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Periprosthetic bone mineral density changes with femoral components of differing design philosophy

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Abstract We measured the bone mineral density in 22 patients with the cylindrical stemmed cobalt-chrome AML prosthesis (collared) and in 22 patients with the tapered stem titanium CLS prosthesis (collarless). DEXA scanning was undertaken at a mean of 40 months in the AML and 52 months in the CLS group from the time of implant insertion. In both groups the greatest mean loss of BMD was found in Gruen zone 7 and the least change in Gruen zone 5. In all zones the BMD loss was greater in the AML group but only statistically significant in zones 6 ($P<0.05$) and 7 ($P<0.01$). Although numerous factors affect BMD changes around cementless implants, this study suggests that less bone loss can be associated with the titanium CLS stem.

Résumé Nous avons mesuré la densité minérale de l'os chez 22 patients porteur d'une prothèse AML en cobalt-chrome à tige cylindrique (avec colerette) et chez 22 malades avec une prothèse CLS en titane avec une tige conique et sans colerette. Une scanographie DEXA a été entreprise en moyenne 40 mois après implantation des prothèses AML et 52 mois après prothèse CLS. Dans les deux groupes la plus grande perte moyenne de DMO a été trouvée dans la zone 7 de Gruen et le plus petit chan-

gement dans la zone 5 de Gruen. Dans tous les zones la perte de densité osseuse était plus grande dans le groupe AML mais statistiquement uniquement dans les zones 6 ($P<0.05$) et 7 ($P<0.01$). Bien que de nombreux facteurs affectent les changements de DMO autour des implants sans ciment, cette étude suggère qu'il y a moins de perte osseuse avec la tige CLS en titane.

Introduction

Many factors affect the periprosthetic bone mineral density (BMD) around cementless femoral implants [13] including age, gender, pre-operative diagnosis and bone mineral content [8], the type of implant used [7, 9, 14] and duration of implantation [11], and the mechanical loading environment.

Uncemented femoral implants have been preferentially implanted into younger patients but controversy still remains over the use of such implants and their possible benefits over cemented femoral stems [15]. The use of the DEXA scan allows quantitative measurement analysis of BMD which can be used to evaluate bone resorption due to stress shielding and correlation to projected remodelling of bone [10].

The aim of this retrospective cross-sectional study was to compare and contrast the pattern of bone loss in the form of BMD change in two groups of patients with different femoral implant designs, one being a cobalt-chrome stem and the other titanium. The change in bone mineral density surrounding the implant was calculated by scanning the contralateral non-operated femur of each patient at the same time as the operated side and expressing the result as a percentage. Although the DEXA scan allows the measurement of BMD with time, it cannot distinguish between bone loss due to osteolysis or osteoporosis [8], and in this study only measurement of the BMD in the anterior-posterior plane was possible.

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Patients and methods

We compared two groups of patients who underwent uncemented total hip arthroplasty for degenerative osteoarthritis performed by the two senior authors. From 1989 onwards the anatomic medullary locking (AML) uncemented femoral component (De-Puy) has been used by one author and the CLS femoral component (Protek-Sulzer) by the other in suitable patients.

Patients with bilateral total hip replacements, distorted proximal femoral anatomy, or evidence of metabolic bone disease were excluded from the study. All procedures were performed using a modified lateral approach in the supine position, and immediate full weight bearing allowed in each patient.

Forty-four patients were included in the study, 22 patients in the AML and 22 patients in the CLS group. The age and sex distribution, and time from implant insertion were similar in both groups (Table 1). Both the proximal femur of the operated and the non-operated side were scanned after written consent was obtained.

The DEXA scan was performed using a Lunar DPX-L scanner. Patients were positioned in a standard fashion with the leg in a neutral position, which allowed scanning in the anterior-posterior projection of the proximal femur including the area distal to the prosthesis tip and the surrounding soft tissues. An orthopaedic software package allowed the measurement of BMD directly adjacent to the prosthesis using an edge detection algorithm. The software package allowed the area surrounding the prosthesis to be divided into seven regions of interest corresponding to Gruen zones [3]. The mirror image of these zones was transferred to the scan of the contralateral femur to allow comparison of the bone mineral content.

All scan results were produced in a standardised format recording the BMC (g) and area (cm²) of the regions of interest (Gruen zones) allowing calculation of the BMD (g/cm²).

The BMD of the operated proximal femur was converted to a percentage of that of the control side, and the mean % values of the BMD on the operated side were calculated in both groups for each Gruen zone. The mean BMD changes in both groups were compared and statistical significance calculated using an independent samples *t*-test procedure.

Results

Bone mineral density loss

With each periprosthetic region of interest which corresponded to a Gruen zone the mean percentage value of the bone mineral density (compared to the control femur) was found to be less in the AML group compared to the CLS group (Table 2).

The greatest loss of bone density was found in Gruen zone 7 (medial proximal cortex) in both groups compared to the control side, with the mean percentage loss being 38% and slightly over 20% in the AML and CLS groups, respectively. The difference in the groups was found to be statistically significant ($P < 0.01$).

The smallest changes in bone density loss were found in Gruen zones 2, 3, 4 and 5 in both groups. The only increase in mean bone density change was in Gruen zone 5 in the CLS group by almost 3%, and the difference between the groups was not statistically significant.

Gruen zone 1 showed the second highest bone mineral density loss in both groups (nearly 22% for AML and 13% for CLS), but the difference between the groups although substantial was not statistically significant.

Table 1 Patient details

	AML	CLS
Patients (no.)	22	22
Mean age (range; years)	54 (43–62)	60 (39–69)
Sex ratio (M:F)	9:13	10:12
Mean follow-up (range; months)	40 (20–79)	52 (20–116)
Diagnosis	OA	OA

Table 2 Mean percentage ratio in BMD with each implant compared to contralateral femur

Gruen zone	AML (SD)	CLS (SD)
1	78.4 (16.5)	86.5 (19.4)
2	94.2 (13.5)	96.4 (14.1)
3	94.9 (10.8)	97.6 (11.1)
4	94.8 (8.6)	95.2 (9.1)
5	98.2 (11.6)	102.8 (7.9)
6*	87.5 (7.1)	93.3 (12.5)
7**	62.0 (13.8)	79.5 (16.2)

* $P < 0.05$

** $P < 0.01$

Discussion

The two groups of patients in this study have different cementless femoral implants with differing design philosophy. The AML implant (Fig. 1) is a partially porous coated cobalt-chrome-molybdenum alloy which is straight stemmed and designed to obtain diaphyseal fixation [2]. All the AML implants in this study were 5/8 porous coated and had collars. The CLS implant (Fig. 2) is a collarless titanium alloy wedge design incorporating metaphyseal fluting and a corundum blast finish. The implantation of the CLS component requires less bone removal because of the wedge design and no requirement for distal canal fit [12].

A comparison of the percentage of BMD loss to the contralateral femur across the seven Gruen zones shows a similar pattern for both groups. The similarity of pattern of bone loss is surprising in view of the difference in stem designs and their interactions with the femoral cortices. The percentage loss was greater in the AML group but the mean length of time from implant insertion was 12 months less at 40 months. The greatest loss was found in Gruen zone 7 in both groups (38% in the AML as compared with 20% in the CLS group) which is consistent with previous studies [1, 5, 6, 8]. This is clear evidence that the collar of the AML stem does not transfer significant loads to the medial cortex.

Kiralti et al. [6] found proximal bone loss in the range of 13–24% in a proximally coated implant. In another study Engh et al. reported a 45% decrease in bone mineral content in the proximal femur with a fully porous coated implant [1]. Maloney et al. harvested 24 pairs of femora at post-mortem from patients who had previously had unilateral hip replacements. Eleven patients had uncemented implants and with a mean duration from im-

Fig. 1 The partially porous coated AML stem designed to obtain diaphyseal fixation

Fig. 2 The collarless CLS stem incorporating metaphyseal fluting

plantation of 6 years the proximal medial cortex showed maximal BMD loss of 39% [8]. Another study reviewing 72 femora containing AML implants showed the greatest decrease in BMD in the most proximal 1 cm of the medial femoral cortex [5].

In our study Gruen zone 1 showed the second largest percentage drop in BMD in both groups, which may be explained by the design of both prostheses and the greater amount of bone loss at implantation at this site with the AML prosthesis. The AML implant is designed to obtain diaphyseal fixation while the CLS implant relies on a wedge fit proximally. Wixson et al. also found similar results with proximally porous coated stems up to 2 years from implantation [15].

The least changes in percentage BMD loss were found in the distal periprosthetic area in both groups (zones 3, 4 and 5), and in Gruen zone 5 where there was even a net gain of 3% with the CLS implant. Femoral hypertrophy at the stem tip is normally associated with the stress concentration caused by the sudden change in bending stiffness in designs where the stem tip fills the medullary cavity, so it was surprising to find a greater effect near the CLS stem tip.

Further examining of percentage gain or loss of BMD with time shows a tendency to less percentage change

with time in the CLS group. Wixson et al. repeated DEXA scans from implant insertion to 24 months at regular intervals in individual patients [15]. They found an initial BMD loss of 15% at 6 months and then a positive bone remodelling response resulting in a 1% loss at 24 months in Gruen zone 1. Hughes et al. also found in a retrospective study a generalised loss in bone density in the proximal femur which appeared to stabilise and was not progressive [4]. In our study (Table 2) we found the amount of bone loss was most variable in the proximal zones, with a 95% confidence interval of ± 2 standard deviations (SD) giving relatively large ranges for the proximal zones in both groups of patients. Thus it seems that there are other factors beyond just the stem design which have a large effect on the early femoral bone loss in individual patients.

In conclusion the use of DEXA scan analysis of these two different femoral implants in patients with degenerative osteoarthritis has shown that both implants show the same pattern of BMD loss around the stem, although the designs are different. However, the percentage loss in the titanium CLS group was consistently smaller in all zones as compared with the AML group. This study confirms that DEXA scanning is useful in measuring BMD even in areas near prosthetic implants, even though the scan is only in the AP plane and changes in the anterior and posterior cortex will be missed. In order to allow further evaluation of the bone remodelling responses of these different implant designs with time, we plan to repeat the scans at a later date and analyse the results within the framework presented in this study.

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