Periprosthetic bone loss after cemented total hip arthroplasty

A prospective 5-year dual energy radiographic absorptiometry study of 15 patients

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Submitted 00-12-06. Accepted 02-06-18

ABSTRACT – **In this prospective 5-year study, we determined the periprosthetic bone loss after cemented total hip arthroplasty (THA) in 15 patients using dual energy X-ray absorptiometry (DXA). A reduction in the periprosthetic bone mineral density (BMD) of 5–18% occurred in all Gruen regions, or regions of interest (ROI), during the first 3 months after THA. The bone loss continued up to 6 months in almost all ROIs. From 1 to 5 years, we found only minor changes in BMD in periprosthetic bone. After the follow-up, the mean greatest bone loss (26%) was seen in the femoral calcar area. The reduction in mean BMD was 5% in men, and 16% in women. The lower the preoperative BMD, the higher was the postoperative bone loss. We found that after the phase of acute bone loss, further loss was minimal, reflecting merely the normal ageing of bone after uncomplicated THA.**

Proximal femoral bone loss may threaten the survival of a hip prosthesis (Kobayashi et al. 2000). It occurs after both uncemented and cemented total hip arthroplasties (THA). Many factors, such as implant size, material and method of fixation may affect bone loss (Huiskes 1990, Bobyn et al. 1992). Using dual energy radiographic absorptiometry (DXA), even small changes in bone mineral density (BMD) can be accurately detected near the prosthesis (Kiratli et al. 1992, Kilgus et al. 1993, Kröger et al. 1996). Previously, periprosthetic BMD studies have focused mainly on changes in bone mass after uncemented THA. The greatest bone loss has been found during the first 3–6 months after surgery in the proximal part of the femur. Thereafter, a plateau stage seems to be reached in the periprosthetic bone (Cohen and Rushton 1995, Marchetti et al. 1996, Nishii et al. 1997, Kröger et al. 1998, Sabo et al. 1998, Venesmaa et al. 2001a).

No long-term prospective DXA studies on periprosthetic BMD changes after cemented THA have been published. In this prospective study, we determined the periprosthetic BMD change in femoral bone after cemented THA over a 5-year period. We also studied the effects of patient-related factors on the bone response.

Patients and methods

17 patients (10 women) who underwent cemented primary THA in Kuopio University Hospital from December 1993 to February 1995 were included in this prospective study. The mean ages of the men and women were similar, 69 (58–74) years. Their mean body mass index (BMI) was 27 (21–34) kg/m^2. In all cases the indication for the arthroplasty was primary hip arthrosis. The subjects belong to a prospective study, which aims to determine periprosthetic BMD changes after uncemented and cemented THA (Venesmaa et al. 2001a).

The criteria for inclusion in the study were that patients should have no diseases affecting bone metabolism and nor have used bone-inducing drugs before or during the study. 3 patients did not follow the study protocol as planned; 1 of them missed the 1-year control visit, but attended the following examinations. 2 were lost after 3-year follow-up at 3 years; of these, the first patient died and the second one was excluded because the THA was performed on the other side. Therfore 15 patients were followed for 5 years (Table 1).

We used an anterolateral or posterolateral approach without a trochanteric osteotomy. The prostheses were fixed into the bone, using a modern cementing technique (Kale et al. 2000) and Palacos R-40 cum Gentamicin (contrast medium: zirconium) (Schering-Plough, Brussels, Belgium). All femoral implants consisted of cobalt-chrome Lubinus SPII stems with a collar (Waldemar Link CMBH&CD, Germany). Although full weight-bearing was permitted immediately after surgery, some patients used crutches for a few weeks. No postoperative complications occurred during the follow-up.

Femoral BMD was measured using Lunar DPX or Lunar DPX-IQ densitometry (Lunar DPX, Lunar Corporation, Madison, WI, USA). BMD measurements were made preoperatively, and postoperatively over 4–14 days, and at 3, 6, 12, 24, 36, and 60 months after THA. All measurements were made by the same experienced technician. During scanning the patient was placed in the supine position. In each scan, the femur was kept in the null rotation position using standard knee and foot supports to minimize measurement error. The scan window included the prosthesis, cement mantle, bone, and soft tissues. We used orthopedic software (V1.2 and V4.6d; Lunar Corporation, Madison, WI, USA), which automatically excluded soft tissues and the prosthesis. No attempt was made to distinguish between cement mantle and bone. The analysis of the Gruen regions was done (Gruen et al. 1979) by calculating the bone mineral content (BMC, g), area (cm^2) and BMD (g/cm^2) in 7 regions of interest (ROI). Regions 1–7 were combined to form a total periprosthetic BMD. The preoperative BMD scans were taken on both sides before surgery. The software was used to isolate the prosthesis from the postoperative scan, and the prosthesis was superimposed over the preoperative scan (Kröger et al. 1996).

We have already reported the results of our precision measurements. The average precision error for cemented stems was 2.5 (SD 1.5)%. It varied from 1.0–5.3%, depending on the ROI (Kröger et al. 1996). While the DXA scanner was changed from DPX to DPX-IQ during the study, 10 patients with hip arthroplasty (8 women, mean age 62 (SD 6) years, mean body length and weight 162 (SD 9) cm and 79 (SD 21) kg, respectively) were scanned with both instruments to establish a cross-calibration between the instruments. In each ROI, a high linear correlation (mean $r = 0.965$, range 0.938–0.993) was found for the BMD values obtained with DPX and DPX-IQ instruments. Because of the high linearity, a first order polynomial could be fit into the data in each ROI to derive a correction for the BMD values with DPX-IQ. Using these best fit corrected equations, "DPX-compatible" BMD values were calculated for the DPX-IQ measurements.

Clinical and radiographic evaluations were also done at these scheduled times (Barrack et al. 1992). The patient's clinical outcome after THA was assessed with a modified Harris Hip Score (HHS; maximum 80 points)—i.e., pain (max 40 points), walking distance (max 15 points), need for support (max 5 points), go to public transportation (max 5 points), use of stairs (max 5 points), able to put on shoes or socks (max 5 points) and presence of a limp (max 5 points).

Statistics

Postoperative BMD changes were calculated using the immediate postoperative BMD value as a reference, the change being expressed as a percent. The statistical analysis was done with SPSS software V9.0 (SPSS Inc., Chicago, Ill., USA). Wilcoxon, Mann-Whitney, and Friedman non-parametric tests were used for the data. The Spearman test was used to determine correlations between changes in periprosthetic BMD and patient-related factors (BMI, age, modified HHS, and preoperative BMD) in the calcar region (region 7) and the total area. Statistical significance was defined as $p < 0.05$.

Table 1. The mean bone mineral density (g/cm^2, SD) in 7 Gruen regions and total area during the 5-year follow-up

Gruen region	Postop. (n=17)	3 months (n=17)	6 months (n=17)	1 year (n=16)	2 years (n=17)	3 years (n=17)	5 years (n=15)
1	1.03 (0.17)	0.94 (0.20) [a]	0.93 (0.21)	0.94 (0.21)	0.93 (0.21)	0.91 (0.23)	0.87 (0.16)
2	1.77 (0.18)	1.59 (0.25) [c]	1.53 (0.29)	1.51 (0.30)	1.49 (0.33)	1.46 (0.32)	1.49 (0.36)
3	1.76 (0.30)	1.63 (0.35) [b]	1.61 (0.36)	1.58 (0.34)	1.61 (0.38)	1.60 (0.38)	1.66 (0.37)
4	1.90 (0.28)	1.80 (0.29) [b]	1.82 (0.29)	1.78 (0.29)	1.79 (0.32)	1.72 (0.31)	1.84 (0.30)
5	1.76 (0.23	1.66 (0.26) [a]	1.66 (0.27)	1.66 (0.29)	1.67 (0.30)	1.68 (0.29)	1.69 (0.32)
6	1.55 (0.21)	1.34 (0.26) [c]	1.30 (0.25)	1.31 (0.30)	1.29 (0.31)	1.29 (0.33)	1.25 (0.32)
7	1.13 (0.17)	0.93 (0.21) [c]	0.90 (0.22)	0.85 (0.24)	0.84 (0.22)	0.84 (0.25)	0.83 (0.21)
Total	1.56 (0.15)	1.41 (0.21) [c]	1.39 (0.21)	1.38 (0.22)	1.37 (0.24)	1.36 (0.22)	1.37 (0.26)

Significant change, as compared to previous BMD value. Bonferroni correction was done.
[a] $p < 0.05$
[b] $p < 0.01$
[c] $p < 0.001$ (Wilcoxon test).

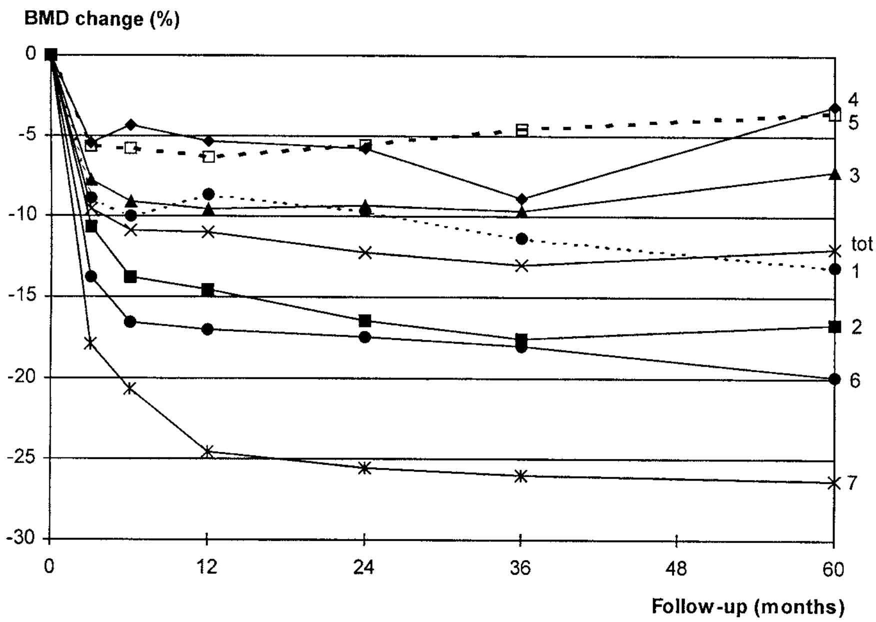

Figure 1. The mean periprosthetic changes in BMD in 7 Gruen regions and in the total periprosthetic area 5 years after THA. These changes were statistically significant in regions 1 ($p < 0.05$), 3 and 4 ($p < 0.01$) and 2, 6, 7, as well as in the total area ($p < 0.001$) (Friedman test).

Results

The modified HHS changed from the mean preoperative value of 38 to 71, 72, 72, and 70 at 1, 2, 3, and 5 years after surgery, respectively. Significant reductions occurred in periprosthetic BMD in all ROI during the first 3 months after THA, ranging from 5.4% to 18% with p-values ranging from < 0.001 to 0.04. A definite decrease in BMD continued for up to 6 months in almost all ROI (Table 1, Figure 1). During the first postoperative year, the greatest bone loss (25%) occurred in the calcar region (region 7).

In the follow-ups from 1 to 5 years, only small and insignificant changes in periprosthetic BMD (a few percent) were noted (Table 1, Figure 1).

We analyzed the correlations between the periprosthetic change in BMD and factors, such as

Table 2. The linear correlations between the change in bone mineral density change in the calcar region (region 7) and the total area, on the one hand, and selected factors at the end of the follow-up, on the other (number)

	Region 7		Total area	
Body mass index	0.28	(n 15)	0.23	(n 15)
Age	0.11	(n 15)	–0.19	(n 15)
Modified HHS	–0.15	(n 14)	–0.18	(n 14)
Preoperative BMD	0.17	(n 13)	0.73 [a]	(n 9)

[a] $p < 0.05$

BMI, age, modified HHS and preoperative BMD in the calcar region (region 7) and the total area (Table 2). The preoperative BMD correlated with the periprosthetic the change in the BMD in the total area. The lower the preoperative BMD, the higher was the periprosthetic bone loss during the 5-year follow-up ($r = 0.73$, $p < 0.05$). As regards gender, the periprosthetic changes in BMD in the total area differed ($p < 0.05$; Mann-Whitney test; Figure 2). At 5 years after THA, the mean total periprosthetic BMD in men (n = 6) was 1.62 (SD 0.14) g/cm^2, and in women (n = 9) 1.21 (SD 0.18) g/cm^2, the mean percentage BMD changes being –5.4 (SD 6.3)% and –16.3 (SD 10)%, respectively.

Discussion

Bone cement alone and barium or zirconium mixed into the cements is thought to cause artefacts in BMD measurements. This has led various authors to study mainly prostheses fixed without cement (Nishii et al. 1997, Sabo et al. 1998, Venesmaa et al. 2001a). Marchetti et al. (1996) followed the periprosthetic bone mass for 2 years with DXA after cemented THA. They measured the width of the cement mantle and bone cortex from the initial postoperative radiographs, which accounted for the degree of magnification. They excluded the cement mantle from their analysis. They mentioned no problems in excluding the cement mantle. McCarthy et al. (1991) found it impossible to distinguish the cement from the bone: the cement intruded into the bone, and therefore the boundary of the bone and cement could not be clearly seen. Cohen and Rushton (1995) came to the same conclusions.

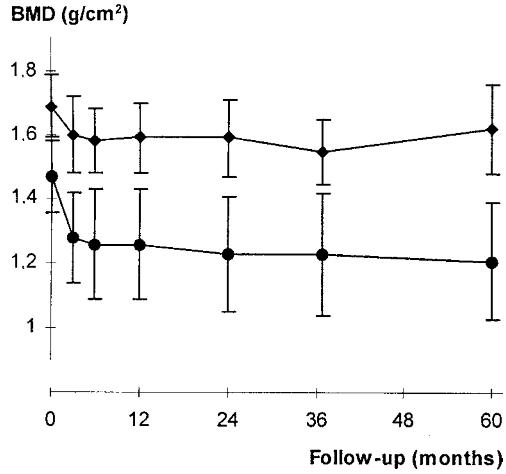

Figure 2. The mean periprosthetic BMD (with sd) in the total area in men (◆; n = 6) and women (●; n = 9) at the 5-year follow-up. The changes in BMD differed significantly between the sexes ($p < 0.05$) (Mann-Whitney test).

We were likewise unable to distinguish cement from bone. The pressurized cement intruded locally into the bone. In the scan window, the cement induced an artefactual increase in periprosthetic BMD in the DXA measurements. However, it can be assumed that the density of the cement mantle does not change with time (Kröger et al. 1996). Therefore all the BMD changes found during follow-up reflect the periprosthetic bone density.

To estimate long-term changes in periprosthetic BMD, the immediate postoperative BMD value should be used as the baseline value on the operated side (Nishii et al. 1997, Sabo et al. 1998, Venesmaa et al. 2001a). With this method, the bone loss due to operation is excluded, which has been estimated at 13–19% in the calcar region (Kröger et al. 1996). The BMD measurement should be done as soon as possible after THA—i.e., within 1 or 2 weeks, when the neutral rotation of femur can be correctly obtained (Venesmaa et al. 2001a).

We found the greatest reduction in periprosthetic BMD during the first 3 months after THA, ranging from 5% to 18%. This persisted for up to 6 months in most of the ROI, but it was most marked in the proximal part of the femur. The immediate bone response to implantation was similar to that reported in other studies (Cohen and Rushton 1995, Marchetti et al. 1996, Nishii et al. 1997, Sabo et al. 1998). However, small differences have been found between the results of these studies. Their study design, the nature of the implant used, or the method of fixation may explain some of the variations in the BMD changes. This early bone loss is primarily a consequence of stress shielding and bone disuse atrophy (Huiskes 1990, Bobyn et al. 1992, Kannus et al. 1994). After implantation, the femur is loaded more distally with stresses bypassing the proximal femur. On the basis of Wolf's law, bone mass increases in areas under loading and decreases in unloaded ones (Huiskes et al. 1992).

Only a small reduction in total periprosthetic BMD was detected 6 months after THA. The response of the periprosthetic bone reached a plateau in the later part of the follow-up. This change in BMD seems to be similar in degree to the normal ageing of bone, in which the reduction amounts to about 1% a year (Hannan et al. 2000). McCarthy et al. (1991) determined retrospectively the changes in periprosthetic BMD at 7–14 years after THA. They measured BMD from two medial cortical scan boxes, using the contralateral femur as a reference. In the proximal femur, the reduction in periprosthetic BMD was almost 50%. In our study, the bone loss in the proximal femur was only a few percent a year after the acute bone loss phase. The study by McCarthy et al. seems to overestimate the changes in BMD in the periprosthetic bone after THA. To obtain exact data on such changes, the operated side should always be used as a reference and each patient should be followed prospectively.

Many factors seem to play a role in periprosthetic bone loss (Huiskes 1990, Santavirta et al. 1990, Bobyn et al. 1992, Huiskes et al. 1992, Sychterz and Engh 1996). We analyzed the effects of BMI, age, modified HHS, and preoperative BMD on periprosthetic bone loss. Only preoperative BMD correlated with the change in periprosthetic bone mass ($p < 0.05$). The lower the preoperative BMD, the higher was the postoperative bone loss. Kobayashi et al. (2000) did a multivariate analysis of 405 Charnley cemented stems at mean follow-up of 14 years to determine risk factors for aseptic fixation failures. They suggested that poor bone quality is a risk factor for socket survival and poor bone structure for survival of the femoral prosthesis.

The bone response to implantation differed significantly in men and women although the mean ages at operation were similar. At the end of the follow-up, the mean reduction in total BMD was 5% in men and 16% in women. In Sabo et al.'s study (1998), where an uncemented prosthesis was inserted in younger patients, a significant difference in periprosthetic BMD was found between men and women; however, the course of mineralization was about the same in both. We likewise found no significant difference in periprosthetic BMD after uncemented THA between the genders (Venesmaa et al. 2001a). In the present study, patients were, on average, more than 10 years older than patients in those two studies. Our findings therefore suggest that, after THA, postmenopausal women lose more periprosthetic bone than men of the same age.

We found that net bone loss was less than expected. After the initial phase of acute bone loss, further loss is minimal, reflecting merely the normal ageing of bone after uncomplicated THA. Patients with low preoperative BMD risk losing more bone near the prosthesis. Bone loss may make revision surgery more complicated or predispose to periprosthetic fractures. Wilkinson et al. (2001) and Venesmaa et al. (2001b) have shown that bisphosphonates can reduce the periprosthetic bone loss after THA, which would suggest that patients with low bone density may benefit from drugs which reduce bone resorption.

We thank Riitta Toroi, R.N., and Eila Koski, R.N., for their expert technical assistance and Pirjo Halonen, Biostatistician, M.Sc., for excellent help with the statistical analysis.

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