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ORIGINAL STUDY

Hydroxyapatite-coated total hip arthroplasty : The impact on thigh pain and arthroplasty survival

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The purpose of this study was to evaluate the long-term clinical outcomes of primary total hip arthroplasty using an uncemented, hydroxyapatite-coated implant. We followed a consecutive series of 164 patients, who underwent total hip arthroplasty with the Furlong fully-hydroxyapatite coated implant over a mean time period of 12.8 years. Clinical and radiological analyses were performed. Roentgenographic evaluation for the femoral side of the hip was performed using the Gruen zones, for the acetabular side using the DeLee and Charnley zones. Engh's radiological score was employed to assess fixation and stability of the stem. Clinical results were evaluated by Harris Hip Score. The mean Harris hip score was 46 preoperatively and 85 at last follow-up. The mean Engh score was 23. No hips had been revised for aseptic loosening of the femoral component. Thigh pain incidence was very low (1.2%). Survival analysis showed excellent results (95.8% at end point). The Furlong hydroxyapatite-coated implant appears as a reliable and safe option for hip arthroplasty.

Keywords : hydroxyapatite-coated ; total hip arthroplasty ; thigh pain.

INTRODUCTION

Cementless total hip arthroplasty was introduced partly in the belief that periprosthetic osteolysis could be eliminated by eliminating the need for cement (*20*). Primary and secondary fixation of the femoral and acetabular components of a total hip arthroplasty is essential for prosthesis survival. Early experience with cementless total hip replacement led to design modifications to increase the initial press-fit and stability of the femoral component, to reduce the diameter of the femoral head, and to improve the acetabular component, including the shell locking mechanism and the polyethylene liner quality.

Hydroxyapatite-coated (HAC) implants have osteoinductive properties, enhancing direct bone formation at the interface without forming an intermediate layer of fibrous tissue (*12,32,33*). Bonding to living bone occurs over a relatively short period of time even under loaded conditions (*8,28*). Short and medium-term results of HAC total hip arthroplasty (THA) have been promising, according to

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the literature (*1,14,15*). HAC histologic analysis has shown that bone ingrowth with osseous integration occurs as early as 10 days (*13*). Furthermore, animal studies have proved that hydroxyapatite has a positive effect on filling gaps between implant and bone by converting fibrous tissue into bone around the loaded implant (*1,28,29*). The Furlong HA-coated prosthesis has been on the marketplace for several years, but documentation of its performance as well as evaluation of the material effect on the occurrence of thigh pain is sparse and inadequate.

We performed a prospective study to assess the results of THA performed with the Furlong HAC implant in 176 patients who had been followed for 11-14 years.

PATIENTS AND METHODS

We surveyed 164 patients (176 stems) who underwent THA performed with the Furlong hydroxyapatite coated implant (Joint Replacement Instrumentation, London, UK) in our department, from September 1992 to October 1996. Mean age at the time of arthroplasty was 68 years (range : 26 to 87) ; there were 123 female and 41 male patients. Their mean body weight and height were 71 kg (range : 41 to 106) and 1.64 m (range : 1.33 to 1.84), respectively. The right hip was replaced in 118 cases, twelve of the operations were two-staged bilateral. Patients were assessed preoperatively with routine radiographs (anteroposterior [AP] pelvis, lateral hip) of the affected hip(s). Primary osteoarthritis was the most common diagnosis, next to secondary osteoarthritis, rheumatoid arthritis and avascular necrosis (table I).

All patients were operated by the senior author or under his supervision. Surgery was performed in a standard operating room. Systemic prophylactic antibiotics and thrombosis prophylaxis (unfractionated heparin or LMWH) were given routinely. The anterolateral approach was used in all cases. The Furlong HAC femoral component is fully coated (95% pure hydroxyapatite, mean crystallinity 62%, density 99% of the theoretical density of a solid block of hydroxyapatite) and has a body made of Ti-6Al-4V alloy. The HA coating is produced by the plasma spraying technique and has a thickness of 200 μm and a bonding strength of 40 MPa measured in both tension and shear tests (*14*). The component has a cylindrical stem with a collar and a lateral fin to control rotation. The junction of the body and stem is shaped as a cone to ensure primary mechanical stability. Ceramic heads with a diameter of 28 mm, available in three neck lengths, and metallic heads, available in five neck lengths were used upon anthropometric indices. The acetabular components matched were according to availability the Rim Fix Cup (RFC) (37 cases) for the early period or the Surface Fixation Cup (SFC) (139 cases), the latter being according to surgeons' opinion technically simpler to use. The rim-fix type of acetabular cup was secured to the bony acetabular floor with titanium screws.

Table I. — Pre-operative diagnoses

Diagnoses	Number of hips	
Osteoarthritis	161	91.47%
Primary	149	84.65%
Secondary*	12	6.8%
Avascular necrosis	8	4.5%
Idiopathic	3	1.7%
Post-traumatic	5	2.8%
Rheumatoid arthritis	7	3.9%

* Dysplasia (9 hips), slipped femoral epiphysis (3 hips).

Immediate partial weight bearing with crutches was encouraged at 48 hours postoperatively, continued for a period of 4 to 6 weeks, and then full weight bearing without crutches was allowed. There were no exclusion criteria and the follow-up was prospective. All patients were evaluated postoperatively at 3, 6, 12 months, two and five years and subsequently recalled for clinical and radiological review for the current study. Mean follow-up period was 12.8 years (range : 11 to 14).

Clinical examination

Clinical assessment was done preoperatively, postoperatively and at each follow-up visit by the same orthopaedic clinician. All patients were assessed with the modified Harris hip score (100 points total). The Harris score was developed to assess patients with traumatic arthritis of the hip (*18*). It can be used to follow patients over time and to help plan management including timing for surgical intervention, to assess patients before and after surgery to evaluate improvement. The maximum score was 100 (pain 44, function 47, absence of deformity 4, range of motion 5) and the goal was to have a value as close as possible to 100. However, a score above 80 was defined as excellent (*17*). Patients were asked specifically about thigh pain. Although 19 patients did not attend the 2-year follow-up and 23 the 5-year follow-up, all patients were examined at the last follow-up.

Radiological evaluation

Standardised anteroposterior (AP) and lateral radiographs were used. All radiographs were analysed by two observers together. Standard measurements were made on the 3, 6, 12 months, 2 and five years postoperative radiographs and compared with the final follow-up films. The AP projection was centered on the symphysis pubis and was taken at a standard distance of 1 m.

Postoperatively, the method used for roentgenographic evaluation of the femoral prosthesis stem was the seven zones Gruen method (*16*) on the AP film. Roentgenographs were evaluated for resorption of the medial femoral neck (calcar), femoral shaft cortical hypertrophy, implant subsidence, cancellous bone formation (spot welds), radiolucent lines around the prosthesis, and heterotopic bone formation graded according to Brooker's classification (*3*). The radiolucent line had to extend at least 50% of the length of any zone to be considered significant. The comparison of the measurements of the distance between the most proximal point of the implant and the tip of the greater trochanter determined the femoral component's subsidence. A difference of 2 mm or more between roentgenographs was required to identify subsidence. An increase in the outside diameter of the cortex measured at the point of maximum hypertrophy indicated cortical hypertrophy (cortical thickening). Intramedullary cancellous bone formation (spot welds) was defined as new bone formation occurring between the implant and the femoral cortex when compared with the immediate postoperative roentgenograph. Resorption or densification of bone was not quantified but graded as present or absent, compared with the previous set of radiographs. Engh's radiological score was employed to assess fixation (maximum 10 points) and stability (maximum 17 points) of the stem (*10*). The femoral component was recorded as loose if there was progressive subsidence or migration or if there was a radiolucent line wider than 2 mm around the stem.

The acetabular component was evaluated using the three DeLee and Charnley zones (*7*). Acetabular cups were evaluated for radiolucency, component migration, and bone condensation. The inclination angle of the acetabular component was measured on the anteroposterior view of the pelvis. Acetabular component migration was assessed by referencing the center of the femoral prosthesis head to the line joining the two teardrops. If there was a > 3 mm linear change (medial, superior, or both), migration of the acetabular component was considered significant. Rotational change was regarded as significant if there was a change of > 3° in the angle of the acetabular component. Acetabular component loosening was diagnosed if there was migration of the component or a continuous radiolucent demarcation greater than 1 mm.

Failure criteria were revision or impending revision due to pain or loosening. Survival analysis for the prosthesis was performed using a cumulative life-table method. The confidence intervals were determined from the effective number at risk using the Rothman equation (*24*).

RESULTS

During the study period, none of the patients died and although some had lost contact and did not attend all visits as instructed, they were assessed clinically and radiologically at the last follow-up.

Complications

Operative complications are summarised in table II. Intraoperatively, 13 femoral crack fractures occurred just above the lesser trochanter. Femoral cracks did not result in any implant subsidence, fixation loss, or radiolucencies formation around the implant.

Acute postoperative complications

There were four cases of deep vein thrombosis, diagnosed during the first postoperative month and treated with intravenous heparin and oral anticoagulant drugs for six to twelve months ; none progressed to fatal pulmonary embolism. Three transient common peroneal nerve palsies were recorded. Five superficial infections during the first 3 weeks were treated with the appropriate antibiotic medication and debridement.

Clinical evaluation

The Harris hip score was improved in all patients, with the exception of three patients who developed Brooker grade IV heterotopic ossification. The mean Harris hip score was 46 points preoperatively, 88 points 12 months postoperatively

Table II. — Complications

Type of complication	No. of Hips	
Femoral cracks (fracture)	13	7,3%
Postoperative dislocations	2	1,1%
Aseptic loosening	1	0,5%
Superficial infection	5	2,8%
Acetabular cup infection (deep)	0	0%
Anterior thigh pain	0	0%
Deep vein thrombosis	4	2,2%
Common peroneal palsy	3	1,7%
Brooker grade (heterotopic ossifications)		
0	72	40,9%
I	81	46%
II	15	8,5%
III	5	2,8%
IV	3	1,7%

and 85 points at the last follow-up (table III). Occasional mild hip pain was present in 11 patients (6.25% of the total number of stems) and usually occurred after walking for periods longer than 30 minutes. Two patients (1.21%) reported thigh pain either in the early post operative period (3 months evaluation) or at later time points (1 year evaluation, last follow-up visit).

Radiographic evaluation

Roentgenographic changes around the femoral implant ranged from none to minor. No femoral implant was loose, had migrated or subsided over time. There were no radiolucent lines at the bone/stem interface, no changes at the interface and no osteolysis in any radiological follow-up. Increased trabecular bone at the prosthesis tip (pedestal, zone 4) was present in 138 hips (78.4%). Mean Engh score for fixation and stability was 23 at the end-point visit. Structural changes of the femoral bone presenting as spot welds became apparent between 3 and 6 months (fig 1).

With regard to the acetabular component, there was no migration in either vertical or horizontal direction and no change in cup inclination. Radiolucent lines were absent in 96.0%. Cancellous bone formation became visible on radiographs, in DeLee and Charnley zones 1 and 3 in all hips, and in zone 2 in 143 hips (fig 2). Periarticular ossifications were recorded using the Brooker grading system. At the last visit 2.84% hips had grade III ossifications and 1.70% grade IV.

Revisions

No hips had been revised for aseptic loosening of the femoral component by the time of final follow-up. Revision surgery was carried out in three cases. Two hips were revised for periprosthetic femoral fracture, caused by a car accident and a fall 9 and 10 years respectively after the primary operation, while the third one was performed in a 39-year-old patient, eleven years after the primary operation. He was a workman exposed daily to intensive physical activity, and also participated in several recreational activities. During revision operation, osteolysis and loosening of the acetabular component were encountered as well as a damaged polyethylene cup, whereas the stem was well fixed.

Table III. — Outcome of the Fully Hydroxyapatite-coated Furlong THA
Harris Hip score (n = 176)

Harris Hip score		No of Hips Preoperatively (mean : 46 p)	No of Hips Postoperatively 12 mo (mean : 88 p)	No of Hips Postoperatively Last Follow up (mean : 85 p)
Excellent	90-100	-	138 (78.4%)	130 (73.8%)
Good	80-89	-	31 (17.6%)	32 (18.1%)
Fair	70-79	-	7 (3.9%)	11 (6.25%)
Poor	< 70	176 (100%)	0 (0%)	3 (1.7%)

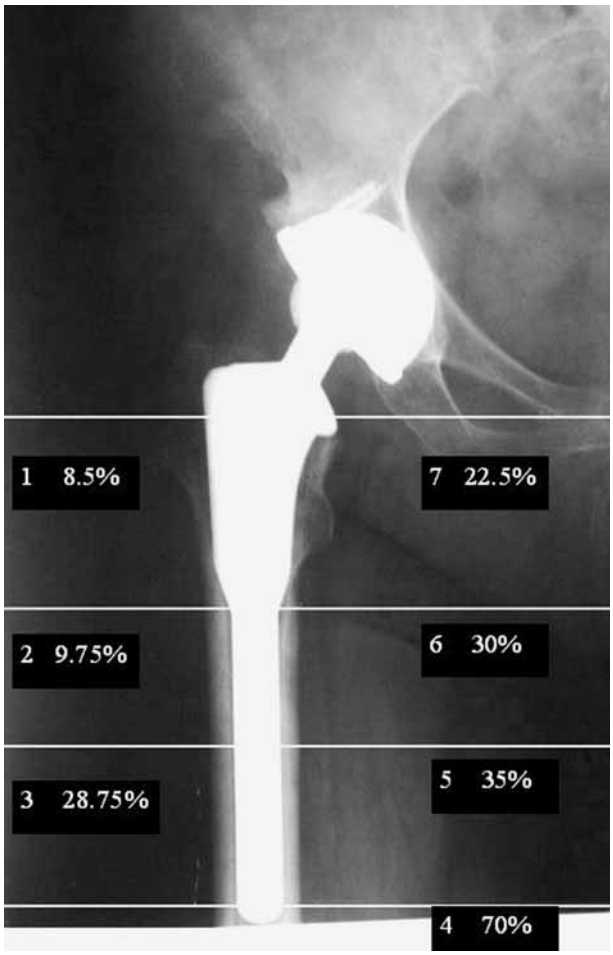

Fig. 1. — On the anteroposterior view of a 69-year-old female patient, 7 years postoperatively, the incidence of subcortical bone formation was highest at the tip of the stem (70%). Subcortical bone formation in the seven zones of Gruen was more on the medial side.

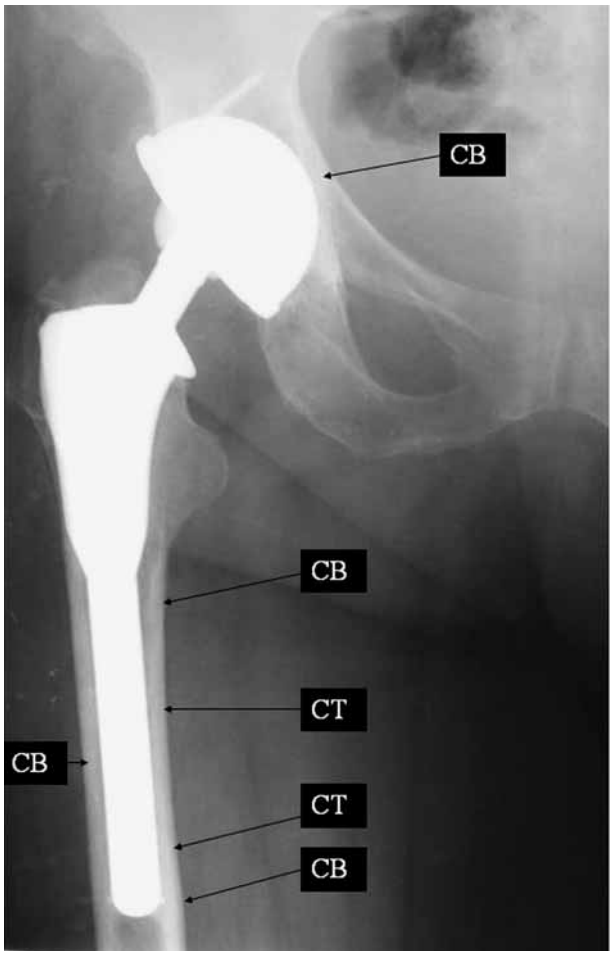

Fig. 2. — Postoperative anteroposterior roentgenograph, 9 years after total hip arthroplasty with a fully hydroxyapatite – coated total hip implant in a 67-year-old woman, showing good proximal and distal fit of the stem and no signs of resorption. Cortical thickening (CT) at the distal part of the stem is evident and cancellous bone formation (CB) can be demonstrated on the medial, lateral and distal parts of the stem, as well as in all three zones of the acetabular cup. There have been no subsidence or radiolucencies. The patient was assigned a Harris hip score of 96.

Survival analysis

Survivorship curves for the HAC hip prosthesis were constructed using information from the cumulative life tables. Cumulative survival was 100% at ten years (95%, CI : 97.9 to 100), 99.3% at eleven years (95%, CI : 96.6 to 99), 98.2% at twelve years (95%, CI : 94.7 to 99), and 95.8% at thirteen to fifteen years using revision or impending revision due to loosening or osteolysis as an endpoint (fig 3, table IV).

DISCUSSION

After more than 30 years clinical use of THA, no consensus has been achieved with respect to such basic points as the choice of material or the mode of fixation of the components to bone. Today, we have increasing possibilities to analyse long-term results and to pave the way for the future more safely. Previous studies have documented the 10-

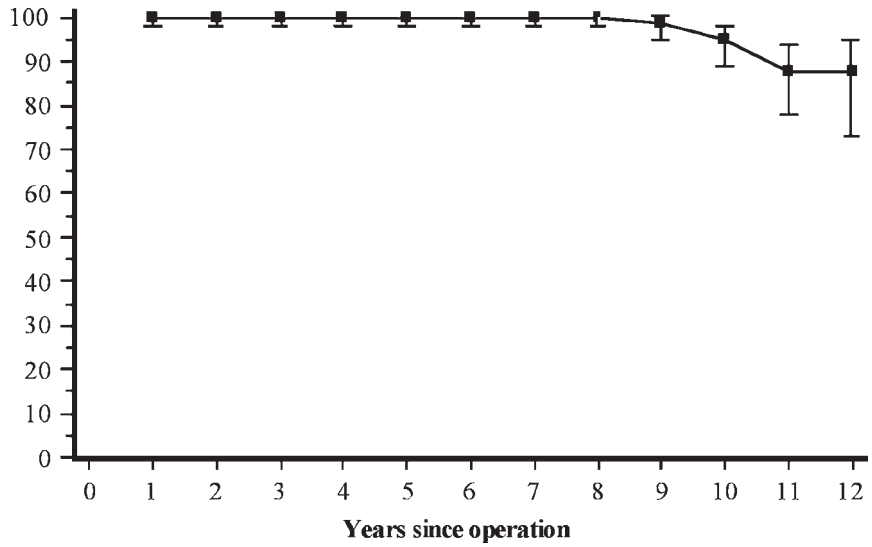

Fig. 3. — Survival curve for the Furlong HAC total hip arthroplasty

Table IV. — Cumulative life table for the Furlong HAC total hip arthroplasty

Years since Operation	Number at Start	Failure	Withdrawn	Number at Risk	Effective Number at Risk	Annual Failure Rate	Annual Success Rate	Survival Rate	95% CI
0 to 1	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
1 to 2	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
2 to 3	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
3 to 4	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
4 to 5	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
5 to 6	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
6 to 7	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
7 to 8	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
8 to 9	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
9 to 10	176	0	0	176	176.00	0.0	100.0	100.0	97.9 - 100
10 to 11	176	1	56	148	173.02	0.7	99.3	99.3	96.6 - 100
11 to 12	119	1	67	85.5	159.42	1.2	98.8	98.2	94.7 - 99
12 to 13	51	1	18	42	139.19	2.4	97.6	95.8	91.0 - 98
13 to 14	32	0	16	24	108.21	0.0	100.0	95.8	90.2 - 98
14 to15	16	0	0	16	80.56	0.0	100.0	95.8	88.9 - 98

year results of several uncemented stems designs (*6,9,19, 22*).

The results of the survival analysis in this study illustrate an excellent progression at 10 and 11 years after primary hip arthroplasty, with a 95% confidence interval (CI) of 97.9 to 100 and 96.6 to 99, respectively. Concerning the 12th postoperative year, the survival rate (98.2%) meets high standards, although the survival analysis conducted represents the worst-case scenario as two out of the three revision cases, considered as failures, were due to periprosthetic fracture with primary signs of impending loosening of the acetabular screws of the RFC. Results have been found to be excellent considering the patients' ages and concur with other authors' results (*23,25-27*).

As far as clinical outcome is concerned, D'Antonio *et al* (*5*) reviewed 320 proximally HA-coated hip implants, reporting mean Harris hip scores of 95 at 2 years and 96 at 3 years. Geesink (*14*) reported an average Harris hip score of 98 points after a follow-up period of 2 years in 100 patients implanted with a proximally HA-coated femoral stem. In a prospective multicenter study, Tonino *et al* (*31*) reported a mean Merle d'Aubigné score of 17.4 with a follow-up of 2 years in 222 patients treated with a proximally HA-coated prosthesis. The clinical results of the current study show a major postoperative improvement of the Harris hip score. Deterioration of the Harris hip score was recorded in three patients with heterotopic ossification Brooker grade IV and 5 patients with Brooker grade III.

Stem implantation alters the mechanical load environment in the host bone, taking away a relatively larger share of the load from the femur. Once the stem has been inserted, the stress that would normally be borne by the bone alone is reduced, which leads to proximal femoral bone resorption. This resorption phenomenon around the femoral stem called "stress shielding" is one of the major complications of cementless THA (*2*). Potential complications resulting from stress shielding include thigh pain, late stem loosening and femoral fracture during revision surgery. In our study, anterior thigh pain was not a problem, contrary to some other studies of cementless hip arthroplasty (*10*). Thigh pain after uncemented THA remains a controversial topic (*10,11,21*). Activity-related thigh pain is frequently associated with radiographically stable cementless stems. The low incidence of thigh pain in our series may be related to the rapid and early bone bonding that the hydroxyapatite coating allows, along with the distal stability which seems to prevent micromotion at the bone-prosthesis interface. Furthermore, the stem design features incorporating a collar for primary mechanical fixation mainly in the metaphyseal region and a large diameter cone (greater than 13 mm) create a bone-loading pattern with a wide base for absorption of weight and tension forces, probably resulting in diminished pain induction.

According to the radiographic evaluation, bony fixation seemed to be consistently achieved with the Furlong HAC stem. This is supported by histological and histomorphometric examinations of autopsy-retrieved specimens after years of successful hip functioning (*32,33*). The mean Engh radiological score was 23, showing an excellent status of fixation and stability (*10,13*). There was a satisfactory presence of spot welds and no radiolucent lines, except in seven cases (3.97%) where acetabular cups with screws (R.F.C.) were used. Of note is the fact that although 37 of the acetabular cups revealed lower Engh radiological scores (12 to 18), they appeared to remain well fixed. The radiological changes for both femur and acetabulum showed in the vast majority gap-filling, cyst remodelling, bony ingrowth and no signs of secondary or impending loosening.

As far as the short term postoperative complications are concerned, the results of this study correlate with those of other series (*10,23,26*). The incidence of intra-operative femoral cracks was similar to other studies, and all of them were treated conservatively with no long-term consequences.

The most common mechanical problem with the cementless THA is failure of fixation of the femoral component. To achieve initial success with cementless femoral stems, it is important to obtain rigid initial fixation so that micromotion between the implant and the bone would be minimal. In view of the direct intimate bonding with bone without an intervening layer of fibrous tissue, ceramic HAC implants have been recommended for clinical use by several investigators (*4,30*). It is believed by many authors that this layer is the beginning point of the loosening process, causing thigh pain. The fibrous layer is stripped off and appears black stained during a revision operation.

In our series, it is evident that biological fixation of hydroxyapatite to bone does occur, as manifested by the radiological appearance of sclerosis around the implant due to bony ingrowth. However, absence of sclerosis does not mean that bony ingrowth has not taken place. This would also explain the fixation of the acetabulum without any obvious reaction and the low revision rate seen in this series after 11 to 14 years of operation.

Anyhow, the weak link in the system concerning the future survival of the prosthesis seems to be the metal – polyethylene articulating interface. In the revision case due to periprosthetic femoral fracture, macroscopic appearance of the polyethylene insert revealed wearing of the insert in the RFC acetabular prosthesis .

In conclusion, our results confirm that fixation by means of osseointegration of a HAC hip prosthesis is very reliable but any comparison with the results of other types of uncemented total hip implants is difficult, as differences in prostheses materials, patients characteristics, bone mass density, incidence of osteoporosis, and possible pharmacological treatment as well as examiners' experience may influence the final outcome. Controlled clinical studies would be required to evaluate the relative efficacy of the fully HAC and the proximally HAC hip prostheses.

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