Medium-term results of cementless hydroxyapatite-coated primary total hip arthroplasty: A clinical and radiological review

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ABSTRACT

Purpose. To evaluate the clinical and radiological outcomes following cementless primary hydroxyapatite-coated total hip arthroplasty.

Methods. A retrospective study of 69 patients (82 hips) who underwent uncemented hydroxyapatite-coated Anatomic Benoist Girard total hip replacement between October 1991 and October 1995 at our institution was conducted. Patient records were reviewed. All patients were evaluated clinically using the Merle D’Aubigne hip score, and osteointegration was assessed radiographically by analysing the bone implant interface in the 7 zones of Gruen on follow-up review.

Results. The mean follow-up period was 7.3 years. Clinical results were excellent with an improvement seen in clinical score from 9.9 preoperatively to 16.5 at last review. A total of 15% of patients recorded some thigh discomfort, which was intermittent and not functionally limiting, except in 2 cases. There were 3 cases of severe acetabular osteolysis and loosening requiring revision surgery, and 4 cases of localised proximal femoral osteolysis around well-ingrown implants. There were few perioperative complications, with the exception of 5 dislocations of which 3 were recurrent and required a revision procedure.

Conclusion. Clinical and radiological outcomes following cementless hydroxyapatite-coated total hip arthroplasty were seen to be favourable in this medium-term retrospective study.

Key words: arthroplasty, hip; cementless; hydroxyapatite

INTRODUCTION

The aim of primary total hip arthroplasty is to restore pain-free function of the diseased hip. Osteolysis and
aseptic loosening are the major factors limiting the longevity and clinical success of total hip arthroplasty,\textsuperscript{1–4} and this is no more evident than among young and active patients.\textsuperscript{3,5} Hydroxyapatite coating of total hip replacements has been developed during the last 2 decades, and experimental studies have established its efficacy.\textsuperscript{6,7} Hydroxyapatite has the property of osteoconduction, achieving a strong bond with living bone in a short period of time, even under loaded conditions.\textsuperscript{8–11}

We report on the medium-term clinical and radiological results of 82 primary cementless hydroxyapatite-coated total hip arthroplasties performed at our institution.

METHODS

The medical records of 69 patients (82 hips) who underwent primary cementless hydroxyapatite-coated total hip arthroplasty between October 1991 and October 1995 were reviewed. Most of these patients were younger than 60 years, active and male. All other patients during this period underwent standard cemented arthroplasty. All operations were performed at the same institution by one of the 3 orthopaedic surgeons. The mean follow-up period was 7.3 years (range, 5–10 years).

The mean age at operation was 57.4 years (range, 31–74 years). One third of the patients were younger than 55 years. There were 44 male and 25 female patients. Primary osteoarthritis was the preoperative diagnosis in 88% (n=60), secondary osteoarthritis in 8% (n=6), and avascular necrosis in 4% (n=3).

All patients underwent surgery through a direct lateral approach. The original Anatomic Benoist Girard (ABG) total hip prosthesis (Stryker Howmedica, Allendale [NJ], US) was used in all patients (Fig. 1). This uncemented implant made of titanium alloy is covered with a 60±10 µm thick hydroxyapatite coating. The stem has an anatomical shape and fixation is restricted to the metaphyseal portion, which is coated with hydroxyapatite. The acetabular component is a hemispherical hydroxyapatite-coated press-fit cup, with primary fixation being enhanced by the addition of 2 spikes through the cup. Supplementary screws can be used in addition or as an alternative. The head size used was 28 mm, except for the first 14 patients for whom a 32-mm head was used.

Routine postoperative management included 24 hours of antibiotic prophylaxis (second generation cephalosporin), and perioperative and postoperative thromboprophylaxis (anti-thromboprophylactic stockings and subcutaneous low-molecular-weight heparin). Patients were generally mobilised within 48 hours after surgery, and continued partial weight-bearing with crutches for the first 6 weeks. Thereafter the crutches were discarded, and full weightbearing was allowed.

Clinical evaluation

All patients had been evaluated preoperatively, perioperatively, and postoperatively at 3, 4 and 12 months, and then at approximately yearly intervals until their last review. All but 3 hips in 2 patients were available for follow-up assessment, but in all cases clinical notes and radiographs were available for review. The Merle D’Aubigne functional grading system\textsuperscript{12} was used as part of the clinical assessment at all stages, using the original definitions of pain, mobility and ability to
walk. Postoperatively, emphasis was placed on the evaluation of pain, especially localisation if present.

Radiological evaluation
An anteroposterior view of the pelvis and proximal femurs, and a lateral view of the involved hip were taken preoperatively, postoperatively, and at each follow-up visit. Radiographs were evaluated using Gruen zones for the femoral stem,13 and DeLee and Charnley zones14 for the acetabular cup. Variables assessed included signs of bone resorption, radiolucent lines, cancellous and cortical densification, thickening and tip sclerosis, and cyst formation. Also considered were the position of the femoral implant (varus, valgus, or central), gross evidence of distal migration, and the position of the cup and the angle of lateral opening. Heterotopic bone formation was recorded according to the Brooker classification system.15 All radiographic assessments were evaluated in comparison with the immediate postoperative result.

RESULTS

Clinical results
Postoperative complications are shown in the Table. All of the complications resolved. There were 2 intraoperative complications directly related to technical aspects of the procedure. In both cases minor cracks occurred in the anterior neck region of the femur on preparation of the femoral canal. These cracks were treated with cerclage wire fixation, and did not interfere with implant fixation or influence the subsequent clinical result.

Two patients developed acute subsidence of the femoral stem in the immediate postoperative period. One case was due to an unrecognised calcar fracture, and the patient underwent surgical revision to a cemented implant. The other was due to undersizing, but the implant was stable and further surgery was not required.

There were 5 dislocations, 3 of which were recurrent and required a revision procedure. Both the femoral stem and acetabular cup were noted to be soundly fixed at the time of the revision. One patient died from bronchial carcinoma at one year postoperatively. There were no cases of deep sepsis.

Analysis of clinical data revealed an average Merle D'Aubigne score of 9.9 preoperatively (maximum 18), which had improved postoperatively to 16.5 at the last review. Only 4 patients had a score of 14 or less at a minimum of 5 years' postoperative follow-up. Three of these patients had persistent abductor weakness, which had not responded to physiotherapy and limited their ability to walk. One patient had preoperative abductor weakness as a result of multiple procedures for slipped capital femoral epiphysis, whereas the other 2 had neurogenic abductor weakness probably due to surgical damage of the superior gluteal nerve. In the 4th patient, the development of chronic trochanteric bursitis caused pain and limiting mobility.

At a minimum follow-up of 5 years, only 2 patients continued to have typical lateral thigh pain of clinical significance for which analgesics were taken. In the remainder of patients who reported some discomfort (15% of hips; n=12), this was for the most part intermittent and not functionally limiting. There were no obvious implant or patient differences in these patients compared to the rest of the group.

Three patients developed severe osteolysis around the acetabular cup (Fig. 2), with significant migration and loosening. They underwent revision of the cup only and the stems were well fixed at surgery with moderate proximal osteolysis which was bone grafted. All 3 patients were young and very active, and this explained the marked polyethylene wear noted at cup retrieval. The other contributing factor was that 2 of the femoral heads were 32 mm in diameter.

Radiographical results
Apart from the 3 cases of severe osteolysis around the acetabular cup requiring revision, there was no evidence of acetabular migration, spike fracture or motion. This was presumably because of good initial stability and rapid osseointegration. Bone apposition was seen within 3 to 9 months, with disappearance of the gaps seen in the immediate postoperative period at the bone implant interface.

At a minimum of 5 years' follow-up, radiolucent lines were seen in DeLee and Charnley zones 1 and 2 around the acetabulum in 3 patients (4 hips). Cancellous densification was seen in 12 hips,
predominantly involving zones 2 and 3. This was felt to represent normal load transmission and a satisfactory outcome. The remainder of the radiographs showed normal bone adjacent to the acetabular cup.

In the femur, significant distal stem migration (>5 mm) was seen in one patient. This occurred during the immediate postoperative period due to undersizing, and thereafter no further migration on further follow-up was recorded. This result did not significantly alter the clinical outcome.

There were 4 cases of proximal femoral osteolysis (Fig. 3), 3 of which were associated with acetabular osteolysis. The implants were well fixed, and bone grafting was carried out at the time of acetabular revision.

Because of the press-fit nature of the proximal, hydroxyapatite-coated part of the stem, there were no gaps seen in this area in the immediate postoperative radiographs. Varying degrees of resorption were seen around the proximal femoral region in 11% of hips, predominantly in zone 7A. There were no cases of cortical erosion or cyst formation. The majority of patients whose radiographs showed evidence of resorption were in the initial group of hips where a 32 mm head size was used. At the latest follow-up, none of these patients had clinical signs of loosening.

Radiolucent lines were completely absent in all cases around the hydroxyapatite-coated parts of the femoral stem. In a minority of cases reactive line formation was visible in the upper part of Gruen

Figure 2  X-rays showing severe acetabular osteolysis, and loosening at 6-year follow-up from (a) lateral view, and (b) anteroposterior view.
zone 1A, near the shoulder of the stem, where the hydroxyapatite coating begins.

Reactive line formation was regularly seen around the distal non-coated part of the stem. It usually began around the stem tip in Gruen zone 4 and became visible after 6 months. With time these lines often progressed more proximally into Gruen zones 3 and 5. They were present in 75% of hips at the 1-year follow-up. Pedestal formation was not seen in any of the patients. A few cases showed minor signs of bone formation adjacent to the stem tip, especially when the stem tip touched one cortex of the femur, or where the implant had a very tight distal fit.

Subcortical cancellous densification, representing new bone formation between the implant and the femoral cortex, occurred most commonly at the interface between the hydroxyapatite-coated and the uncoated portions of the stem. This was noted in 54% of hips, typically in Gruen zones 2 and 6 (laterally and medially). This appearance became more prominent the longer the follow-up. Several cases also showed symmetrical thickening of the femoral cortex circumferentially around the same Gruen zones, always in association with extensive endosteal bone formation over the hydroxyapatite-coated areas of the stem. This endosteal and cortical bone formation was interpreted as a sign of bony remodelling to the new pattern of stress transfer.

Formation of heterotopic bone occurred in 41% of hips, only one of which was classified as grade 3 or above, according to the Brooker classification system. All patients with lower grades of heterotopic bone formation (Brooker grade 1 or 2) had an acceptable range of motion.

**DISCUSSION**

This paper reports medium-term results of hydroxyapatite-coated primary total hip arthroplasty performed at our institution. The clinical results were excellent, with the patients reporting very early relief of pain and rapid restoration of activities of daily living. The very low incidence of clinically significant pain at one year was especially striking, and comparable with that reported for cemented hip replacement. The average Merle D’Aubigne score of 16.5 at final review compared favourably with other reported series of both cemented and cementless total hip arthroplasty, including those where hydroxyapatite-coated hip implants have been used. The only low clinical scores in the current study were in patients with either persistent abductor weakness or pain secondary to trochanteric bursitis, both of which are likely to relate to the surgical approach used.

There were only 2 intra-operative complications specifically related to implant insertion. This appears more related to surgical technique and experience, although previous reports have shown that less aggressive reaming is required for hydroxyapatite-coated implants than for other types of cementless prostheses. Both experimental and clinical evidence have shown that the limits of tolerance for acquiring reliable bone apposition are much greater with hydroxyapatite coatings. The femur requires less extensive reaming and thus more trabecular bone is preserved, with obvious advantages in younger, more active patients. This also allows for a smaller and less stiff stem to be used, reducing the amount of proximal stress and shielding osteoporosis.
The incidence of loosening was 3.6% based on the number of hips with acetabular osteolysis requiring revision surgery. Localised proximal femoral osteolysis around a well-fixed femoral stem occurred in 5% of hips. The incidence and amount of heterotropic bone formation were comparable with that reported for other types of total hip replacement.\textsuperscript{15,23}

Our low incidence of combined Brooker grades 3 and 4 compares favourably with some recent studies, including a multicentre study by the ABG Group (personal communication), where hydroxyapatite-coated implants have been used.\textsuperscript{18,19}

There was no radiographic evidence to support the theoretical increased incidence of heterotropic bone formation with hydroxyapatite, which is so osteoconductive.

The radiographic pattern of bone apposition around hydroxyapatite-coated stems is one of early endosteal bone condensation at the hydroxyapatite-coated/uncoated junction on the femoral stem, followed by reactive line formation around the distal non-coated stem section.\textsuperscript{24} Most of these changes occurred within the first postoperative year, becoming more prominent within the second year. From postmortem studies, it has been shown that the formation of new woven bone adjacent to the hydroxyapatite layer does not pass through an intermediate stage of fibrous tissue.\textsuperscript{8–11,24} Hydroxyapatite therefore enhances secondary fixation of the components, with stabilisation seen within the first 3 to 6 months. Other porous-coated stems are still migrating at that time, as seen using roentgen stereophotogrammetric analysis.\textsuperscript{11} Because no gaps were seen in the hydroxyapatite-coated areas with the pressfit technique used for this prosthesis, this phenomenon of secondary fixation and osseointegration can be understood as the cancellous or cortical bone densification seen growing on to the implant.

No reactive lines were observed in the hydroxyapatite-coated portion of the implant in any patient, whereas new bone formation in the form of cancellous densification at the junction of the coated/uncoated region of the femoral stem was progressive. There were no cases of clinical or radiographic loosening in the 82 stems at an average of 7.5 years; one must therefore assume complete proximal femoral integration in all cases. Reactive lines were seen, but only adjacent to the non-coated distal part of the stem. These distal reactive lines are probably due to micromotion between the relatively stiff distal stem and the more elastic bone, enhanced by the strong proximal fixation.\textsuperscript{20,22,25,26} This is not necessarily associated with significant load bearing at the tip, as evidenced by the absence of pedestal formation.

Geesink and Hoefnagels\textsuperscript{19} found these bone reactive lines reached a maximum at 3 years post-surgery. From the third year on, increasing bone density stiffens the femur, reducing distal micromotion. The reactive line was observed to regress after 3 years, causing an increase in stability. This was believed to allow spontaneous secondary osseointegration of the non-coated section of the titanium stem.

Two patterns of periosteal and cortical bone remodelling were seen. The symmetrical type, which was only seen in association with endosteal bone formation around the junction of hydroxyapatite-coated and uncoated parts of the stem, probably reflects adaptive remodelling to high local stress patterns. This was felt to be a favourable response. The less common asymmetrical response, seen usually at the level of the stem tip, was seen more commonly with a very tight fit of the distal stem, or where the stem tip touched one cortex. This is likely to represent some irritation of the inner cortex of the femur. Certain types of bone remodelling are regarded as an adverse feature,\textsuperscript{25,27} but it is believed that with the hydroxyapatite-coated prosthesis the symmetrical cortical thickening seen is evidence of good implant fixation.

Proximal bone resorption seen in Gruen zone 7A has been reported in a number of other clinical studies.\textsuperscript{17,28} This usually starts after 3 to 6 months and is felt to represent a stress shielding effect. This resorption was seen in 11% of our hips. Proximal stress relief has been well documented with the use of porous-coated implants, and results from the intramedullary fixation of an implant stiffer than bone.\textsuperscript{3,22,26,29} With hydroxyapatite-coated implants it is recognised less frequently, and is usually seen at the proximal transition of coated to uncoated portions of the stem. Our low figure for bone resorption in the current series supports the idea that there is more load transfer proximally in the design of the prosthesis evaluated in this study.

New bone was seen to fill the gaps between the reamed acetabular surface and the coated acetabular implant within 3 to 9 months, with only 4 hips showing persistent radiolucent lines which were non-progressive. Cancellous densification was seen in 12 hips, predominantly in DeLee and Charnley zones 2 and 3. This can only be due to secondary load transmission according to Wolff’s Law. The small number of hips seen with these changes presumably reflects a more even distribution of strain with the use of hemispherical cups.\textsuperscript{30}
CONCLUSION

Cementless primary hydroxyapatite-coated total hip arthroplasty is a reliable procedure resulting in excellent implant fixation and a predictable clinical outcome in the medium term. We have shown low rates of aseptic and mechanical failure in a series of relatively young and active patients, but long-term outcome assessments are required to determine whether this type of fixation will stand the test of time.

REFERENCES