Long-term results of the cementless porous-coated anatomic total hip prosthesis

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Between January 1984 and January 1986, 131 porous-coated anatomic total hip replacements were performed in 119 consecutive patients. Of these, 100 patients (110 hips) who were alive at a minimum of 18 years after replacement were included in the study. The mean age of the patients at surgery was 48.4 years and that of surviving patients at the latest follow-up was 67.8 years. The mean duration of the clinical and radiological follow-up was 19.4 years (18 to 20).

The mean Harris hip score initially improved from 55 points before to 95 points at two years after operation, but subsequently decreased to 91 points after six years, 87 points after 11.2 years, and 85 points after 19.4 years. At the final follow-up, 23 hips (18%) of the entire cohort and 21% of survivors had undergone revision because of loosening or osteolysis of the acetabular component and eight hips (6%) of the entire cohort and 7% of survivors for loosening or osteolysis of the femoral component. Only four femoral components (4%) were revised for isolated aseptic loosening without osteolysis and two (2%) for recurrent dislocation. On the basis of these long-term results, the porous-coated anatomic femoral component survived for a minimum of 18 years after operation while the acetabular component was less durable. The findings identify the principles of uncemented joint replacement which can be applied to current practice.

The aim of uncemented joint replacement is to achieve better results than with cemented replacement. First-generation cementless implants were associated with a high incidence of thigh pain, aseptic loosening, stress shielding and osteolysis,1-10 but the longevity of some of the components was impressive.11,12 One first-generation cementless total hip prosthesis, the porous-coated anatomic (Howmedica, Rutherford, New Jersey) was extensively investigated in the early 1980s, and 15-year results have been reported.13

In this study, a prospective and consecutive series of patients was observed for a minimum of 18 years after primary total hip replacement (THR) with the original porous-coated anatomic implant. This consisted of a two-pronged acetabular component and a one-third porous-coated femoral component with a femoral head of 32 mm. Although the porous-coated anatomic arthroplasty has not been used for almost a decade, study of the long-term data may establish principles which could be applied to modern implants.

Patients and Methods

Between January 1984 and January 1986, 131 porous-coated anatomic hip prostheses were implanted in 119 consecutive patients by one surgeon (YHK). They were then reviewed prospectively. The size of the components is given in Table I. The study was approved by our institutional review board before the operations were done, and all patients gave informed consent. Fifteen patients (16 hips) died from unrelated causes less than ten years after the operation. All had well-functioning THRs until they died. Four patients (five hips) were lost to follow-up. The remaining 100 patients (110 THRs) were included in the study. All had radiography at a minimum of 18 years after

Table I. Components used in 131 porous-coated anatomic THRs

<table>
<thead>
<tr>
<th>Femoral component</th>
<th>Acetabular component*</th>
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<tbody>
<tr>
<td>Size (mm)</td>
<td>Number of hips</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>4</td>
<td>23</td>
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<td>5</td>
<td>28</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
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<td>7</td>
<td>8</td>
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* inner diameter 32 mm
operation. The mean clinical and radiological follow-up was 19.4 years (18 to 20).

The mean age of the patients at surgery was 48.4 years (19 to 69) and at follow-up 67.8 years (38 to 84). The presenting diagnosis was avascular necrosis of the femoral head in 62 hips (47%), fracture of the femoral neck in 27 (21%), osteoarthritis secondary to childhood septic arthritis in 24 (18%), tuberculous arthritis in five (4%), post-traumatic arthritis in five (4%), rheumatoid arthritis in four (3%) and ankylosis in four (3%).

The surviving patients were assessed clinically using the Harris hip score.14 Thigh pain was reported using a ten-point visual analogue scale with 0 indicating no pain and 10 severe pain.6 Clinical and radiological assessment was performed by a single independent observer.

The isthmus ratio as described by Dorr15 was assessed on pre-operative radiographs. Of the 131 hips studied initially, 102 were type A, 23 type B and six type C.15 The measurement of the ratio of the width of the femoral component to that of the femoral canal in the coronal and sagittal plane was performed as described by Kim and Kim.16 Definite loosening of the femoral component was defined as progressive axial subsidence exceeding 3 mm or varus or valgus migration17 and possible loosening when a complete radiolucent line surrounded the entire porous-coated surface on both the anteroposterior and lateral radiographs.17 Definite loosening of the acetabular component was defined as a change of angle, vertical or horizontal migration exceeding 2 mm or a continuous radiolucent line wider than 2 mm on both the anteroposterior and the lateral radiographs.16 Vertical migration was measured between the inferior margin of the cup and the inferior margin of the ipsilateral teardrop and horizontal migration between Köhler's line and the centre of the outer shell of the acetabular component.18

Osteolysis was recorded in acetabular and femoral zones.19,20 The extent was estimated by multiplying the longest diameter (cm) by a second diameter perpendicular to the first.

Linear wear of the polyethylene liner was measured using a software program (Auto CAD release R 13; Auto Desk Inc, Sausalito, California).21 A scan maker 9600XL flat bed imaging scanner (Auto Desk Inc) digitised the anteroposterior view of the pelvis as two-dimensional gray scale arrays of 12-bit (256 gray level) integers. The scanning resolution was 600 pixels per square inch. Wear was defined as penetration of the head into the liner and determined annually from anteroposterior pelvic radiographs. The degree of penetration on post-operative radiographs at six weeks was assigned the ‘zero’ position and wear estimated from this point.

The antversion and abduction angles of the acetabular component were recorded and correlated with wear of the polyethylene.

Statistical analysis. The data were analysed by the chi-squared test with Yates's correction, Student's two-tailed t-test, and analysis of variance.22 A regression analysis was performed to determine any correlation between independent variables and osteolysis and loosening. Kaplan-Meier survivorship analysis23 was performed with revision for any cause as the end-point. The reason for revision was loosening of the component, loss of bone stock due to osteolysis and recurrent dislocation. Greenwood’s formula24 was used to calculate confidence intervals.

Results

Table II gives details of the clinical rating. After a minimum follow-up of ten years, 86 of 116 hips (74%) and at a minimum of 18 years, 72 of 110 hips (65%) had no or only slight pain. After 19.4 years, mild thigh pain after vigorous activity was present in six hips (5%) and severe pain in eight (7%). Patients with severe thigh pain had loosening of the femoral component. The mean Harris hip score improved from 55 points before to 95 points at two years after surgery, but decreased subsequently to 91 points (55 to 100) at six years, 87 (30 to 100) at 11.2 years and 85 (45 to 100) at 19.4 years. In most cases, this could be attributed to age-related deterioration in function.

The Dorr isthmus ratios ranged from 0.29 to 0.55 which reflected the young patients in this series.

Overall, 23 acetabular components (21%) were revised after a mean of 10.6 years (6 to 20). Twenty-one, well-fixed components were removed because of extensive periprosthetic osteolysis and two because of loosening and osteolysis. Overall, ten femoral components were revised for aseptic loosening after a mean of 9.8 years (5 to 20). Four femoral components (4%) were revised for loosening and osteolysis, four undersized stems (4%) for aseptic loosening alone (Fig. 1) and two for recurrent dislocation. In surviving patients, 23 acetabular components and ten femoral components had been revised.
The mean linear wear of the polyethylene liner was 3.49 ± 0.69 mm. The mean annual rate of linear wear of the polyethylene liner was 0.18 ± 0.09 mm. In patients without osteolysis it was 0.08 ± 0.02 mm and in those with osteolysis 0.28 ± 0.09 mm. Wear of polyethylene was associated with age under 40 years (Student’s t-test, p = 0.031), male gender, (chi-squared test, p = 0.028), and acetabular components with an angle of more than 50˚ (Student’s t-test, p = 0.036). It was not associated with presenting pathology (chi-squared test, p = 0.17), weight (Student’s t-test, p = 0.16), hip score (Student’s t-test, p = 0.19), range of movement (Student’s t-test, p = 0.31) or acetabular anteverision (Student’s t-test, p = 0.38).

In the surviving patients, there was osteolysis around 59 acetabular (54%) and 44 femoral components (40%). Sixteen of 59 hips (27%) had osteolysis in zone I of the acetabulum, 13 (22%) in zones I and II, 15 (25%) in zones II and III, ten (17%) in zones I and III, and five (8%) in zone III. Twenty-seven acetabular components were revised and the remaining 32 remain under close review for osteolysis. After a minimum follow-up of ten years, 37 of 44 hips (84%) had osteolysis in zones 1 and 7 or zone 7 of the femur and seven (16%) distal osteolysis. There were no new cases of femoral osteolysis distal to the porous coating between 11 and 20 years (Table III).

The rate of survival after 20 years was 79% (95% confidence interval (CI) 0.73 to 1.0) for the acetabular and 91% (95% CI 0.86 to 1.0) for the femoral component (Fig. 2). In serial radiographs of surviving patients, 102 femoral components were ingrown with bone and eight were unstable. No stem with bone ingrowth was loose at the latest follow-up (Fig. 3).

### Table III. Location and mean size (cm²) and range of osteolysis at six, 11 and 20 years after operation

<table>
<thead>
<tr>
<th>Zone</th>
<th>6 years</th>
<th>11 years</th>
<th>20 years</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Number of hips</td>
<td>Mean</td>
<td>Number of hips</td>
</tr>
<tr>
<td>Acetabular component</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td>0.26 (0.5 to 1.2)</td>
<td>15</td>
</tr>
<tr>
<td>I and II</td>
<td>2</td>
<td>0.46 (0.4 to 0.5)</td>
<td>12</td>
</tr>
<tr>
<td>II and III</td>
<td>3</td>
<td>0.43 (0.4 to 0.6)</td>
<td>15</td>
</tr>
<tr>
<td>I and III</td>
<td>1</td>
<td>0.82 (0.6 to 2.3)</td>
<td>9</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>0.28 (0.2 to 0.4)</td>
<td>5</td>
</tr>
<tr>
<td>Femoral component</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 3 and 5</td>
<td>2</td>
<td>4.9 (2.8 to 7.4)</td>
<td>2</td>
</tr>
<tr>
<td>1, 2, 3, 6 and 7</td>
<td>3</td>
<td>6.1 (4.5 to 9.3)</td>
<td>3</td>
</tr>
<tr>
<td>3 and 4</td>
<td>2</td>
<td>1.1 (0.3 to 2.1)</td>
<td>2</td>
</tr>
<tr>
<td>1 and 7</td>
<td>7</td>
<td>5.3 (3.8 to 8.6)</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>1.7 (1.1 to 3.8)</td>
<td>30</td>
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</table>
Bojescul et al\textsuperscript{13} were impressed with the longevity of the femoral component of the porous-coated anatomic THR particularly as it was a first-generation design and was implanted by surgeons with little experience of cementless hip replacement. Only 4\% of their hips were revised for aseptic loosening and 7\% for loosening and osteolysis. The results in this series are similar which is encouraging since the patients were young and had a high incidence of avascular necrosis. In addition, an incidence of thigh pain of 13\% after 20 years with no implant removed because of pain is encouraging since the torsional stability of the implant, the benefit of more extensive porous coating into the metaphysis, and avoidance of point contact at the tip of the stem at the time of joint replacement were not appreciated.\textsuperscript{25-28} Severe thigh pain was present in eight patients (7\%) at 19.4 years and they all had loosening of the stem, probably because of axial and/or rotational movement.

The results suggest that satisfactory filling by the stem in the sagittal and coronal planes of the femoral canal are equally important. Pre-operative templating on the antero-posterior and lateral radiographs is important to obtain satisfactory filling of the femoral canal in both planes. Intra-operatively, the stability of the broach was assessed by applying rotation manually and by applying approximately 20 Nm of torque with a torque wrench.

The age and pathology of the patients in this series is very different from those in the West with about 50\% having avascular necrosis of the femoral head and 3\% having rheumatoid arthritis.

Although 29 hips (22\%) had childhood pyogenic or tuberculous arthritis, none was revised for infection. These patients had been free from infection for more than ten years pre-operatively. This supports earlier studies\textsuperscript{29-31} which suggested that freedom from active infection for ten years reduced the risk of recurrence.

The acetabular component was the major problem in the current series; 21\% of components were revised for loosening and/or osteolysis related to wear of the polyethylene liner. It is suggested that polyethylene debris caused progressive osteolysis and subsequent loosening and that this rather than failure of osseointegration was the cause of acetabular revision. Late recurrent dislocation in two patients was related to wear of the polyethylene liner.

Astion et al\textsuperscript{32} reported that osteolysis was more prevalent around acetabular components with a polyethylene liner 8.5 mm thick or less (an outer diameter of the acetabular component of $\leq 55$ mm). They observed that it was positively associated with the time since operation and predicted that osteolysis around porous-coated anatomic components would continue to increase with time. In this series 89\% of acetabular components had an outer diameter of $\leq 55$ mm. The number of cups of $> 55$ mm was too small (14) to state that the incidence of osteolysis was lower in cups of $> 55$ mm.

The high prevalence of wear and osteolysis in this series appears to be related to a thin polyethylene liner, the use of a femoral head of 32 mm and the time since operation. Osteolysis was strongly associated with an increased rate of polyethylene wear and with loosening of the femoral component ($p < 0.01$ for both). The low prevalence of distal osteolysis around the femoral stem suggests that a stem with a satisfactory filling of the femoral canal and a circumferential porous coating which extends into the proximal cortical bone limits the spread of particulate debris. The fact that osteolysis was found exclusively in the proximal femur suggests that this form of fixation limits the so-called effective joint space.\textsuperscript{33}

On the basis of these long-term results, the porous-coated anatomic femoral component survived well for 18 years, while the acetabular component was less successful. These long-term data of the porous-coated anatomic arthroplasty are useful and suggest that uncemented acetabular components with polyethylene of better quality and a better capturing mechanism, or with alternative bearing surfaces such as ceramic-on-ceramic, may provide longer lasting results.

\textbf{Discussion}

Bojescul et al\textsuperscript{13} were impressed with the longevity of the femoral component of the porous-coated anatomic THR particularly as it was a first-generation design and was implanted by surgeons with little experience of cementless hip replacement.

Only 4\% of their hips were revised for aseptic loosening and 7\% for loosening and osteolysis. The results in this series are similar which is encouraging since the patients were young and had a high incidence of avascular necrosis. In addition, an incidence of thigh pain of 13\% after 20 years with no implant removed because of pain is encouraging since the torsional stability of the implant, the benefit of more extensive porous coating into the metaphysis, and avoidance of point contact at the tip of the stem at the time of joint replacement were not appreciated.\textsuperscript{25-28} Severe thigh pain was present in eight patients (7\%) at 19.4 years and they all had loosening of the stem, probably because of axial and/or rotational movement.

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\textbf{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