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Comparison of wear and osteolysis in hip replacement using two different coatings of the femoral stem

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Abstract We compared the clinical and radiographic results of two matched series of total hip arthroplasties, one with hydroxyapatite-coated femoral stems, the other with a similar but porous-coated femoral stem. The prevalence of radiographic osteolysis was 16% in hips with hydroxyapatite-coated stems and 43% in hips with porous-coated femoral stems. In hips with hydroxyapatite-coated stems, osteolysis was always limited to Gruen zones 1 and 7. In contrast, distal osteolysis was present around 26% of the porous-coated stems. At 7 years, the survival-free rate of distal osteolysis was 100% in hips with hydroxyapatite-coated stems but 90% in hips with porous-coated stems ($p=0.04$). Circumferential hydroxyapatite coating of the femoral component reduced the occurrence of osteolysis and eliminated distal osteolysis at 5–10 years of follow-up. In addition, hydroxyapatite coating did not alter the wear rate.

Résumé Nous avons comparé les résultats cliniques et radiographiques de deux séries appariées d'arthroplasties totales de la hanche l'une avec des tiges fémorales recouvertes d'hydroxyapatite, l'autre avec des tiges fémorales semblables mais à revêtement poreux. La prévalence de l'ostéolyse radiographique était 16 pour cent dans les hanches avec hydroxyapatite et 43 pour cent dans les hanches avec les tiges fémorales poreuses. Dans les hanches avec hydroxyapatite l'ostéolyse a toujours été limité aux zones 1 et 7 de Gruen. Par contraste, l'ostéolyse distale était présente autour de 26 pour cent des tiges à revêtement poreux. À sept années, la survie sans ostéolyse

distale était 100 pour cent dans les hanches avec hydroxyapatite mais 90 pour cent dans les hanches avec les tiges poreuses ($p=0.04$). Le revêtement ciconférenciel d'hydroxyapatite du composant fémoral a réduit la survenue de l'ostéolyse et a éliminé l'ostéolyse distale pendant les cinq à dix années de suivi. De plus, le revêtement d'hydroxyapatite n'a pas changé le taux d'usure.

Introduction

Hydroxyapatite (HA) coating is commonly used for fixation of uncemented femoral components, and several studies have shown satisfactory results [5, 7, 9, 12, 17, 21, 22]. However, it has been suggested that HA particles detached from the stem surface may enhance osteolysis either by stimulating bone loss or by migration to the joint space producing third-body wear [2, 4].

We conducted a retrospective matched-pair study of patients who had a primary hip replacement with insertion of either a porous-coated (PC) or a HA-coated Omniflex femoral component. This allowed comparison of two groups of patients that differed with respect to only one variable: the surface finish of the femoral component.

Material and methods

Patients

Between 1991 and 1993, 68 consecutive primary total hip arthroplasties were performed in 61 patients with insertion of an Omniflex HA-coated femoral component (Osteonics Corporation, Allendale, NJ, USA). Between 1988 and 1992, 316 consecutive primary total hip arthroplasties had been performed with insertion of an Omniflex PC femoral component (Osteonics Corporation, Allendale, NJ, USA). A cohort of 68 hips with a PC femoral stem (PC group) was chosen to have similar distribution regarding gender, age, and weight as the cohort of 68 hips with an HA-coated stem (HA group). Sixty-one hips could be matched on diagnosis, and 52 could be matched on surgeon. Sixty-eight PC femoral stems

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Table 1 Features of the two groups of study. *BMI* body mass index, *OA* osteoarthritis, *AVN* avascular necrosis, *CDH* congenital hip dysplasia, *LCPD* Legg-Calve-Perthes disease, *SCFE* slipped capital femoral epiphysis, *UHMWPE* ultra-high molecular weight polyethylene.

	Hydroxyapatite-coated	Porous-coated
Hips	68	68
Hips in male patients	40 (59%)	40 (59%)
Age (years) ^a	54 (23–66)	56 (22–67)
Weight (kg) ^a	82 (47–131)	82 (51–125)
Height (cm) ^a	172 (149–190)	172 (150–195)
BMI (kg ² /cm) ^a	27.9 (17.9–37.9)	27.4 (20.7–37.8)
Underlying diagnosis		
OA	49 (72%)	47 (70%)
AVN	7 (11%)	9 (13%)
CDH	9 (13%)	8 (12%)
LCPD	3 (4%)	1 (<1%)
SCFE	–	3 (4%)
Femoral head diameter		
22 mm	9 (13%)	2 (3%)
28 mm	59 (87%)	66 (97%)

^aMedian (minimum–maximum).

had been implanted in 66 patients. The features of the two groups are summarized in Table 1.

Implants

The PC- and HA-coated versions of the Omniflex stem were identical in their design except for the type of surface finish. The initial design had noncircumferential titanium microstructured PC beading on the upper third of the stem. Subsequently, the stem was modified with the application of a circumferential HA coating on the upper third of the stem.

The acetabular components used were Dual Geometry (Osteonics) in 93 hips, PSL (Osteonics) in 33 cases, and Spherical (Osteonics) in ten cases. Screws were used to augment the fixation of the acetabular component in 58 cases, and the diameter of the prosthetic femoral head was 28 mm in 125 cases and 22 mm in 11 cases.

Evaluation

Data regarding the outcome were collected prospectively at 3 months, 1, 2 and 5 years postoperatively and every 5 years thereafter and were collated retrospectively at the time of the study. Modified Harris hip scores [14] were derived from the clinical data.

The immediate postoperative and all subsequent radiographs were reviewed. Areas of osteolysis and radiolucent lines were recorded by size and location according to the acetabular zones of DeLee and Charnley [8] and the femoral zones of Gruen [13]. Femoral component fixation was categorized using the criteria described by Engh et al. [11]. Radiographic loosening of the acetabular component was defined as a continuous radiolucent line at the bone-implant interface or a change in the component position. Linear polyethylene wear was determined according to the method of Livermore et al. [16].

Statistical analysis

Univariate, revision-free survival and 95% confidence intervals were estimated using the Kaplan–Meier method [15] for four different end-points: revision for aseptic loosening, mechanical failure (which included both revision for aseptic loosening and radiographic loosening), distal osteolysis, and mechanical failure or femoral osteolysis. A Log Rank test [18] was used to compare revision between the HA and the PC groups.

Results

Reoperations and complications

Thirty reoperations (ten in the HA group and 20 in the PC group) were performed in 28 patients (two had both hips reoperated) 2–12 years after the index operation.

In the HA group, one femoral component was revised for aseptic loosening and another was revised for osteolysis. The polyethylene liner was also changed in the first case, and the acetabular component was revised in the second case for acetabular osteolysis. The remaining reoperations included revision of the acetabular component, exchange of the polyethylene liner, removal of a trochanteric claw, and internal fixation of two femoral periprosthetic fractures. Bone grafting for osteolysis was required in two cases on the acetabular side and in three cases on both the acetabular and the femoral sides.

In the PC group, six femoral components were revised for aseptic loosening 3–9 years postoperatively. One of them was revised after occurrence of a periprosthetic fracture. The acetabular component was revised in two cases, and the liner was exchanged in the remaining four. One additional component was revised for osteolysis along with the acetabular component. Two components were revised for thigh pain, one hip was resected for deep infection, and one hip was revised elsewhere for unknown reasons. The remaining reoperations included revision of the acetabular component for osteolysis, liner exchange for wear, and removal of a trochanteric claw. Bone grafting for osteolysis was performed in nine cases, three on the acetabular side, one on the femoral side, and five on both sides.

Intraoperative fractures of the calcar occurred in 11 cases. The fractures were stabilized intraoperatively and healed uneventfully. Five hips had a single episode of postoperative dislocation that was successfully treated with no additional surgery. One additional hip in the HA group dislocated after revision surgery for bone grafting and liner exchange but did not require further surgery.

Follow-up

Of the original cohort of 136 hips included in the study, at most recent follow-up, a total of 13 femoral components (two in the HA group and 11 in the PC group) had been revised or removed. Eight additional patients (eight hips) had died with their implants in place. Thus, at most recent

follow-up, there were 115 hips with an intact femoral stem. In the HA group, median follow-up was 6.7 (2.4–9.1) years and for the PC group 9.3 (2.2–11.4) years.

Clinical results

The mean Harris hip score improved from 56 (29–77) points preoperatively to 90 (45–100) points at the latest follow-up evaluation ($p<0.001$). Patients with surviving femoral components of both groups had similar clinical results in terms of residual pain and Harris hip scores (Table 2).

Radiographic results

For intact femoral components in patients alive at most recent follow-up, the median radiographic follow-up was 5.8 (2–9) years for the HA group and 8.4 (2–11) years for the PC group. At the latest radiographic examination, femoral osteolysis had developed in 40 cases: 11 in the HA group and 29 in the PC group. In the HA group, osteolysis was always limited to zones 1 and 7 (Fig. 1). In contrast, 18 hips in the PC group had involvement of zones 2, 3, 4, 5 and/or 6. This difference was statistically significant ($p=0.04$). In the HA group, osteolysis was categorized as mild in seven cases and moderate in four. In the PC group, it was considered mild in nine cases, moderate in 12, and severe in eight.

One HA-coated femoral component and six PC femoral components were revised for aseptic loosening and seven additional PC stems were radiographically loose. Thus, the incidence of aseptic loosening of the femoral component was 1.5% in the HA group and 19% in the PC group. The cumulative probability of femoral aseptic loosening at 7 years was 1.5% for the HA group and 10.1% for the PC group.

The median rate of polyethylene wear was 0.17 mm/year in both groups. As noted above, in the HA group, two acetabular components were revised for loosening, three were revised for wear, and one liner was exchanged for wear—all showing associated acetabular osteolysis. In the

Fig. 1 Distribution of the osteolytic lesions according to the frequency of involvement of each femoral zone [13]

PC group, two acetabular components were revised for loosening and four for wear and osteolysis; six hips required a liner exchange for wear and osteolysis, and one component was revised for unknown reasons. One additional component in each group was radiographically loose. Acetabular osteolysis was present in seven hips in the HA group and 15 hips in the PC group. It was mild in four cases, moderate in ten, and severe in eight.

Survivorship analysis

Survival of the femoral component free of revision for aseptic loosening at 7 years was 96.6% (95% confidence interval, 92.9–100%) for the whole series, 98.5% (95% confidence interval, 93.5–100%) for the HA group, and 95% (89.6–100%) for the PC group.

Survival free of mechanical failure (revision for aseptic loosening or radiographic aseptic loosening) of the femoral component at 7 years was 93.7% (95% confidence

Table 2 Clinical and radiographic results

	Hydroxyapatite-coated ^a	Porous-coated ^a
Clinical follow-up (years) ^b	6.7 (2.4–9.1)	9.3 (2.2–11.4) ^c
Harris hip score		
Preoperatively	55 (29–77)	59 (37–75)
Most recent	98 (69–100)	92 (45–100)
Radiographic follow-up (years) ^c	5.7 (2–9)	8.2 (2–11)
Polyethylene wear rate (mm/year)	0.17	0.17
Femoral osteolysis		
Zones 2, 3, 4, 5 or 6	0	18 (26%)
Any zone	11 (16%)	29 (43%)
Mild	7	9
Moderate	4	12
Severe	—	8

^aMedian (minimum–maximum).

^bFor alive patients with surviving femoral components.

^cSix hips in the hydroxyapatite-coated group and one in the porous-coated group had less than 2 years of radiographic follow-up.

Table 3 Survival rates for the femoral component

End point	Hydroxyapatite-coated	Porous-coated	<i>p</i> -value
Revision for aseptic loosening	98.5 (93.5–100)	95 (89.6–100)	0.29
Mechanical failure ^a	98.5 (93.5–100)	89.9 (82.5–97.9)	0.06
Osteolysis			
Zones 1 or 7	75.7 (60.6–93.2)	86.3 (77.4–96.3)	0.08
Zones 2, 3, 4, 5 or 6	100	90 (82.0–98.8)	0.04
Mechanical failure ^a or osteolysis in zones 2, 3, 4, 5 or 6	95.8 (88.5–100)	86.6 (78.3–95.7)	0.05

The 95% confidence intervals are given in parentheses.

^aRadiographic loosening or revision for aseptic loosening.

Fig. 2 Survival free of femoral revision for mechanical failure or osteolysis or radiographic evidence of osteolysis with 95% confidence intervals according to the Kaplan–Meier method

interval, 88.8–98.4) for the whole series. Comparing the two coatings, the 7-year rates were 98.5% (95% confidence interval, 93.5–100%) for the HA group and 89.9% (82.5–97.9%) for the PC group ($p=0.06$) (Fig. 2).

The 7-year survival free of distal osteolysis (in zones 2, 3, 4, 5 or 6) was 100% for the HA group and 90% (95% confidence interval, 82–98.8%) for the PC group. This difference was statistically significant ($p=0.04$). Survival free of mechanical failure of the femoral component or distal osteolysis was 95.8% (95% confidence interval, 88.5–100%) for the HA group and 86.6% (95% confidence interval, 78.3–95.7%) for the PC group. This difference was also statistically significant ($p=0.05$) (Table 3).

Discussion

The relationship between HA coating, wear, and osteolysis has not been determined fully. HA coating has been shown to seal the periprosthetic interface preventing the access of wear debris particles [19]. Avoidance of periprosthetic particle migration is in turn expected to decrease osteolysis [20]. However, some authors have reported substantial osteolysis around HA-coated components [2, 4]. These osteolytic lesions have been attributed to detachment of

HA particles from the surface resulting in either third-body wear or direct macrophage stimulation through mechanisms similar to those described for other particulate material [4, 6].

In order to assess the role of HA coating on wear and osteolysis, we selected a femoral component manufactured initially with patches of porous-coating and latter with a circumferential layer of HA with no other changes in the design. A matched cohort was used so that patients in the two groups were similar for age, gender, weight, surgeon, underlying diagnosis, and polyethylene characteristics. We wanted to know if the substitution of the patches of porous-coating by a circumferential layer of HA would increase the polyethylene wear rate and also how this potential increase in the load of particles of both polyethylene and HA would influence the rate of femoral osteolysis in the presence of circumferential sealing of the interface.

Regarding polyethylene wear, we were unable to find increased wear rates in the HA group. Although HA particulate material found in the periprosthetic tissue of retrieved implants has been proposed to be implicated in third-body wear [2, 3], we found no increased polyethylene wear in the HA group. This is in accordance to the findings of Bauer et al. [1] of less femoral head surface damage in the presence of HA, suggesting no evidence of third-body wear with HA-coated stems.

Regarding osteolysis, circumferential HA coating of the femoral component increased survivorship free of osteolysis and eliminated distal osteolysis. None of the hips with a HA-coated stem developed osteolysis in Gruen zones 2–6. This contrasts with the 26% rate of distal osteolysis found in the porous-coating group. We think this difference is mainly due to the fact that the porous coating was noncircumferential whereas the HA coating was circumferential [10].

Our study had several limitations: it was retrospective in nature, the extent of the coating was different in the two groups, and the length of follow-up was longer in the PC group. We believe it is unlikely that HA stems will develop a substantial rate of distal osteolysis with longer follow-up, but that needs to be proven.

In summary, our results show that just changing the surface finish of the femoral stem from a noncircumferential porous-coating to a circumferential HA coating

resulted in better implant survival free of mechanical failure and osteolysis without increasing the polyethylene wear rate. Information available at present time does show that the use of HA-coated femoral components should not be expected to increase polyethylene wear and that HA coating is effective for both implant fixation and prevention of distal osteolysis.

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