obtained by the method of Nunn et al (1989) which measures the distance from the centre of the prosthetic head to the inter-teardrop line with an accuracy of ±2 mm. This relative inaccuracy does not preclude use of the method when comparing means of large groups, and the measurement of proximal migration from standard radiographs will provide sufficient accuracy for clinical follow-up (Stocks et al 1995).

The mean figures for migration of 0.31 mm for SLF+HA and 0.58 mm for SLF–HA at the two-year follow-up compare well with previous reports on uncemented acetabular components. Using RSA a mean two-year migration of 1.3 mm was reported for a threaded design (Snorrason and Kärholm 1990) and 0.3 mm for a press-fit (Önsten et al 1994). Krismer et al (1994) compared the migration of porous-coated and HA-coated implants. They used the EBRA method, which measures migration from plain radiographs by computerised calculations, and found longitudinal migration of 0.5 mm and –0.1 mm after two years for porous-coated and HA-coated implants, respectively. This study was a comparison of two different designs, however, and the difference in migration cannot be attributed conclusively to HA coating.

Table III shows a tendency towards less migration in HA-coated cups and in the calculated mean migration based on regression lines fitted to each hip (Fig. 2); this difference was not statistically significant. The better stabil-
clinically successful cemented joint replacements.

**Conclusions.** We found no major differences in the early clinical performance of HA-coated compared with the uncoated press-fit cups. The vertical migration and the vertical linear wear as measured from the radiographs showed no statistical differences between the groups. If HA particles were shed from the coated group they did not accelerate polyethylene wear. The changes in the angle of inclination and the fewer RLLs during follow-up, however, may indicate a slightly improved stability and closer bonding to bone of the HA-coated acetabular cups.

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**REFERENCES**


