Comparison of hydroxyapatite- and porous-coated stems in total hip replacement

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ABSTRACT **24 patients underwent bilateral hip replacement, using the SROM modular system (Depuy Johnson & Johnson, MA, USA) with the porous-coated sleeve in one hip and an HA-coated sleeve in the other. 20 patients were followed for at least 4 years with clinical and radiographic evaluations. We found no difference between the two sides as regards the time of disappearance of thigh pain and hip scores. Radiographs showed a buttress sign in 18 HA-coated and 15 porous coated stems. There were no differences in the serial bone-remodeling pattern around the proximal sleeve and measurement of wear volume between the two groups. In the short- to medium-term, our findings support the view that the hydroxyapatite-coated femoral stem has no advantages over those with porous coating.**

There are still some controversies regarding treatment of the stem surface for ideal bone fixation in the uncemented prosthesis of total hip replacement (THR). Ciccotti et al. (1994) found no difference between the hydroxyapatite-coated femoral stem and the porous-coated stem in the radiographic evaluation. McPherson et al. (1995) reported no clinical or radiographic differences in a matched-pair comparison of porous-coated stems with or without hydroxyapatite coating. A matched study comparison by Rothman et al. (1996) produced excellent clinical results in the first 6 months with hydroxyapatite, but there were no clinical or radiographic differences thereafter. Furthermore, Dorr et al. (1998) suggested that although the hydroxyapatite stem showed better radiographic results than the porous-coated stem, the clinical results were similar. Despite some randomized studies, which compared hydroxyapatite-coated with porous-coated stems, none have evaluated bilaterally-operated patients who were given different coatings on the two sides.

This study was done to compare the outcome of total hip replacement in patients with the same basic design of prosthesis on both sides. On one side, the implant had a hydroxyapatite coating, and on the other, a porous coating. Clinical and repeated radiographic examinations were done.

Patients and methods

From October 1995 to June 1997, 24 patients received a bilateral hip arthroplasty with a porous-coated femoral stem in one hip and a hydroxyapatite-coated stem in the contralateral hip. Among them, 20 patients (40 hips, 14 males), who were followed for at least 4 years, were evaluated in this study. 4 patients were lost during follow-up. 9 patients had both hips replaced at the same operation; in the remaining 11, there were intervals of 3 (4 patients), 6 (4 patients), 9 (2 patients), and 12 (1 patient) months between the first and second arthroplasty. The average age of the patients at the time of operation was 54 (29–68) years, and their average weight 62 (50–82) kg. The average follow-up of the hydroxyapatite group was 52 (47–64) months and of the porous group, it was 52 (47–60) months. Both hips of all patients had the same diagnosis before surgery, with avascular necrosis in 17 patients and osteoarthrosis in 3.

Table 1. Data in 20 patients with a porous-coated sleeve in one hip and a HA-coated sleeve in the other

Gender	Age	Diagnosis	Femoral head R / L (mm)	Stem (R / L) (mm)	Sleeve (R / L)	Acetabular cup (R / L) (mm)	Thigh pain [a] HA (month)	Thigh pain [a] PC (month)	Buttress sign [b] HA (month)	Buttress sign [b] PC (month)
M	61	AVN	Z(28) / Z(28)	18x13 / 18x13	18B L PC / 18B L HA	54 / 54	3	3	6	12
M	63	AVN	Z(28) / Z(28)	20x15 / 20x15	20B L HA / 20B L PC	56 / 56	3	5	3	3
M	61	AVN	Z(28) / Z(28)	22x17 / 22x17	22D L PC / 22D S HA	54 / 51	6	24	3	12
M	61	AVN	C(28) / C(28)	18x13 / 18x13	18B L HA / 18B L PC	54 / 54	4	3	12	12
M	61	OA	Z(28) / Z(28)	20x15 / 20x15	20D S PC / 20D S HA	54 / 54	2	3	12	12
M	63	AVN	Z(28) / Z(28)	20x15 / 20x15	20B S PC / 20D S HA	54 / 54	4	4	3	3
M	56	AVN	Z(28) / Z(28)	18x13 / 18x13	18B L PC / 18B L HA	54 / 54	5	3	24	12
M	65	AVN	Z(28) / Z(28)	18x13 / 18x13	18B L HA / 18B L PC	51 / 51	15	5	6	–
M	66	OA	C(28) / C(28)	18x13 / 18x13	18D L PC / 18D L HA	54 / 54	3	4	–	6
F	30	AVN	Z(28) / Z(28)	18x13 / 18x13	18B S PC / 18B S HA	54 / 54	4	5	3	–
M	48	AVN	C(28) / C(28)	20x15 / 20x15	20B L PC / 20B L HA	51 / 51	5	5	12	24
F	36	AVN	Z(28) / Z(28)	16x11 / 16x11	16B S HA / 16D S PC	52 / 51	3	3	3	24
F	60	AVN	Z(28) / Z(28)	20x15 / 20x15	20B S HA / 20B S PC	52 / 52	4	12	3	–
F	68	OA	Z(28) / Z(28)	18x13 / 18x13	18D L HA / 18D L PC	54 / 54	3	3	–	12
F	29	AVN	Z(28) / Z(28)	16x11 / 16x11	16B S HA / 16D S PC	54 / 54	2	4	3	–
M	51	AVN	Z(28) / Z(28)	20x15 / 20x15	20D S PC / 20D S HA	54 / 54	4	3	6	3
M	42	AVN	Z(28) / Z(28)	18x13 / 18x13	18D L HA / 18D L PC	57 / 57	3	6	12	–
M	47	AVN	C(28) / C(28)	20x15 / 20x15	20D S PC / 20D S HA	57 / 57	3	5	3	6
F	57	AVN	Z(28) / Z(28)	20x15 / 20x15	20B L PC / 20B L HA	51 / 54	3	3	3	12
M	57	AVN	Z(28) / Z(28)	18x13 / 18x13	18D L PC / 18D L HA	54 / 54	2	4	6	6

HA hydroxyapatite-coated, PC porous-coated, Z zirconia, C cobalt chrome, AVN avascular necrosis, OA osteoarthrosis
[a] Month-to-disappearance of thigh pain after surgery.
[b] Month-to-appearance of the buttress sign after surgery.

The operations were performed by the first author. The patients were placed in the lateral decubitus position, using an anterolateral surgical approach (modified Watson and Jones).

In the hydroxyapatite-coated sleeve, the thickness of the coating was 50 μm. In the porous-coated sleeve, monolayer metallic beads had a coating that was 110 μm thick. The coatings were applied to the proximal sleeve of the (S-ROM) (DePuy Johnson & Johnson, MA, USA) modular cementless stem. In all cases, a 28 mm size head was used. The same head material was used bilaterally. 16 patients received zirconium and 4 cobalt chrome heads (Table 1).

The Harris (1960) hip score was evaluated before and at 3, 6, 12, 24, 36, 48 and 60 months after surgery. Presence and time-to-disappearance of thigh pain was recorded. Anteroposterior radiographs of the pelvis taken before and after the operation at 3 and 6 months, and 1, 2, 3, 4, and 5 years after surgery were evaluated. We recorded the cortical bone density around the sleeve, polyethylene wear and inclination of the acetabular cup, femoral stem canal-filling ratio, vertical migration of the stem, and buttress sign appearance (Johnston et al. 1990, Kakabayashi and Terayama 1990). The sleeve was arbitrarily divided into 3 (Z4, Z5, Z6) medial and 3 (Z1, Z2, Z3) lateral areas to evaluate the bone remodeling process (Figure 1). By measuring the pixel value on digitized radiographs of the PACS

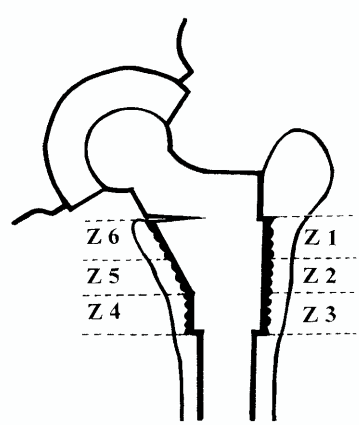

Figure 1. The subzones of the proximal sleeve.

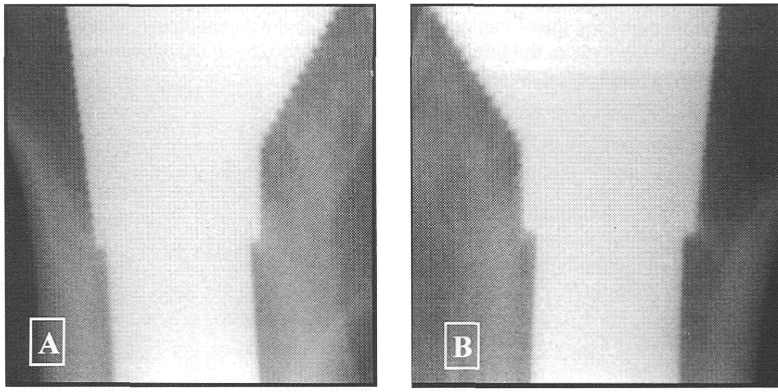

Figure 2. Buttress sign (spot weld) 6 months after surgery in the hydroxyapatite (A)- and porous-coated proximal sleeves (B) of the same patient. Note the "spot weld" at the distal end of the proximal sleeve.

(Picture Archiving Communicating System), cortical bone density in each period was assessed (Shim et al. 2002). The annual wear of the acetabular cup was determined by Livermore et al.'s method (1990). The femoral stem: canal-filling ratio was measured by comparing the intramedullary diameter of the femur and the diameter of the stem at its mid portion (Kabayashi and Terayama 1990).

Statistics

Wilcoxon's signed rank test was used for the statistical analysis of the pain score, limp score and total Harris hip score, and the independent sample t-test was used to determine the degree of polyethylene wear and inclination of the acetabular cup, and the femoral stem: canal-filling ratio. The differences in bony density in each area were analyzed with ANOVA of repeated measures, the significance of the p-value being less than 0.05.

Results

Clinical results

At the final follow-up, the median pain scores were 44 (40–44) in each group. The median limp scores were 11 (8–11) and 11 (5–11), respectively ($p = 0.3$). The average total Harris scores were the same, 92 (88–98) and 92 (85–97). The times-to-disappearance of thigh pain were less than 6 months in most cases, apart from 1 case with a HA-coated stem, in whom the pain lasted for more than a year, and 2 cases with a porous stem, in whom the pain persisted for 1 and 2 years after surgery, respectively. There were no differences between the two groups as regards the time-to-disappearance of thigh pain.

Radiographic findings

The buttress sign, so-called 'spot welding,' indicate an early stage of bone fixation in the distal part of the proximal sleeve. This was detected in 18 hips with HA coating, and 15 with porous coating (Ciccotti et al. 1994, McPherson et al. 1995). 9 hips in the hydroxyapatite-coated group showed the buttress sign at 3 months after surgery, 4 hips at 6 months, 4 hips at 12 months, and 1 hip at 24 months after surgery. 3 hips in the porous-coated group showed the buttress sign at 3 months after surgery, 3 hips at 6 months, 7 hips at 12 months, and 2 hips at 24 months after surgery (Table 1). The hydroxyapatite-coated vs. porous-coated showed an improvement in earlier fixation ($p = 0.05$).

Remodeling was assessed by determining the cortical bone density in 6 regions. We found a reduction in all 6 regions after surgery ($p = 0.01$), with no difference between the two groups ($p = 0.08$, Table 2). On the side with the hydroxyapatite coating, bone density was reduced at 3 months after surgery, and it slowly decreased further until 2 years. After that, no change occurred. The bony density of the porous-coated stem decreased greatly during the first 3 months after surgery, more slowly for 2 years; and it then increased slightly after 4 years. Both groups showed a similar

Table 2. Serial mean bone densities (pixel values, percentage) of the subzones in hydroxyapatite- and porous-coated proximal sleeves. In both groups, the bone densities decreased ($p < 0.05$). However, there was no significant difference between the two groups

	Bone density in hydroxyapatite-coated						Bone density in porous-coated					
	Z1	Z2	Z3	Z4	Z5	Z6	Z1	Z2	Z3	Z4	Z5	Z6
Preop.	1	1	1	1	1	1	1	1	1	1	1	1
3 months	0.93	0.94	0.95	0.95	0.92	0.94	0.93	0.93	0.95	0.93	0.92	0.94
6 months	0.91	0.93	0.94	0.94	0.91	0.92	0.93	0.93	0.91	0.92	0.91	0.92
1 year	0.92	0.91	0.92	0.93	0.88	0.90	0.92	0.92	0.89	0.89	0.89	0.90
2 year	0.88	0.87	0.88	0.90	0.85	0.86	0.92	0.92	0.88	0.87	0.86	0.87
3 year	0.90	0.91	0.89	0.89	0.85	0.85	0.89	0.88	0.85	0.88	0.87	0.86
4 year	0.86	0.87	0.84	0.88	0.84	0.83	0.89	0.88	0.86	0.85	0.87	0.85
5 year	0.89	0.90	0.86	0.90	0.86	0.85	0.91	0.90	0.88	0.89	0.90	0.88

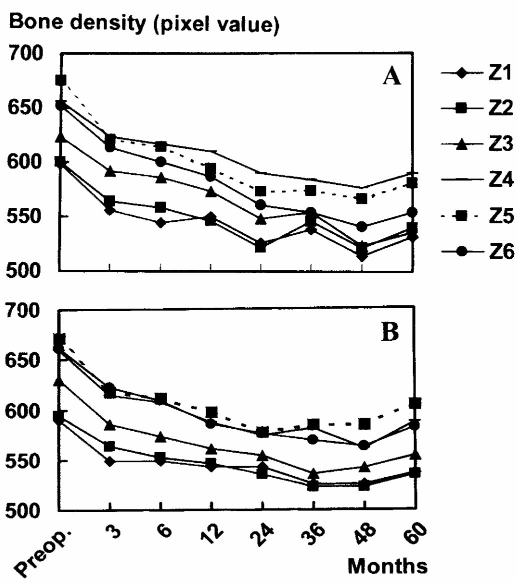

Figure 3. Serial mean bone densities (pixel values) in the subzones of the hydroxyapatite (A)- and porous (B)-coated proximal sleeves.

pattern of change in bone density (Figure 3). The annual polyethylene wears of the acetabular cup were 560 mm^3/year in the hydroxyapatite group and 591 mm^3/year in the porous group ($p = 0.7$). The median inclinations of the acetabular cup were 41 (34–49)° and 39 (30–46)°, respectively, and the canal-filling ratios were 90 (78–100)% and 91 (83–100)% ($p = 0.5$, $p = 0.7$). An increase in the radiolucency around the stem or changes in the position or vertical migration of the stem was not seen in any case.

Discussion

It has been suggested that the hydroxyapatite-coated femoral stem is better than the porous-coated stem in early bone fixation of the uncemented prosthesis in THR. In general, the hydroxyapatite has been shown to give faster bone growth and more uniform and firm fixation (Engh and Massin 1989, Ciccotti et al. 1994). It may improve fixation despite microscopic movements of the components (Søballe et al. 1991, 1993). However, there are potential problems related to hydroxyapatite: surface absorption, loss of the hydroxyapatite coating, and a possible increase in third body wear of polyethylene by detachment of particles from the coating.

On the basis of animal experiments of hydroxyapatite-coated and uncoated titanium stems in dogs, Cook et al. (1988) and Thomas et al. (1989) claimed that the hydroxyapatite-coated stem had 5–7 times stronger contact than the uncoated titanium stem. The stem fixation with 50-micron thick, plasma-sprayed hydroxyapatite was reported to improve the fixation (D'Antonio et al. 1992a, b, 1996, Dorr et al. 1998). In stem revisions, Bauer et al. (1991) detected no signs of dissociation or absorption of the hydroxyapatite. Therefore, they suggested that once a stem is fixed, the hydroxyapatite would not increase osteolysis or wear. Engh and Massin (1989) reported a significant reduction in thigh pain with a hydroxyapatite-coated stem, as compared to the porous-coated stem during the first 6 months after surgery, but no difference thereafter. The reduction in pain at an early stage may be due to early bone growth around the hydroxyapatite-coated stem. On the basis of his investigation of 30 cases of THR with a hydroxyapatite-coated stem in one hip and a porous-coated stem in the contralateral hip, Dorr et al. (1998) reported that the former group showed better outcomes in terms of early bone fixation and bone formation, but no significant difference in clinical results. However, they used different stem designs.

The proximal sleeve with a hydroxyapatite or porous coating was separated into 6 divisions and pixel values were arbitrarily determined. These were used to evaluate bone remodeling by objective measurements of bone density (Shim et al. 2002). In 2002, on the basis of the pixel value of the PACS and the measurement of bone density by dual energy x-ray absorptiometry, Shim et al. reported that this value is a good indicator of bone density using the same standardized x-ray technique. The bone densities were similar in the hydroxyapatite- and porous-coated stems. 2 years after surgery, the bone density was evenly distributed, which suggests that dynamic equilibrium of bone resorption and reformation had occurred.

In our study, we used the same stem system in both hips of the same patients, with one hip implanted with a porous-coated femoral stem and the contralateral hip with a hydroxyapatite-coated one. We therefore excluded variables that may affect bone formation, such as the patient's activity and weight. In an ideal prospective study, the design and size of the inserted components, diagnosis of the patient, and the surgeon, as well as the surgical technique, should be identical. The clinical outcomes did not differ significantly after surgery.

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