

■ HIP

Primary total hip replacement with a Furlong fully hydroxyapatite-coated titanium alloy femoral component

RESULTS AT A MINIMUM FOLLOW-UP OF 20 YEARS

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We present the extended follow-up (≥ 20 years) of a series of fully hydroxyapatite-coated femoral components used in 72 primary total hip replacements (THRs). Earlier results of this cohort have been previously published. All procedures were performed between 1986 and 1991. The series involved 45 women and 15 men with 12 bilateral procedures. Their mean age at the time of surgery was 60 years (46 to 80) and the mean duration of follow-up was 22.5 years (20 to 25). At final follow-up, the mean Merle d'Aubigné and Postel hip scores were 5.5 (4.5 to 6), 3.8 (3.5 to 5) and 3.3 (3.0 to 5.0) for pain, mobility and function, respectively. Of the patients 92% were very satisfied at the time of final follow-up.

There were seven revisions: six of the acetabular component for aseptic loosening and one of both the stem and the acetabular component for loosening due to deep infection. The survival of this prosthesis at 22.5 years with revision for any reason as the endpoint was 91.7% (95% confidence interval (CI) 84 to 99). Survival with aseptic loosening of the stem as the endpoint was 100% (95% CI 90 to 100).

This prosthesis provides pain relief in the long term. Survival of this component is comparable to the best results for primary THR with any means of fixation.

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Primary uncemented total hip replacement (THR) has become an accepted method of providing pain relief and return to function in patients with symptomatic osteoarthritis (OA) of the hip. Good medium-term results have been reported with the use of partially^{1,2} as well as fully hydroxyapatite (HA)-coated femoral components at follow-up of up to ten years.^{3,4}

A recent review identified relatively few long-term survival reports on uncemented femoral components.⁵ Only 17 unique studies were found that included a minimum of 50 patients. Two reviews of registry data comparing > 150 patients were found with follow-up periods > 15 years. A total of 16 femoral components were included, both HA- and non-HA coated. Survival rates $> 90\%$ were found for these uncemented stems.⁵

This study presents the results at a minimum 20-year follow-up of a previously reported cohort of patients treated with a fully HA-coated femoral component.

Patients and Methods

This prospective study was performed between 1986 and 1991 and includes 72 primary THRs performed in 60 patients (45 women and 15 men) using the Furlong femoral component (JRI Ltd, London, United Kingdom). This

prosthesis was used in our department for all patients in whom an uncemented THR was required. All procedures were performed by or under the direct supervision of a single surgeon (JANS). No patients were lost to follow-up.

Bilateral procedures were performed in 12 patients (four men, eight women). These were staged procedures in five patients and under the same anaesthetic in seven. The mean age of this cohort was 82.9 years (70 to 100) at the final follow-up. At the time of surgery 11 patients were < 55 years of age (Table I). All patients presented with disabling hip pain.

Surgical technique and prosthesis. All procedures were performed via a Watson Jones approach⁶ with the patient in the supine position. Each patient received three doses of prophylactic antibiotics and subsequently were allowed to bear full weight on the first post-operative day.

The Furlong femoral component (JRI Ltd) was used in all cases. This is manufactured from a titanium alloy (Ti-6Al-4V). The surface of the body and distal stem are plasma sprayed with a 200 μm -thick layer of hydroxyapatite of high crystallinity. The stem is collared and designed to achieve primary stability via a metaphyseal fit, and has a trunnion with a 12/14 Morse taper. A Furlong UHMWPE acetabular

Table I. Characteristics of the 60 patients at operation

Characteristic	
Gender (n, %)	
Male	15 (25)
Female	45 (75)
Mean age at surgery (yrs) (range)	
Males	58 (46 to 80)
Females	65 (49 to 78)
Age group (n, %)	
< 55 years	11 (18)
> 55 years	49 (82)
Bilateral procedures	12

component was used in 47 patients (59 hips) and a HA-coated threaded acetabular shell with an ultra-high molecular weight polyethylene (UHMWPE) liner (JRI Ltd) was used in 13 patients (13 hips). A modular 32 mm ceramic femoral head was used in all hips.

Follow-up. Clinical and radiological follow-up was performed at six weeks, 12 weeks, six months and 12 months post-operatively, and annually thereafter. Patients were interviewed, examined, the wound was assessed, and all medical and surgical complications were documented. Specific enquiry was made about anterior thigh pain. Clinical assessment of pain, mobility and function was performed using the Merle d'Aubigné and Postel (MDP) scoring system.⁷ Patient satisfaction was assessed using a visual analogue scale (VAS), which ranged from 0 (poor satisfaction) to 10 (high satisfaction).

Radiological review. At each visit anteroposterior (AP) and lateral radiographs of the pelvis and operated hip were obtained and reviewed by two separate reviewers (NS, CD). These were examined for changes in the position or orientation of the components as well as for evidence of osseointegration or loosening of the prosthesis.

Signs of loosening included lytic lesions (balloon-shaped lucencies around the prosthesis), migration of the implant (measured as the distance between the shoulder of the implant and the greater trochanter), radiolucent lines (RLL; linear lucencies > 2 mm at the bone-prosthesis interface⁸ and occupying > 30% of any Gruen zone⁹). Solid fixation was indicated by 'spot welding' and trabeculae of cancellous bone extending to the stem as described by Engh, Sychterz and Engh.¹⁰

Radiographs were also assessed for signs of heterotopic ossification (HO) and stress shielding of the calcar region of the femur: HO was classified according to the system of Brooker et al,¹¹ and stress shielding was considered to be significant if there was selective bone resorption of the calcar region of the femoral neck.¹²

Statistical analysis. Statistical analysis was performed using Student's *t*-test. The level of significance was set at $p < 0.05$. Survival analysis was performed using the

Kaplan-Meier method with 95% confidence intervals (CI). All analyses were performed using GraphPad software (GraphPad, San Diego, California).

Results

The mean duration of follow-up was 22.5 years (20 to 25). At the last follow-up the mean scores for the pain, mobility and function components of the MDP score were 5.5 (4.5 to 6), 3.8 (3.5 to 5) and 3.3 (3.0 to 5.0), respectively. Two patients (3.3%) were not satisfied, three (5%) were moderately satisfied and 55 (91.7%) were very satisfied with their result up to the last follow-up. The latter group had a VAS ≥ 8 . Clinical improvement was noted at the six-week follow-up and was maintained. All patients reported excellent pain relief at their last review.

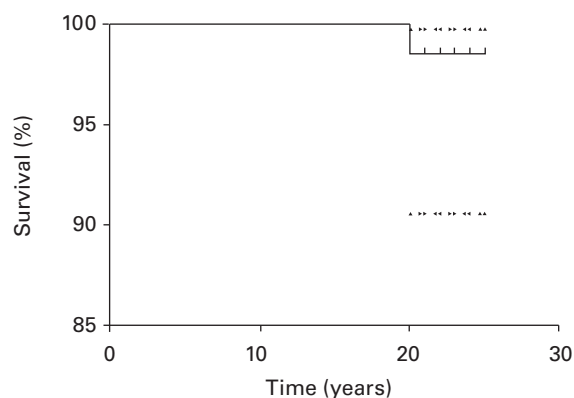
The mean MDP scores for pain, function and mobility at ten years were 5.8 (4 to 6), 5.6 (3 to 6) and 5.5 (1 to 6), respectively, and at 17 years they were 5.6 (3 to 6), 5.4 (2 to 6) and 3.8 (0 to 6), respectively. There was no statistically significant difference between the ten- and 17-year MDP scores ($p = 0.87$). Similarly, there was no significant difference between these parameters between the 17- to 22.5-year follow-up ($p = 0.82$).

In all, at the final review 17 patients (17 hips) had died: six at 20 years post-operatively, four at 21 years, three at 22 years, three at 23 years and one at 25 years post-operatively. Their deaths were not related to their hip surgery. These patients were all reviewed within a year of their deaths and were therefore included in this study. We reviewed their clinical notes as well as their radiographs and contacted their GPs to determine whether they had any complaints regarding their hips, and none were identified.

A total of seven patients (seven hips) had undergone revision surgery. This involved both components in one patient and the acetabular component alone in six. Loosening of the femoral component occurred in one patient 21 years after their primary procedure associated with deep infection. This was the patient who had both components revised and accounted for the only stem revision in this series. There were no cases of aseptic loosening of the stem in this cohort. At final follow-up one female patient was awaiting revision of the acetabular component but had a well-fixed femoral component *in situ*. There were no dislocations in this group.

Survival analysis. With revision of the femoral component for any reason as the endpoint, survival at a mean follow-up of 22.5 years was 98% (95% CI 90 to 99). With revision for aseptic loosening as the endpoint survival was 100% (95% CI 90 to 100) (Fig. 1). If we consider the endpoint to be revision for any reason, then survival of the femoral component was 91% (95% CI 88.6 to 98.9) at a mean 22.5 years follow-up (Fig. 2).

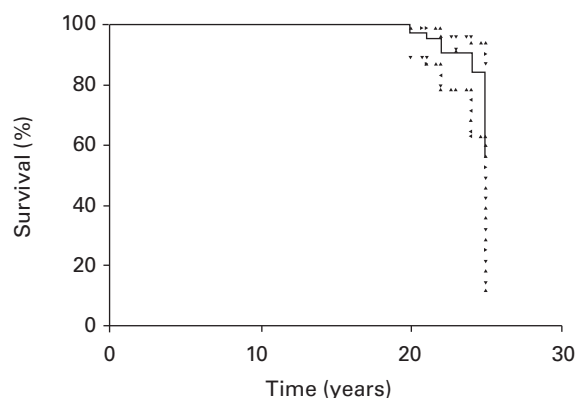
Radiological results. There were no cases of subsidence of the femoral components. Radiological evidence of solid stem fixation, including 'spot weld' formation¹² as well as an osteoblastic reaction at the stem tip, was observed in all radiographs (Fig. 3).



Time (years)	20	21	22	23	24	25
Number at risk	72	57	39	23	14	3

Fig. 1

Kaplan-Meier survival curve with 95% confidence intervals, showing revision for aseptic loosening as the endpoint.



Time (years)	20	21	22	23	24	25
Number at risk	72	57	39	23	14	3

Fig. 2

Kaplan-Meier survival curve with 95% confidence intervals, illustrating the worst-case survival scenario with all revisions considered as failures.

Radiolucent lines were seen in 19 femoral components. Of this group, 16 patients (16 hips) died at a mean of 22.0 years (20 to 23) post-operatively. One of these patients had undergone isolated revision of the acetabular component for wear and loosening two years before death. Specific enquiry of their GPs, family members and review of their notes implied no complaints regarding their hips between their last clinical review and the time of their deaths. Of the three patients who were alive, one had undergone revision of the femoral component for septic loosening and the remaining

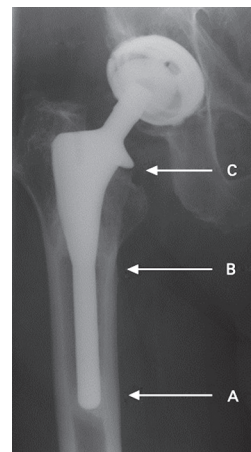


Fig. 3

Radiograph of an hydroxyapatite-coated Furlong stem at 25 years post-operatively, showing an osteoblastic reaction at the tip of the stem (A), trabeculae extending to the surface of the prosthesis (B), and localised bone resorption immediately under the polished collar (C).

Table II. Radiolucent lines around the femoral and acetabular components at the last follow-up

Zones of interest	Femoral component (patients)	Acetabular component (number of patients)
1	4	12
2	7	5
3	7	15 (zones 1, 2 & 3)
4	-	-
5	-	-
6	-	-
7	1	-

two lived independently at the time of final follow-up with no expressed concerns about their operated hips.

The radiolucent lines were predominantly present in Gruen zones 2 and 3. They were 1 mm wide and non-progressive over two years (Table II). They were not associated with pain and there were no overt signs of movement of the femoral components.

Focal areas of resorption of the calcar were noted in ten hips (Fig. 3). This feature was associated with signs of good fixation of the metaphyseal segment. These patients had no complaints that might suggest loosening of the implant. On 35 radiographs (48.6%) HO was observed. This was Brooker grade 2 or 3 in 57.1% of cases (Table III).

RLLs were noted around 29 acetabular components (40.3%). These were present in DeLee and Charnley¹³ zone 1 (12 hips), zone 2 (five hips) and zones 1 to 3 (15 hips). Five patients (five hips), all of whom had RLLs in acetabular zones 1 to 3, had mild to moderate start-up pain. However, four patients did not wish to have any further surgery because of their age, and one was awaiting acetabular revision at the time of final follow-up.

Table III. Distribution of heterotopic ossification according to Brooker et al¹¹

	Brooker grade			
	1	2	3	4
Patients (n)	6	6	20	3

**Fig. 4**

Radiograph showing an asymptomatic peri-prosthetic fracture at 25 years post-operatively.

Complications. There were four calcar fractures that occurred at the time of the original surgery. These were treated with cerclage wires in one hip and conservatively in three hips. All patients with these fractures were mobilised non-weight-bearing with crutches for the first six weeks after their procedure. This included the one patient who developed a deep infection 21 years after surgery, which was successfully treated with a two-stage revision. No patients reported anterior thigh pain.

At the final follow-up a peri-prosthetic fracture was noted in an asymptomatic male patient (Fig. 4) who, on enquiry, had no history of trauma or pain. The femoral stem was well fixed radiologically and there were no clinical signs of pain or impaired mobility. The time and cause of this injury remains uncertain.

Discussion

Our results represent those of a non-designer surgeon series. They suggest that HA-coated fixation remains reliable and predictable in the long term, even as the patient ages and the corticomedullary ratio of the femur increases.¹⁴ The fact that HA is soluble *in vivo* and possibly delaminates does not seem to affect long-term survival.¹⁵

Good long-term results of primary THR using fully HA-coated titanium stems have been reported in young as well as older age groups.^{3,16-22} Similar results have been reported when these stems are used in the revision setting.²¹ Previous

reports of the Furlong femoral component in primary THR have been encouraging, with survival rates of 100% and 97.4% at ten and 17 years, respectively.^{3,22} In this now extended series, survivorship of the remaining femoral components with aseptic loosening as the endpoint at a mean 22.5-year follow-up is 100% (Fig. 1). If all revisions including those for the acetabulum and revision for infection are considered to be failures, then survivorship is 91%.

The mobility and functional components of the MDP score show a gradual deterioration from ten to 22.5 years, whereas the pain score shows that pain relief continues to be sustained. We believe this reflects an age-related decrease in general function and mobility. This change was not statistically significant at any of the three measured time points up to a mean of 22.5 years. It is likely that the lack of pain contributed to the high levels of satisfaction reported by 96.7% of this cohort.

All femoral stems showed signs of stable fixation (Fig. 3). Although focal areas of bone resorption were noted in the calcar region immediately adjacent to the collar in ten patients (Fig. 3), this did not correspond to pain or decreased function. This may possibly relate to localised stress shielding of the calcar region immediately adjacent to the collar after full bonding of the bone to implant had occurred. RLLs were noted around acetabular components in 29 patients (29 hips), which in 52% involved zones 1 to 3.

High early revision rates for uncemented primary THR are thought by some to be due predominantly to peri-prosthetic fractures occurring during stem insertion.²³ Our patients experienced four such fractures but recovered without sequelae. Merle et al⁵ alluded to the paucity of true long-term results for uncemented stems. They found good to excellent results with these components at a minimum of 15 years, and suggested that this technique of fixation is reliable and should become a standard treatment option in appropriate patients.

The 2010 report of the Swedish Hip Registry found no significant differences between cemented and uncemented fixation regarding the risk of revision, irrespective of cause.²³ Data from the ninth report of the United Kingdom National Joint Registry²⁴ suggest that the use of uncemented components is increasing but is associated with a higher revision rate for uncemented components in the first ten years. The lowest revision rates up to this point have been found for cemented components. Between four and eight years the revision rates for uncemented components with the ceramic-on-polyethylene bearing couple have been the lowest of all combinations of uncemented components. Data from the Swedish registry demonstrates that after the nine- to ten-year period the failure rate for cemented components surpasses that for uncemented components.

There are several limitations to this study. The sample size is small, as the number of patients who remained alive has decreased. No pre-operative MDP scores were recorded. However, our database provides an accurate record of scores from the time of surgery, and the VAS was consistently used as a patient-reported tool to augment our clinical data.

Our cohort reported significant improvements in pain, mobility and function in their early post-operative phase that has been maintained at the ten-, 17- and now 22.5-year follow-up. There were no cases of aseptic loosening of the femoral component. These results are comparable to the best long-term outcomes in terms of both survival of the component and maintained clinical results for primary THR with any means of fixation of the femoral component.^{20,23,25-27}

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