Periprosthetic bone mineral density with a cementless triple tapered stem is dependent on daily activity

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Abstract

Purpose Periprosthetic bone loss around the femoral stem is frequently found after total hip arthroplasty. We have shown that periprosthetic bone mineral density (BMD) loss using the triple tapered stem is consistently much less in comparison with the straight type component. In this study, we compared periprosthetic BMD change with clinical factors.

Methods Postoperative dual-energy X-ray absorptiometry was evaluated at follow-up. BMD was determined based on seven Gruen zones. We further compared BMD with clinical examination: body mass index (BMI), age, Harris hip score (HHS) or University of California at Los Angeles (UCLA) activity rating score.

Results Periprosthetic BMD loss of the triple tapered stem was maintained. Especially, BMD in Gruen zone 1 which was maintained at 96% in comparison with the straight tapered stem. We compared the BMD change with clinical factors. There is no correlation between BMD and BMI, age or HHS. However, we found significant correlation between BMD and UCLA activity rating score in Gruen zones 1 and 2 of the triple tapered stem. Further, the correlation coefficient was increased at 48 months in comparison with 24 months.

Conclusion The cementless triple tapered stem maintains periprosthetic bone mineral density. Activity may reflect

improving periprosthetic bone quality after THA using a triple tapered stem.

Introduction

Bone changes after total hip arthroplasty (THA) are of interest to orthopaedic surgeons because mechanical loosening of the components is the most frequent complication of THA. Loss of periprosthetic bone mineral can lead to loosening of the prosthesis [1–3]. Therefore, further studies are required to identify the factors determining the pattern of bone remodelling after THA and obtain improvements in the design and durability of the prostheses.

Dual-energy X-ray absorptiometry (DEXA) is a well-documented method of monitoring after THA [4, 5] and detects even small changes in bone mineral density (BMD) around the stem [6, 7].

Recently, we showed that periprosthetic BMD loss using the triple tapered stem in 33 patients was consistently significantly less in comparison with the straight type component [8]. Further, we analysed the correlation between periprosthetic BMD and clinical examination (BMI, age and Harris hip score), but no correlation was found [8].

The triple tapered stem has tapers in the AP and ML planes and a third taper from the wide lateral to the narrow medial planes. The concept of the triple tapered stem is that it can provide rigid fixation and reduce subsidence. Further, the third taper is designed to improve the loading of the proximal femoral neck, therefore maintaining bone quality and avoiding stress shielding. This improvement can be expected in younger, more active patients with good-quality bone and function [9].

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Fig. 1 The panel shows the scheme of seven regions of Gruen zones, and this prosthesis is a G2 stem

Therefore, in this study, we analysed the BMD changes around the cementless triple tapered stem in 50 patients and evaluated the correlation between BMD changes and various clinical factors including daily activity.

Patients and methods

All patients underwent THA between January 2005 and May 2009 for osteoarthritis (60 joints in 53 patients) or idiopathic osteonecrosis of the femoral head (five joints in five patients). Forty-three patients (50 joints; 34 women) underwent THA with a G2 stem (DePuy, Warsaw, IN) which was designed with a triple tapered stem. Fifteen patients (15 joints; 12 women) received VerSys FMT stem (Zimmer, Warsaw, IN) which was designed with a straight tapered stem. Patients with distorted proximal femoral anatomy, osteoporosis (BMD of lumbar spine <0.8) or evidence of metabolic bone disease were excluded from the study. All procedures were performed at Kobe University Hospital, and immediate full weight bearing was allowed in each patient.

The DEXA scan was performed using a DPX-L scanner. The detailed method of a DEXA scan was described in our previous report [8]. BMD was determined in seven regions of interest based on Gruen zones [10] (Fig. 1). The values were expressed as areal BMD, in g/cm^2 . The BMD around the stem was assessed within two months of operation, after six, 12 and 24 months. BMD ratio was calculated as a changing rate in comparison with BMD within two months post operation.

Fig. 2 Each panel shows change of bone mineral density (%) at 6, 12 and 24 months in comparison with less than 2 months postoperatively according to seven Gruen zones. Columns represent mean $\pm$ SD. * indicates $p < 0.05$ in comparison between the G2 group and the VerSys FMT group

Postoperative follow-up was evaluated by DEXA scan in addition to clinical examination Harris hip score (HHS), body mass index (BMI), age and UCLA activity rating scores.

These clinical examinations were determined at 12 and 24 months post operation. The region around the stem was divided according to seven Gruen zones.

All data were expressed as mean±standard deviation (SD) unless otherwise indicated. Statistical analysis was performed using one-way analysis of variance, with Tukey's post hoc test for multiple comparisons of paired samples. Mann-Whitney U test was used for comparisons between the two groups. P values less than 0.05 were considered significant.

Correlation between BMD and HHS, BMI, age or UCLA activity rating scores were calculated by Pearson chi-square test. In all cases P value<0.05 was considered significant.

Results

Periprosthetic BMD change

Minimum BMD changes were found in the distal femur (Gruen zones 3, 4, and 5) in keeping with previous reports

[6, 11]. BMD changes in the G2 group at 24 months were as follows: zone 3, 98%; zone 4, 98%; zone 5, 98% (Fig. 2), and VerSys FMT group at 24 months were: zone 3, 97%; zone 4, 97%; zone 5, 95% (Fig. 2). There were similar changes between two groups. However, when we focused on the proximal femur BMD, BMD loss in zone 1 was just 3% at 24 months. BMD changes in the G2 group at 24 months were as follows: zone 1, 97%; zone 2, 95%; zone 6, 88%; zone 7, 86% (Fig. 2). In contrast, BMD changes in the G2 group at 24 months were as follows: zone 1, 71%; zone 2, 90%; zone 6, 89%; zone 7, 86% (Fig. 2).

Clinical evaluation

The average value of HHS was 87.9±9.0 in the G2 group and 85.7±6.4 in the VerSys FMT group at one year after operation and 88.15±12.8 in the G2 and 89.1±2.5 in VerSys FMT at two years after operation. BMI was 23.7±3.1 in G2 and 22.5±2.2 in VerSys FMT at one year after operation and 24.7±2.8 in G2 and 24.5±1.9 in VerSys FMT at two years after operation. UCLA activity rating score was 5.4±2.1 in G2 and 4.9±1.5 in VerSys FMT at one year after operation and 6.3±2.2 in G2 and 6.3±1.5 in VerSys FMT at two years after operation. The mean age at operation was 66.7

Table 1 Correlation coefficient (RR) and P-value between BMD ratio and clinical factors (BMI, age, HHS and UCLA activity rating score) in seven Gruen zones at 12 months. *Boldface* indicates $p<0.05$

Correlation coefficient (post 1 y)							
Variable	zone1	zone2	zone3	zone4	zone5	zone6	zone7
G2							
BMI	0.09	0.118	0.189	0.104	0.114	0.058	0.02
Age	0.128	0.052	0.025	0.008	0.05	0.365	0.169
HHS	0.149	0.151	0.068	0.109	0.001	0.065	0.223
UCLA scale	0.325	0.403	0.223	0.309	0.109	0.21	0.18
VerSys FMT							
BMI	0.32	0.457	0.065	0.094	0.008	0.375	0.189
Age	0.042	0.19	0.392	0.455	0.318	0.202	0.013
HHS	0.0174	0.043	0.013	0.403	0.192	0.37	0.094
UCLA scale	0.055	0.153	0.573	0.002	0.066	0.171	0.359
P-value (post 1y)							
Variable	zone1	zone2	zone3	zone4	zone5	zone6	zone7
G2							
BMI	0.36	0.272	0.324	0.59	0.556	0.776	0.367
Age	0.311	0.489	0.311	0.484	0.399	0.051	0.367
HHS	0.22	0.216	0.361	0.287	0.496	0.369	0.121
UCLA scale	0.042	0.014	0.122	0.051	0.285	0.137	0.174
VerSys FMT							
BMI	0.439	0.255	0.877	0.825	0.983	0.359	0.654
Age	0.915	0.624	0.297	0.219	0.404	0.602	0.974
HHS	0.974	0.917	0.972	0.283	0.62	0.327	0.809
UCLA scale	0.201	0.743	0.179	0.996	0.107	0.713	0.43

BMI body mass index, HHS Harris hip score, UCLA scale University of California at Los Angeles activity rating score

± 8.2 in G2 and 57.8 ± 6.8 in VerSys FMT. There was no significant difference in these average values between one and two years after operation and between the G2 and VerSys FMT groups.

Correlation between periprosthetic BMD and clinical evaluation

We compared periprosthetic BMD changes with clinical examinations. There was no correlation between BMD changes and HHS, BMI or age at either one or two years post operation in either the G2 or the VerSys FMT groups (Tables 1 and 2). These results were in line with our previous report [8]. However, we found significant correlation between proximal periprosthetic BMD changes and UCLA activity rating scores in the G2 group. The correlation coefficient of zone 1 was 0.325 ($P < 0.05$) and in zone 2 was 0.403 ($P < 0.05$) at one year following operation. Furthermore, the correlation coefficient was increased at two years in comparison to one year. The correlation coefficient of zone 1 was 0.520 ($P < 0.05$) and zone 2 was 0.480 ($P < 0.05$) at two years after operation. In contrast, there was no correlation between BMD changes and UCLA activity rating scores at either one or two years following operation in the VerSys FMT group (Table 2).

Discussion

The triple tapered stem provides good fixation and minimises subsidence, with the third taper designed to improve loading of the proximal femur, therefore maintaining bone quality and avoiding stress shielding.

In this study, the proximal lateral BMD (Gruen zones 1 and 2) in the triple tapered stem group was almost maintained, but BMD loss at the proximal lateral site was found in the straight tapered stem group. The proximal medial BMD (Gruen zones 6 and 7) decreased slightly. However, the BMD changes in the proximal medial was much less than in other previous reports [12, 13]. Several papers measured baseline BMD within six weeks [14, 15]. Sabo et al. reported slight periprosthetic BMD loss at three months after operation [15]. In this study, most cases were measured for baseline BMD within one month of operation. Furthermore, we compared periprosthetic BMD between the triple tapered stem and the straight tapered stem. Our findings suggest that periprosthetic BMD with the triple tapered stem was consistently maintained in the proximal femur in comparison with the straight tapered stem.

The C-stem (DePuy) is also a triple taper stem with cement fixation. Wroblewski et al. reported that the C-stem was designed as a proximal fixation and maintained

Table 2 Correlation coefficient (RR) and P-value between BMD ratio and clinical factors (BMI, age, HHS and UCLA activity rating score) in seven Gruen zones at 24 months. *Boldface* indicates $p < 0.05$

Correlation coefficient (post 2y)							
Variable	zone1	zone2	zone3	zone4	zone5	zone6	zone7
G2							
BMI	0.177	0.041	0.353	0.004	0.041	0.045	0.268
Age	0.477	0.212	0.043	0.04	0.034	0.083	0.476
HHS	0.075	0.163	0.164	0.068	0.066	0.152	0.167
UCLA scale	0.52	0.48	0.468	0.338	0.308	0.433	0.447
VerSys FMT							
BMI	0.41	0.292	0.139	0.612	0.294	0.065	0.09
Age	0.607	0.483	0.042	0.45	0.393	0.487	0.651
HHS	0.149	0.214	0.279	0.108	0.548	0.625	0.143
UCLA scale	0.233	0.059	0.53	0.168	0.308	0.233	0.257
P-value (post 2y)							
Variable	zone1	zone2	zone3	zone4	zone5	zone6	zone7
G2							
BMI	0.281	0.447	0.17	0.494	0.447	0.442	0.187
Age	0.099	0.486	0.888	0.497	0.455	0.393	0.375
HHS	0.404	0.297	0.296	0.413	0.415	0.309	0.298
UCLA scale	0.033	0.048	0.053	0.29	0.152	0.07	0.062
VerSys FMT							
BMI	0.313	0.483	0.743	0.107	0.48	0.88	0.185
Age	0.083	0.187	0.915	0.224	0.385	0.184	0.058
HHS	0.749	0.683	0.593	0.839	0.26	0.184	0.787
UCLA scale	0.615	0.9	0.221	0.719	0.502	0.615	0.578

BMI body mass index, HHS Harris hip score, UCLA scale University of California at Los Angeles activity rating score

bone quality and avoided stress shielding [9]. However, it is unlikely that improvements of bone quality take place in all cases. For the concept of C-stem to show improvement in bone quality and the bone–cement interface, the implant needs to be loaded to a certain level. If that level of function is not reached because of infirmity, age, or the patient's declining function, such improvements are unlikely to be observed [16]. Thus improvement can be expected more reasonably in younger, more active patients with good-quality bone and good function.

In this study, we analysed the correlation between periprosthetic BMD and UCLA activity rating scores which represented daily activity levels. We found significant correlation between BMD and UCLA activity rating scores in Gruen zones 1 and 2 in the triple tapered stem. Furthermore, the correlations increased in a time dependent manner.

These results suggest that daily activity may contribute to femoral stem fixation in the triple tapered stem.

We also compared the periprosthetic BMD change with other clinical factors (HHS, BMI or age). Several studies demonstrated a relationship between BMD and HHS, age or BMI [17–19]. Korovessis demonstrated no correlation between age and periprosthetic BMD changes [20]. Karrholm et al. reported that periprosthetic BMD was only influenced by the stem design [21].

In this study, there was no correlation between BMD and age or BMI. Our results suggest that the triple tapered stem does not affect BMD in response to clinical factors except for daily activity.

We also compared the value of BMD within two months of operation as initial BMD and HHS, age, BMI or UCLA activity score (**Supplemental figure**). There was significant correlation between BMD within two months of operation and BMI, age or UCLA activity score. The negative correlation between BMD and aging is well documented [22]. Further, positive correlation between BMD and body weight was reported [17, 18]. Yamauchi et al. reported that leptin directly stimulates osteoblast differentiation. Therefore, it is possible that the anabolic action of this hormone on bone may participate in the positive correlation between weight and BMD [23]. We also found significant correlation between BMD within two months of operation and UCLA activity score. This is understandable, because higher activity can maintain bone quality prior to THA, and the patients who have higher activity prior to THA may obtain higher activity after THA. In this study, we compared activity and BMD change, not BMD value, in the different stem groups. Therefore, we can indicate the significance of activity and bone maintenance.

In conclusion, periprosthetic BMD with the triple tapered stem was consistently maintained in the proximal femur. Especially, BMD in Gruen zone 1 which was maintained.

Activity may reflect improving periprosthetic bone quality after THA using a triple tapered stem. Long-term success can be expected.

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Conflict of interest The authors have no conflict of interest and certify this to be a true and original work.

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