Hydroxyapatite ceramic-coated femoral stems in young patients

A PROSPECTIVE TEN-YEAR STUDY

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We describe the clinical and radiological results of 38 total hip replacements (THR) using the JRI Furlong hydroxyapatite-ceramic (HAC)-coated femoral component in patients younger than 50 years. The mean age at the time of operation was 42 years (22 to 49) and the mean length of follow-up was ten years (63 to 170 months). All patients receiving a Furlong HAC THR were entered into the study regardless of the primary pathology including patients who had undergone previous hip surgery.

The mean Harris hip score improved from 44 before operation to 92 at the last post-operative review. After 12 years the cumulative survival for the stem was 100% (95% confidence interval 89 to 100). No femoral component was revised. Our results show that the Furlong HAC implant gives excellent long-term results in young patients with high demands.

The dramatic relief of pain and restoration of function afforded by total hip replacement (THR) make the procedure attractive to all patients with degenerative hip disease. In young patients there are concerns regarding wear of the bearing surface, aseptic loosening and the need for further surgery.

THR, with cement, is highly successful in the elderly and in patients with low demands, but the rates of failure have been substantially higher in the young, possibly due to their increased level of activity and greater cyclical loading of the joint.¹⁻⁴ Failure most commonly results from aseptic loosening, endosteal bone lysis and occasionally because of fatigue of the cement. Cementless implants without hydroxyapatite (HA) coating have a significant rate of failure,^{5,6} since the formation of a fibrous layer between the bone and the implant prevents osseointegration. This has been associated with thigh pain.⁷⁻¹⁰ The aim of an hydroxyapatite-ceramic (HAC) coating, first introduced in 1985, is to facilitate the formation of a biological bond between the host bone and the implant, creating a firm cementless fixation.

We have assessed the clinical and radiological outcome of the JRI Furlong HAC-coated femoral component (JRI Instrumentation Ltd, London, UK) in 33 patients (38 hips) under the age of 50 years at the time of surgery. This prosthesis is a collared modular implant made of titanium alloy. The HA coating has a crystallinity of 65% and a density of 85%. The

implant is fully coated with more than 90% pure HA to a thickness 150 µm by a plasma-spray process performed in a vacuum (Fig. 1).

Patients and Method

Between December 1988 and October 1997, 38 THRs in 33 patients (22 men, 11 women) under the age of 50 years were performed by the senior author (AJE) or under his direct supervision. The mean age at operation was 42 years (22 to 49) and the mean follow-up 10 years (63 to 170 months). The mean weight of the patients was 76 kg (46 to 105) and the mean height 159 cm (140 to 180). The mean body mass index (BMI) was 27. Eight patients were classed as being overweight (BMI > 30).

The principal diagnosis was osteoarthritis in 19 hips (50%), developmental dysplasia in ten (26%), post-traumatic arthritis in three (8%), Still's disease in two (5%), Perthes' disease in two (5%), slipped upper femoral epiphysis in one (3%) and rheumatoid arthritis in one (3%).

The JRI Furlong HAC femoral stem was used in all cases. The first 14 (37%) were hybrid using cemented polyethylene JRI cups. In the remaining 24 (63%), the JRI cancellous screw fit (CSF) HAC-coated acetabular implant was used. This component was introduced in 1991. It is hemispherical and designed to be a press fit with the HAC coating in contact with the newly-reamed bone surface. It has screw holes so that the initial fixation can be

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Fig. 1

Photograph of the JRI HAC-coated implant.

Fig. 2a

Fig. 2b

Radiographs showing osseointegration of the stem a) AP and b) lateral

supplemented by titanium screws if it is not stable at the time of insertion. With increasing experience and confidence in the rapid bonding potential of the HAC cup, screws were used less frequently. Only ten HAC sockets were fixed with screws. Any screw holes which were not used were filled with bone reamings from the acetabulum.

There were 36 ceramic heads (alumina oxide) of which 23 were 28 mm and 13 were 32 mm in diameter, and two cobalt-chrome heads, one 28 mm and the other 32 mm. All acetabula had polyethylene-bearing surfaces.

A Hardinge¹¹ approach was used for all hips. Patients were allowed full weight-bearing from the first post-operative day. A pre-operative Harris hip score (HHS) was completed for all patients.

Patients were reviewed post-operatively after six weeks and at one, five and ten years. They were examined clinically and evaluated using a visual analogue score for pain, the HHS,¹² the Western Ontario and McMaster Universities osteoarthritis index (WOMAC),¹³ the Oxford hip score¹⁴ and the Merle d'Aubigné and Postel score for pain, range of movement and function,¹⁵ and the presence of thigh pain and the level of physical activity.

Radiological assessment was carried out by all three authors independently and a consensus obtained. Antero-

posterior (AP) and true lateral radiographs were obtained at each follow-up. Peri-operative and post-operative periprosthetic fractures were noted if present. The dimensions and locations of osteolysis or radiolucencies around the acetabular components were recorded, in the three zones described by Delee and Charnley.¹⁶ The acetabular component was considered to be loose if there was a change in its position or a continuous or progressive radiolucent line around it.

The femoral components were assessed for radiolucencies or osteolysis in each of the seven zones as described by Gruen, McNeice and Amstutz¹⁷ and Goetz, Smith and Harris.¹⁸ Radiolucencies with a scalloped or cystic appearance of greater than 2 mm in width were recorded as osteolysis.

The formation of new bone in each of the Gruen zones and at the tip of the prosthesis partially or completely bridging the medullary cavity was recorded. The stability of the femoral component was assessed by a modification of the criteria described by Engh et al.⁷ Stems were defined as stable if there was evidence of osseointegration (Fig. 2) with no radiolucent lines around the stem. An implant was deemed to be unstable if there was evidence of migration.

Using revision or impending revision as the end-point, survival analysis for both the cup and stem was carried out

Fig. 3a

Fig. 3b

AP radiographs a) immediately after operation and b) at one year showing infilling of radiolucencies/demarcation lines at the acetabular bone-prosthesis interface.

using a cumulative life-table method. The confidence intervals (CI) were determined from the effective number at risk¹⁹ using the Rothman equation.²⁰

Results

All the patients attended for regular follow-up and final review. No patient was lost and the fate of every implant was known. One patient died from unrelated causes but was reviewed within one year of death.

Clinical findings. The mean pre-operative HHS was 44, which improved to 92 at the latest follow-up. The result was graded as excellent (90 to 100 points) in 26 hips, good (80 to 89) in six, fair (70 to 79) in four and poor (less than 70) in two. The mean WOMAC and Oxford scores at the latest review were 29 and 16, respectively. Using the Charnley modification of the Merle d'Aubigné and Postel hip score, at the latest follow-up the mean score for pain was 5.37, function 5.47 and range of movement 5.71. The mean visual analogue score for pain was 1.1 (0 to 5). Thirteen patients (39%) returned to sport and 16 (48%) to outdoor activity. There was no reported incidence of thigh pain at any time throughout our study.

Peri-operative complications were rare. There were no cases of infection, thromboembolism, or dislocation. There were no peri-operative fractures associated with insertion of the HAC-coated stem. One late complication occurred in one patient. A 24-year-old man with Still's disease had bilateral hip and knee replacements. He fell two years after his second THR and suffered a fracture of the mid-shaft of his right femur, at the junction of the stems of the hip and knee replacements. This was reduced and fixed by a cable/plate system. It united satisfactorily and at operation the stem was noted to be bonded. Despite his extensive surgery

he was capable of working as an office clerk and walks with one stick.

The 19 with primary osteoarthritis had a mean pre-operative HHS of 52 (31 to 55) which improved to 94 (78 to 100) at the latest review. Fourteen were graded as excellent, three good, and two fair.

The ten hips (seven patients) with dysplasia had a mean pre-operative HHS of 39 (31 to 48) which improved to 90 (71 to 100). Six were graded as excellent, two good and two fair. Previous surgery had been performed in five of these. Despite the altered anatomy we did not experience any particular difficulties in this group of patients, and there was satisfactory cover of the acetabular component without the need for additional bone graft.

Radiological review. The cemented acetabular sockets performed markedly worse than the HAC cementless prostheses regardless of the underlying pathology. At the latest review of the cemented cups, radiolucent lines were present in DeLee and Charnley zone I in three hips, in zone II in two and in zone III in one. One cup, inserted 11 years previously, had radiolucent lines in all three zones and is awaiting revision.

The uncemented HAC-coated cups have shown no radiolucent lines in any zone. Serial review of radiographs revealed infilling of new bone in any lucency present at the bone-cup interface on the immediate post-operative film. These lucencies or demarcation lines had all disappeared by one year (Fig. 3). Radiological review of the femoral components showed no continuous or progressive radiolucent lines around the stem. Osteolysis was not seen. There was no subsidence of the femoral component. At the latest review, all the stems were stable with evidence of bonding,

Table I. Cumulative life table for the JRI HAC stem

Years since operation	Number at start	Failure	Withdrawn	Number at risk	Effective number at risk	95% CI
0 to 1	38	0	0	38	38	90.8 to 100
1 to 2	38	0	0	38	38	90.8 to 100
2 to 3	38	0	0	38	38	90.8 to 100
3 to 4	38	0	0	38	38	90.8 to 100
4 to 5	38	0	1	37.5	37.9	90.8 to 100
5 to 6	37	0	0	37	37.7	90.8 to 100
6 to 7	37	0	1	36.5	37.6	90.7 to 100
7 to 8	36	0	9	31.5	36.7	90.5 to 100
8 to 9	27	0	6	24	34.6	90.0 to 100
9 to 10	21	0	2	20	32.3	89.4 to 100
10 to 11	19	0	6	16	29.5	88.5 to 100
11 to 12	13	0	6	10	25.4	86.9 to 100

Fig. 4

Survival curve for the JRI HAC stem.

Fig. 5

Survival curve for the JRI polyethylene cemented cup.

according to the criteria proposed by Engh et al.⁷ Formation of new bone extending from the femoral cortex to the tip of the stem (Gruen zone 4) was seen in every case (Fig. 2). In 13 patients some bone resorption was observed under the collar of the stem (Gruen zone 7). This did not extend below the lesser trochanter and in no case did it appear to threaten the fixation of the stem.

Revisions. There have been no revisions or impending revisions of any stem.

There have been two acetabular revisions. Aseptic loosening of a cemented polyethylene socket required revision. There was marked polyethylene wear and tissue cultures, taken at surgery, did not reveal any bacterial growth. The HAC stem was securely bonded. There were no adverse radiological features and it was left *in situ*. The latest HHS was 97 and radiological assessment has shown that the new cup has bonded.

In the second revision, the HAC-coated cup failed to bond to the acetabulum. Eighteen months after operation the position of the cup changed. It was successfully revised to another HAC-coated acetabular implant and the initial fixation augmented by screws. Tissue cultures were negative. The retrieved cup showed evidence that it had never

bonded. The latest HHS is 87 and the revised cup has bonded. The stem was securely bonded at the time of revision and left *in situ*.

Survivorship. Survivorship curves were constructed for the HAC-coated stem using the information from the cumulative life table (Table I), and both the cemented and HAC-coated cups with revision or impending revision as the end-point. Survival analysis ended when the actual number at risk dropped below ten as suggested by Murray et al¹⁹ for studies with low patient numbers.

The survivorship of the stem (Fig. 4) was 100% at 12 years (95% CI 87 to 100). The cumulative survival of the cemented cup (Fig. 5) at 12 years was 90.5% (95% CI 64.9 to 98). There were two failures of the cemented cup; one has been revised and another is awaiting operation.

The cumulative survival of the cementless cup (Fig. 6) at ten years was 96% (95% CI 75 to 99.5). One was revised 18 months after insertion as noted above. There was no evidence of impending failure in any other cementless cup.

Discussion

Most young patients in the study had excellent or good results after a minimum follow-up of five years and a mean

Fig. 6

Survival curve for the JRI HAC cementless cup.

of ten. There was survivorship of 100% for the Furlong HAC-coated femoral stem.

These results contrast with those of cemented stems in young patients. Chandler et al¹ reported a rate of failure of 57% at five years in patients less than 30 years old.

Failure was defined as revision or impending revision, migration of a component or ominous radiolucent lines. Other studies in which cemented components had been used in young patients have reported varying results, with actual or impending rates of failure of between 5% and 86% after a similar period of follow-up.^{2-4,21-24}

HAC-coated implants form a strong bond to the host bone which is comparable with the strength of the cortical bone itself.²⁵ There appears to be little reason why this bond should not be permanent. New bone grows into the HA coating on the prosthesis in about the same time that healing of a fracture occurs. Thus, within six weeks the HAC stem and socket appeared to have bonded to the host bone. Living bone replaces the HA over time and the new substitute bone grows on to the prosthesis without an intervening layer of fibrous tissue.²⁶ The radiographs show trabeculae running into the stress-bearing areas of the femoral prostheses, and spot welding is seen at the tip of the prosthesis.

There have been reports of thigh pain, suggestive of micromovement of the prosthesis, with porous-coated implants, but not those coated with HA. This varies between 4% and 22%.⁷⁻¹⁰ It has also been stated that partially HAC-coated stems have an increased radiolucency in Gruen zone 4.²⁷ We observed neither of these problems with the fully HAC-coated Furlong stem. In all our cases we saw new formation of bone and spot welding at the tip of the stem (Fig. 2). Osteolysis was not seen around the stem. It has been postulated that because of biocompatibility of the HA coating and the potential for circumferential osseous apposition, HA implants prevent debris migrating

Fig. 7

AP radiograph 12 years after operation showing osseointegration of the stem in the presence of aseptic loosening of the cemented cup.

distally between the bone-prosthetic interface.^{28,29} This may be the process which prevents osteolysis. We observed that in the same environment, with polyethylene wear particles in the joint space, the acetabular cement-bone interface showed gross signs of aseptic loosening whereas the interface bone of the HAC-coated stem was apparently impervious to the lytic process (Fig. 7). In a dog model it has been shown that HA-coated femoral implants form a protective barrier which prevents wear particles migrating distally between the bone and the implant.^{28,29} There have been concerns about the migration of HA particles into the joint space producing third-body wear.³⁰ Bauer et al³¹ compared the roughness of the femoral head and polyethylene in HA, porous and cemented hips. The HA hips had the best surface characteristics and even very sensitive techniques failed to detect HA particles within the polyethylene. The problem of third-body wear does not appear to be greater with HA implants than with porous or cemented implants.^{26,31} HA coating contributes to the stability of the implant and its degradation does not adversely affect long-term fixation.²⁶

Several studies report encouraging results with HAC-coated implants.³²⁻³⁶ McNally et al³² described 100 consecutive cases using the HAC-coated Furlong prosthesis in patients of all ages. There was a survival of the stem of 90% at ten years. If a stem had bonded it was unlikely to fail, and distal fixation did not lead to stress shielding proximally. Capello et al³³ experienced excellent results after five years with proximally coated stems in patients with a mean age of 39 years. There were no failures caused by aseptic loosening, but four stems were revised, two were revised in conjunction with revision of the cup, one for infection and one after a traumatic femoral fracture. Geesink and Hoefnagels³⁴ also reported encouraging results with a proximally HA-coated stem and fully coated threaded socket in patients under 66 years of age. The survival rate after a mean of six years was 100% for the stem and 99% for the cup. The HHS was 98 after three years.

The revision rate, including impending revision, in our series was 7.89%. Our confidence intervals are broad because of the small sample size.

There have been no revisions or impending radiological failure of the stems. All were bonded at the time of review. Our excellent results of the stem are consistent with those of other studies using partially- or fully-coated stems.³²⁻³⁶ Once the stem has achieved a biological bond with the host femur this bond is likely to be permanent.

The long-term results for cementless implants are limited³²⁻³⁵ and have a shorter follow-up than that for cemented components. In younger patients there have been problems with failure of cemented components.^{1,4,21-24} Recently, resurfacing of a hip with metal-on-metal bearing surfaces has been gaining popularity. The long-term results of these resurfacing procedures are not known³⁷ and their use may be limited by abnormalities in the anatomy of the femur or acetabulum. We present excellent clinical, radiological and survivorship results after ten years with the use of HAC components in young, active patients with varying disorders of the hip.

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