

# Preservation of the bone mineral density of the femur after surface replacement of the hip

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From Osaka University School, Osaka, Japan We investigated the effect of the Birmingham hip resurfacing (BHR) arthroplasty on the bone mineral density (BMD) of the femur. A comparative study was carried out on 26 hips in 25 patients. Group A consisted of 13 patients (13 hips) who had undergone resurfacing hip arthroplasty with the BHR system and group B of 12 patients (13 hips) who had had cementless total hip arthroplasty with a proximal circumferential plasma-spray titanium-coated anatomic Ti6A14V stem. Patients were matched for gender, state of disease and age at the time of surgery. The periprosthetic BMD of the femur was measured using dual-energy x-ray absorptiomentry of the Gruen zones at two years in patients in groups A and B.

The median values of the BMD in zones 1 and 7 were 99% and 111%, respectively. The post-operative loss of the BMD in the proximal femur was significantly greater in group B than in group A. These findings show that the BHR system preserves the bone stock of the proximal femur after surgery.

Resorption of proximal bone around femoral stems is a common phenomenon in stable cementless total hip arthroplasty (THA).<sup>1-4</sup> This is thought to represent bone atrophy because of mechanical unloading, in accordance with Wolff's Law. Loss of periprosthetic bone may predispose the site to periprosthetic fracture, reduce the stability of the prosthesis and make revision difficult. Therefore, it is desirable to minimise loss of proximal bone after cementless THA.

Maintenance of the quality of proximal femoral bone is thought to require normal transfer of load to the proximal femur. Low-stiffness stems, smaller stems, shorter stems and partial bone ingrowth into a proximal coating are effective as indicated by the periprosthetic bone mineral density (BMD).<sup>3-5</sup> Surface replacement of the hip is the most direct way to maintain load on the proximal femur, but there are no longitudinal quantitative follow-up studies of surface replacement using dualenergy x-ray absorptiometry (DEXA). Our aim therefore was to evaluate the effect of surface replacement of the hip on the BMD of the proximal femur using DEXA.

## Materials and Methods

We studied two groups of patients. Group A consisted of 13 patients (13 hips) who had undergone surface replacement of the hip with the Birmingham hip resurfacing (BHR) system

(MMT, Birmingham, UK) between October 1998 and May 2000. Group B consisted of 12 patients (13 hips) who had received a cementless THA using a hip system with a standard design of stem between July 1997 and October 1998. The hip systems were selected in accordance with standard practices at the time. Patients undergoing arthroplasty were excluded from the study if they had undergone previous operative treatment of the ipsilateral femur. Patients in both groups were matched for gender, state of disease and age (Table I).

In both groups the operations were performed through a posterolateral approach. In group A, a BHR hydroxyapatite-coated cup was fixed without cement while the BHR femoral component was fixed with low-viscosity cement (Surgical Simplex P; Stryker Howmedica, Allendale, New Jersey) after preparation of the femoral head with multiple subchondral anchor holes.<sup>6</sup> Cementing around the short stem of the femoral component was avoided. In group B, an asymmetrical curved stem (Axcel; Cremascoli, Milan, Italy) made of Ti6A14V alloy with proximal circumferential plasma-spray titanium coating was used. All the patients were allowed to bear full weight on the second post-operative day.

Clinical evaluation was performed before, and at six and 24 months after operation using the hip scoring system of Merle d'Aubigné and Postel.<sup>7</sup> In this system, hips receive a score of 0

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#### Table I. Clinical details of the patients in both groups

	Group A	Group B	p value
Number of patients (hips)	13 (13)	12 (13)	
Gender (women/men)	7/6	3/9	0.23*
Median age (range) at operation in years	58.0 (33.0 to 69.0)	58.0 (30.0 to 64.0)	0.94†
Disease (Osteoarthritis/osteonecrosis)	9/4	8/5	>0.99*

\* as determined by Fisher's exact probability test

† Mann-Whitney U test



L1 L2 J M1 M2 J M2 M3

Fig. 2

Dexa image showing that in group A the BMD ratio of the femoral neck was evaluated at the following six locations: L1, proximal-lateral zone; L2, mid-lateral zone; L3, distal-lateral zone; M1, proximal-medial zone; M2, mid-medial zone; and M3, distal-medial zone of the peg.

Fig. 1

Dexa image showing the template of the Axcel system superimposed on the bones treated with the BHR system to allow similar Gruen zones to be measured in both groups.

to 6 points for each of the following: comfort level (pain), range of movement and walking ability. Thus, the maximum total score is 18, indicating a normal hip.

The BMD was measured by DEXA (DPX-L; Lunar, Madison, Wisconsin) at three weeks and then at 3, 6, 12, and 24 months after surgery. The patients were positioned supine on the table with standard knee and foot supports so that the femur was in a neutral position.

The software (Orthopaedic Software Package, version 4.6; Lunar) used in our study was designed to measure the periprosthetic bone mineral content and density in seven

zones of Gruen, McNeice and Amstutz.<sup>8</sup> The resolution of the scan was 0.6 x 1.2 mm. The mean time taken for the scan was seven minutes and the mean scan dose was 2.4 millirems. The surface replacement group A was evaluated by superimposing the templates of the Axcel femoral prosthesis, used in group B, over the femora in group A (Fig. 1). The BMD ratio of each zone was calculated as a percentage of the value obtained three weeks after operation. The area of the femoral neck in group A was evaluated further by. calculating the BMD ratio for each of the following six locations of the femoral neck around the short stem: L1, proximal-lateral zone; L2, mid-lateral zone; L3, distal-lateral zone; M1, proximal-medial zone; M2, mid-medial zone; and M3, distal-medial zone (Fig. 2).

Reproducibility was assessed in all patients at zone 7 which has a large coefficient of variation for the proximally coated stem,<sup>4</sup> by two observers using the method of Bland

			Post-operative period				
	Befo	Before surgery		6 months		24 months	
Group A							
Pain	1.5	(0 to 2)	6.0		6.0		
Mobility	4.0	(2 to 5)	5.0	(4 to 6)	5.0	(4 to 6)	
Walking ability	2.0	(1 to 3)	6.0	(5 to 6)	6.0	(5 to 6)	
Total	8.0	(6 to 9)	16.0	(16 to 17)	16.0	(16 to 17)	
Group B							
Pain	1.0	(0 to 2)	6.0		6.0		
Mobility	4.5	(3 to 6)	6.0	(4 to 6)	6.0	(4 to 6)	
Walking ability	1.5	(0 to 3)	5.0	(4 to 6)	5.0	(4 to 6)	
Total	7.5	(4 to 10)	17.0	(15 to 18)	17.0	(15 to 18)	

Table II. The median (range) hip scores of Merle d'Aubigné and  $\mathsf{Postel}^7$  for both groups

Table III. Median (range) BMD ratios for both groups according to the zones of Gruen et al<sup>8</sup> in the post-operative period

	3 weeks	3 months	6 months	12 months	18 months	24 months
Zone 1						
Group A	100	96.8 (88 to 105)	95.8 (90 to 118)	96.0 (87 to 122)	99.8 (81 to 122)	99.0 (95 to 132)
Group B	100	87.4 (71 to 102)	89.4 (71 to 107)	89.9 (76 to 111)	84.4 (72 to 116)	89.1 (73 to 107)
Zone 2						
Group A	100	98.4 (76 to 105)	97.9 (82 to 113)	99.8 (85 to 110)	99.6 (89 to 113)	100.2 (90 to 113)
Group B	100	93.3 (80 to 99.9)	94.3 (88 to 103)	97.4 (80 to 111)	97.6 (75 to 107)	102.4 (81 to 107)
Zone 3						
Group A	100	98.2 (70 to 135)	94.9 (77 to 146)	96.4 (75 to 115)	97.3 (89 to 122)	100.0 (96 to 106)
Group B	100	93.5 (90 to 106)	101.0 (92 to 109)	102.0 (97 to 113)	101.6 (94 to 112)	103.3 (96 to 119)
Zone 4						
Group A	100	102.8 (91 to 109)	98.8 (93 to 101)	101.0 (93 to 119)	100.0 (92 to 105)	100.0 (98 to 103)
Group B	100	94.7 (90 to 100)	98.1 (90 to 101)	93.4 (89 to 102)	93.7 (83 to 106)	96.2 (83 to 108)
Zone 5						
Group A	100	100.8 (94 to 136)	100.2 (93 to 147)	102.6 (92 to 147)	104.5 (97 to 140)	106.2 (100 to 117)
Group B	100	100 (79 to 118)	101.8 (97 to 128)	101.6 (83 to 129)	96.8 (89 to 112)	98.3 (87 to 127)
Zone 6						
Group A	100	98.4 (89 to 105)	98.2 (92 to 108)	96.3 (87 to 109)	97.8 (82 to 107)	101.0 (86 to 112)
Group B	100	93.4 (90 to 104)	99.9 (82 to 106)	98.6 (82 to 112)	96.5 (88 to 111)	104.0 (84 to 109)
Zone 7						
Group A	100	105.0 (96 to 140)	103.2 (91 to 133)	104.7 (87 to 117)	113.1 (93 to 131)	111.0 (89 to 131)
Group B	100	95.9 (77 to 107)	83.8 (54 to 100)	87.8 (59 to 101)	82.8 (62 to 95)	83.2 (65 to 105)

and Altman.<sup>9,10</sup> The differences in the Merle d'Aubigné and Postel hip scores and BMD ratios between the two groups were examined using repeated measure ANOVA. A p value of <0.05 was considered to be significant.

### Results

The Merle d'Aubigné and Postel hip scores obtained during the follow-up period are given in Table II. There were no significant differences in the scores. The BMD ratios obtained during the follow-up period are shown in Table III. In Gruen zone 1 (Fig. 3a) the median BMD ratio remained at almost 100% in group A, whereas it decreased to 89% at 24 months in group B. In Gruen zone 7 (Fig. 3b) the median BMD ratio increased to 111% at 24 months in group A, whereas it decreased during the first six months in group B and then reached 83% at 24 months.

In Gruen zones 1 and 7, repeated measure ANOVA showed significant differences between the two groups (zone 1; p = 0.04; zone 7; p = 0.008). There were no significant differences in the BMD ratios in the middle and distal zones.

An increase in the BMD of the femoral neck was observed on the plain radiographs of some patients in group A. The BMD ratios of the femoral neck are shown in Figure 4. In the superolateral part of the neck the median BMD ratio at L2 remained at almost 100% at all follow-up times. The median BMD ratios at L1 and L3 increased, reaching a maximum at 24 months. In the inferomedial zone the median BMD ratio at M1 and M3 remained at almost 100% at all follow-up times. There was an increase in the median BMD ratio of the M2 zone beginning at 12 months which reached a maximum of 24 months. A Bland-Altman plot was made of the difference between the two observers against their mean. The mean difference (+2 SD) and limits of agreement were -0.02% and -0.16% to 0.12%, respectively.

## Discussion

DEXA is a precise method of measuring small changes in the BMD around femoral components.<sup>11,12</sup> Cohen and Rushton<sup>11</sup> reported that correct positioning of patients is necessary to obtain precise results with DEXA. Therefore in



Box plots of the BMD ratio in Gruen zone 1 (a) and Gruen zone 7 (b). The median value is represented by the central, horizontal line. The 75% and 25% values are represented by the upper and lower borders of the box and the 90% and 10% values by the extensions of the vertical lines.



Box plots showing the BMD ratio in (a) the lateral and (b) medial areas of the femoral neck. The median value is represented by the central, horizontal line. The 75% and 25% values are represented by the upper and lower borders of the box and the 90% and 10% values by extensions of the vertical lines.

our study we used standard knee and foot supports. We used the BMD at three weeks post-operatively as our reference baseline for all subsequent BMD measurements.<sup>3,12</sup> Several studies have shown that most of the changes in the femoral BMD occur within the first year.<sup>3,5,13</sup> They indicate that the follow-up at two years used in our study is representative of the change in BMD after cementless THA.

Although a randomised comparative prospective study is desirable, our design was a case-control study because we introduced the BHR later. The male:female ratio and patient age were matched between the two groups to eliminate biases which affect changes in BMD. There were no significant differences in the Merle d'Aubigné and Postel hip scores between the two groups and it is reasonable to assume that there was little difference in physical activity between the two.

It is widely accepted that the BMD of the proximal femur generally decreases after cementless THA using standard designs of stem.<sup>3</sup> In our study the median loss of BMD with the Axcel stem was 11% in Gruen zone 1 and 17% in Gruen zone 7 at two years after surgery. These losses were relatively small compared with those in other systems.<sup>3,14,15</sup> By contrast, the post-operative BMD in the proximal femur was significantly greater in patients treated with the BHR system than in those treated with the conventional system. The patients treated with the BHR system demonstrated preservation of the BMD in Gruen zone 1 and an increase in zone 7. These results suggest that transfer of load to the proximal femur was more normal after surface replacement with the BHR system.

Wear debris can also cause resorption of bone and there have been reports of high rates of failure for resurfacing hip arthroplasty.<sup>16,17</sup> In these series high volumetric wear of polyethylene cups played a central role in periprosthetic bone resorption and the failure of resurfacing prostheses. The BHR system uses a cast cobalt-chromium metal-onmetal bearing<sup>6,18</sup> to eliminate aggressive wear and osteolysis and the Axcel system uses an alumina ceramic-onceramic bearing. As a result, we presume that wear debris had a negligible effect on the BMD in our study.

There have been several finite-element analyses of stress on the femur after surface replacement. Huiskes et al<sup>19</sup> evaluated the transmission of load and interface stresses of Wagner resurfaced femoral heads and reported that there were high compressive stress peaks at the superior/lateral interface and high tensile stresses at the inferior/medial interface. However, they concluded that these stresses were not higher than those previously reported for other types of prosthesis. Watanabe et al<sup>20</sup> conducted a finite-element analysis study of the BHR system and found stress shielding in the anterosuperior region of the femoral neck beneath the prosthesis as well as stress concentration around the short stem in the inferior cross-section of the femoral neck. They speculated that these may lead to fracture of the femoral neck and long-term loosening. However, fracture of the femoral neck after BHR is an early complication<sup>6,20</sup> which occurs mainly in female patients with osteoporosis. If it is caused by atrophy of the femoral neck as a result of stress shielding, it should occur as a late complication. Our results show that BHR preserves the BMD in the proximal femur, including the femoral neck, and that the distribution of stress after BHR is relatively normal.

We conclude that the BHR system transfers load to the proximal femur in a more physiological manner than longstem devices, that it prevents stress shielding and preserves the bone stock of the proximal femur. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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