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**Original Article**

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# Periprosthetic bone densitometry of the hip: Influence of prosthetic design and hydroxyapatite coating on regional bone remodelling

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## Abstract

*Objective:* To determine the influence of femoral hip prosthesis design and composition on regional periprosthetic bone remodelling as a function of time in asymptomatic patients. *Materials and methods:* Bone mineral density (BMD) changes surrounding two differently designed porous-coated femoral prostheses (S-ROM™, n=111; and Multilock™, n=62) were determined serially over a 24 month interval. There was a subset of patients with Multilock™ implants that were coated with a 50 micron film of hydroxy-apatite (n=23) over the porous surface. Seven Gruen zones defined the periprosthetic bone regions (LUNAR ORTHO™ software). Inclusion criteria were primary implants, Harris hip scores ≥95 and no radiographic evidence of loosening. *Results:* For the S-ROM femoral component, at 6 months all zones showed a significant decrease in BMD relative to the immediate postoperative baseline measurements; mean loss varied from 4.3% to 17.4%. At 24 months mineral change varied from -10.8% to +1% for Gruen zones 1 to 6. Gruen zone 7, the calcar, differed in that it was the site of greatest mineral loss, attaining a mean of 17% at 24 months, and it was also significantly greater than the losses registered in the other zones at that time point. For the Multilock, maximal mineral losses were registered at zones 1 and 7. There were significant differences in mineral losses between the S-ROM and Multilock implants in zones 1, 2 and 3 at 24 months; S-ROM losses of 7.3%, 10.8% and 3.5% respectively, compared to Multilock losses of 23.8%, 15.9% and 6.9% respectively. Comparison of hydroxyapatite coated and uncoated Multilock implants demonstrated significantly less loss in the coated implants in zones 1 (greater trochanter) and 7 at 24 months. Coated losses were -16.9% and 11.3% for zones 1 and 7, respectively, whereas uncoated losses were 23.8% and 20.5% respectively.

**Keywords:** Bone Densitometry, Bone Remodelling, Total Hip Arthroplasty

## Objective

To determine the effect of design and hydroxyapatite coating on bone remodelling adjacent to the porous-coated cementless femoral component of hip prostheses in asymptomatic patients as a function of time.

## Materials and Methods

Bone mineral density (BMD, gr/cm$^2$) for the seven Gruen zones (Fig. 1) surrounding the femoral component were determined by dual energy x-ray absorptiometry (DXA) using the LUNAR DPX scanner and LUNAR ORTHO™ software (LUNAR CORPORATION, Madison, WI, USA). Two prosthetic designs of titanium alloy composition were studied: S-ROM™ (Johnson & Johnson, Raynham, MA, USA) and Multilock™ (Zimmer, Warsaw, IN, USA). The S-ROM consists of two separate femoral components, a porous-coated sleeve proximally and a stem which is fluted and slotted distally (Fig. 2), whereas the Multilock is a single component femoral design which is porous-coated proximally and fluted distally (Fig. 3). There were 111 S-ROM and 62 Multilock hip prostheses. Twenty-two of the Multilocks had a 50$\mu$m thick coating of hydroxyapatite sprayed over the porous surface and 39 were uncoated. Inclusion criteria required that the patient be asymptomatic with Harris hip scores ≥95, primary implants, no osteotomy of the greater trochanter, no bone graft applications, no fractures during surgery, no radiographic evidence of subsidence and no other complications during follow-up. BMD determinations were made within a week of surgery to

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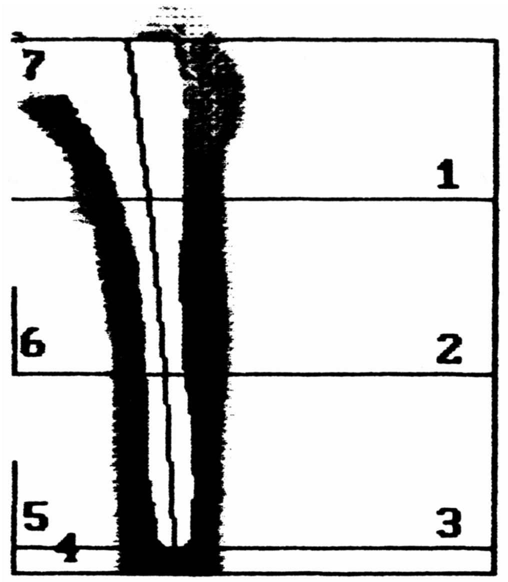


**Figure 1.** The 7 Gruen zones used for measuring periprosthetic bone mineral density.

serve as the baseline reference for percent change and then at 6 months, 12 months and yearly thereafter. As this is an ongoing study with new patients continually added to the study group, and since not all patients met all the time points for BMD measurements, statistical analysis included single factor analysis of variance for repeated measurements with missing values (NCSS 2000, Kaysville, UT, USA).

## Results

Table 1 details the means of the percent BMD change and their 95% confidence interval limits (CIL) of the three prostheses for the seven Gruen zones from 0 to 24 months post-implantation. Figure 4 is a composite of the graphs for the Gruen zones illustrating the temporal percent BMD changes for the S-ROM, Multilock and Multilock-HA devices derived from the data in Table 1. There is a significant BMD loss in all Gruen zones at 6 months, and by 24 months mineral recovery was registered in zones 4 and 5 for the S-ROM, zone 5 for the Multilock, and zones 3, 4, 5 and 6 for the Multilock-HA according to the their 95% CIL. Significant differences were observed in the percent BMD loss between the three prostheses at 24 months as follows:

S-ROM versus Multilock. Significantly lower mineral losses for the S-ROM in zones 1, 2, 3 and 4 compared to the Multilock, differing by a factor that varies from 1.5 to 2.3 S-ROM versus Multilock-HA. Significantly lower mineral loss for the S-ROM in zone 1, differing by a factor of 2.8. In contrast, there are significantly greater mineral losses for the S-ROM in zones 4, 6 and 7 compared to the Multilock-HA, differing by a factor that varies from 1.5 to 9 Multilock versus Multilock-HA At 24 months there are significantly greater mineral losses in the Multilock compared to the Multilock-HA in zones 1, 2, 3, 4, 6 and 7, differing by a factor that varies from 1.4 to 4.6. The change in projected area of Gruen zone 7, the calcar region, was measured in the three prostheses utilizing the software's edge detection capability. It was found that between 0 and 24 months there was a mean(%95 CIL) change of -11.4% (-15.8%, -7.0%) for the S-ROM which was significantly greater than the Multilock and Multilock-HA at -4.4 (-9.5%, 0.8%) and -4.1 (-10.3%, 2.1%), respectively.

## Discussion

Dual energy x-ray absorptiometry (DXA) makes it possible to quantify bone mineral density changes in

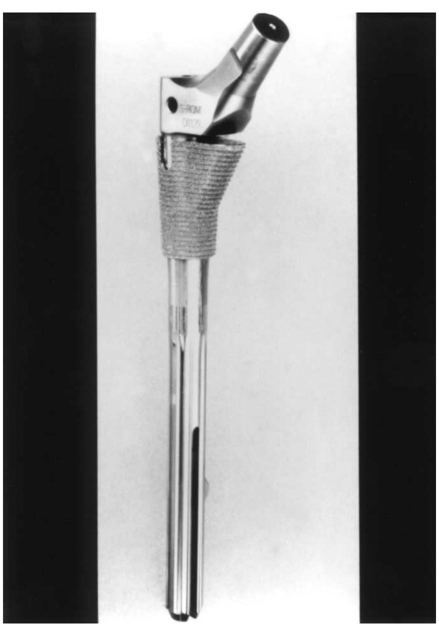

**Figure 2.** S-ROM™ prosthesis consisting of a porous-coated sleeve proximally and a fluted and slotted stem distally. Titanium alloy.

**Figure 3.** Multilock™ prosthesis. Porous-coated proximally and fluted stem distally. Titanium alloy.

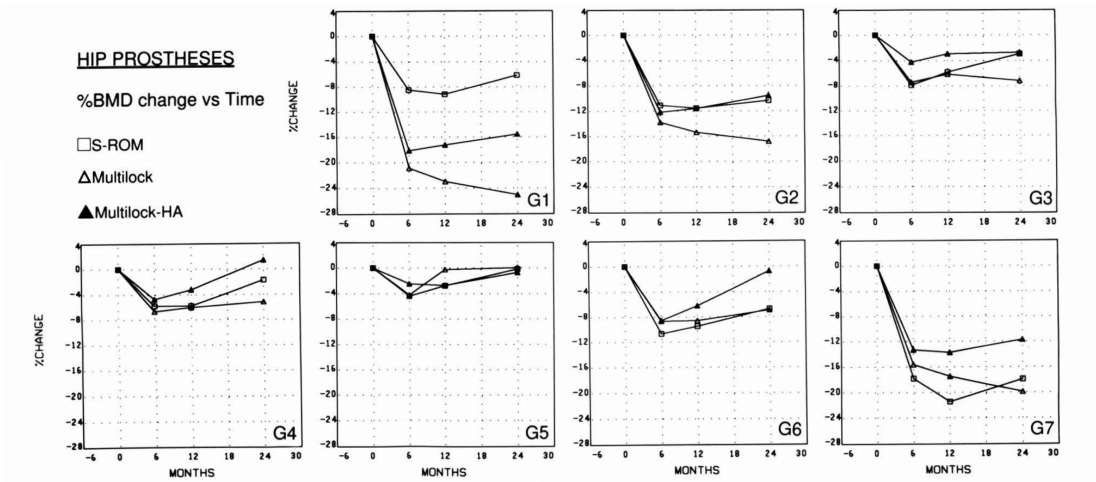


**Figure 4.** Graphs of the percent change in BMD as a function time in the 7 Gruen zones for the S-ROM™, Multilock™ and Multilock-HA™ implants.

periprosthetic bone. A mean precision error of 1.7% was obtained in nine implanted cadaver femora scanned ex vivo. In the same study it was found that there was a variation of 5% in the measurements between 15 degree internal and 15 degree external rotation of the cadaver femora. This indicates that small rotations from the neutral hip position, as recom-mended for scanning patients, do not cause appreciable errors in cross-sectional and longitudinal studies[1].

In vivo precision errors range from 2.6 % to 5%[2, 3]. DXA is more sensitive in disclosing small changes in mineral than conventional radiographs, and serves as a convenient non-invasive vehicle for quantifying periprosthetic bone changes over time.

There are few DXA studies reporting on the comparison of bone mineral changes surrounding prostheses of different design and composition, and they are mostly retrospective analyses[4-7].

The ongoing prospective investigation presented here clearly demonstrates a disparity in regional adaptive remodelling between two titanium alloy prostheses of different design, viz., S-ROM and Multilock.

Furthermore, the comparison of the Multilock implants with and without hydroxyapatite coating showed that hydroxyapatite reduced the mineral loss in all but one Gruen zone significantly. The DXA software is also capable of quanti-fying change in the Gruen zone areas as a function of time, and thereby monitor indirectly the temporal bone volume change. Radiographically, the medial femoral neck cortex in Gruen zone 7 often exhibits variable amounts of bone resorption[8].

In the present study, the S-ROM had a significantly greater loss of bone volume in Gruen zone 7 than either the Multilock or Multilock-HA; the latter two did not differ.

| Gruen Zone | Months | S-ROM Mean %Change (95%CIL) | Multilock Mean %Change (95%CIL) | Multilock-HA Mean %Change (95%CIL) |
|---|---|---|---|---|
| 1 | 6 | -9.0 (-10.4, -7.6) | -21.1 (-24.2, -18.0) | -18.4 (-21.1, -15.6) |
| | 12 | -9.1 (-10.5, -7.7) | -21.8 (-25.2, -18.4) | -16.8 (-18.7, -14.5) |
| | 24 | -7.3 (-9.3, -5.4) | -23.8 (-27.6, -29.9) | -16.9 (-19.4, -14.4) |
| 2 | 6 | -11.3 (-12.8, -10.0) | -13.6 (-15.6, -11.6) | -12.2 (-14.1, -10.3) |
| | 12 | -11.5 (-12.9, -10.1) | -14.8 (-16.9, -12.6) | -11.5 (-13.1, -9.9) |
| | 24 | -10.8 (-12.7, -8.9) | -15.9 (-18.4, -13.4) | -10.3 (-12.0, -8.6) |
| 3 | 6 | -7.5 (-8.6, -6.4) | -7.1 (-8.4, -5.8) | -5.2 (-6.9, -3.5) |
| | 12 | -5.8 (-6.9, -4.7) | -6.6 (-8.0, -5.1) | -3.2 (-4.7, -1.8) |
| | 24 | -3.5 (-5.0, -1.9) | -6.9 (-8.3, -5.2) | -1.5 (-3.1, 0.0) |
| 4 | 6 | -5.4 (-6.7, -4.1) | -5.7 (-7.3, -4.1) | -5.3 (-7.3, -3.4) |
| | 12 | -6.0 (-7.3, -4.7) | -6.8 (-8.6, -4.9) | -3.6 (-5.3, -2.0) |
| | 24 | -2.1 (-3.9, -0.34) | -4.6 (-6.7, -2.5) | 0.9 (-0.9, 2.7) |
| 5 | 6 | -4.3 (-6.0, -2.6) | -3.5 (-5.0, -1.9) | -2.1 (-4.8, 0.7) |
| | 12 | -3.0 (-4.7, -1.3) | -0.3 (-1.4, 1.9) | -2.3 (-4.6, 0.0) |
| | 24 | 1.1 (-1.2, 3.5) | -0.6 (-1.3, 2.5) | -1.7 (-4.2, 0.8) |
| 6 | 6 | -10.8 (-12.1, -9.4) | -8.7 (-10.8, -6.5) | -8.3 (-10.9, -5.7) |
| | 12 | -10.0 (-11.3, -8.6) | -9.1 (-11.4, -6.7) | -5.7 (-7.9, -3.6) |
| | 24 | -7.4 (-9.2, -5.6) | -6.9 (-9.5, -4.4) | -2.2 (-4.6, 0.1) |
| 7 | 6 | -17.4 (-19.2, -15.6) | -15.7 (-18.5, -12.9) | -12.9 (-15.4, -10.4) |
| | 12 | -21.7 (-23.6, -19.9) | -17.6 (-20.6, -14.6) | -12.2 (-14.3, -10.2) |
| | 24 | -17.0 (-19.5, -14.5) | -20.5 (-23.8, -17.1) | -11.6 (-13.9, -9.3) |

**Table 1.** Mean percent change in BMD and the 95% confidence interval limits in the 7 Gruen zones for the S-ROM™, Multilock™ and Multilock-HA™ implants.

## Conclusion

Periprosthetic bone mineral densitometry of porous-coated hip implants can be obtained with good precision and the technique renders insight into one aspect of adaptive bone remodelling. It has been shown that regional bone remodelling can vary with the design of the prosthesis and it is influenced by the presence of hydroxyapatite coating which tends to lessen the mineral loss. Periprosthetic bone densitometry at this stage of development is primarily a research tool.

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