Original Article

Bone remodelling around the Metha[®] short stem implant – Clinical and dual-energy x-ray absorptiometry (DXA) results

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ABSTRACT

Objective: Bony ingrowth of short stems is under investigation.

Method: Over one year bony reactions around the Metha[®] stem were investigated using the DXA method in a standardized zonal system (19 ROIs). Clinical results were documented using the HHS.

Results: HHS significantly improved from 46 points to 97 points. After one year bone marrow density (BMD) increased in the lateral distal and lateral proximal areas as well as in the mid medial area. BMD decreased in the proximal medial and mid lateral areas.

Conclusion: The concept of metaphyseal ingrowth was confirmed, but distal bony reactions need further investigation.

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1. Introduction

With the trend towards younger patients and an increasing life expectancy of THA patients, short stem prostheses have experienced a growing interest in the last years as option, to save bone material for potential later revision surgeries. Over the years, dual-energy X-ray absorptiometry (DXA) became a proven method to examine changes of bone mineral density (BMD) around implants.^{1–9} To describe changes of the interface between bone and femoral implants the Gruen zone system has been established as standard. Originally, it was developed for classifying zones of lucency on plain x-rays following the implantation of standard stems.¹⁰ Until today, there is no clear definition of regions of interest (ROIs) for short stem investigations.

This makes it difficult to interpret and compare DXA results. For example, according to the original Gruen zone system, the proximal tip of the greater trochanter is not captured within zone 1.¹⁰ In contrast, in current studies there is an adjustment of Gruen zone 1 taking in the complete proximal expansion of bone.^{1,2,4,7} Furthermore, in several studies a boundary between medial zones 6 and 7 is to be assumed at the height of the lesser trochanter.^{1,4,7} In contrast, other studies show equal expansions within lateral zones 1–3.^{2,3,6} Thus, there is no common definition concerning the

boundary within the lateral or medial zones. This makes it necessary to introduce a more detailed and defined system regarding the special demands of short stem investigations.

To overcome these shortcomings we introduce in this pilot study a standardized, precisely defined zonal system for evaluation of BMD changes following short stem implantation with a follow up of one year.

2. Material and methods

After approval by the ethical committee (Freiburger Ethikkommission, feki, 010/1910), a total of 50 patients were recruited for this study from December 2010 to February 2014. Inclusion criteria were a minimum age of 18 years, indication for short stem total hip arthroplasty, absence of trauma, physical and mental ability to comply the clinical and radiological follow-up investigations and a signed consent to participate in this study. Exclusion criteria were additional trauma/previous fractures or previous interventions such as total hip arthroplasty on the affected hip, other serious diseases that make it difficult to participate in the study (e.g. cancer), increased risk of anesthesia (ASA IV), clinical relevant infections, existing or planned pregnancy, permanent cortisone therapy, anatomies with shortened or absent femoral neck (e.g. Morbus Perthes), rheumatoid arthritis and alcohol or drug addiction. In all patients a Metha[®] short stem (Aesculap AG, Tuttlingen, Germany) was implanted. Two patients had to be excluded, because even the largest Metha[®] implant was not fitting.

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All operations were performed by a single surgeon (HGS) in supine position using an anterolateral approach.

Overall 48 patients (18 female, 30 male) were evaluated. Mean age at time of surgery was 57 ± 6.22 years. Mean height was 174.33 ± 9.09 cm, mean BMI was 27.62 ± 3.97 kg/m².

Investigations were performed preoperatively, 6 months and 12 months after surgery. For clinical evaluation we used the Harris Hip Score (HHS). Pain status was evaluated using the numeric analog scale (NAS; scale: 0–10 points). DXA measurements were performed using a Lunar DPX NT. Quality controls were done as specified by manufacturer's guidelines. As application software enCORE 2011, version 13.60.033 was used. A leg holder was used to ensure standardized positioning of the leg. DXA data were evaluated using an implant dependent, defined zonal system based on 19 ROIs.

Index ROIs are defined in each case on the first postoperative DXA image according to the extent of the stem. The ROIs exclude the area of the stem within their expansions. These patient-related index-ROIs are subsequently transferred to the other DXA images, ensuring the exactly comparable extent of the zones, allowing the use of preoperative measurements as baseline for an exact longitudinal comparison (Fig. 1).

Nine ROIs are located medially, nine ROIs laterally, and one ROI distal to the stem. The distance from the most proximal point of the greater trochanter to the tip of the stem is divided into nine equal parts. Therefore, the medial and lateral zones have the same proximal-distal expansion and correlate to the stem size. The absolute size of each ROI depends on the length of the stem (1/9 of the proximal-distal expansion), but have the same relative extension to the stem. The medial and lateral zones are located opposite and numbered in ascending order from proximal to distal. The lateral zones (L1–L9) start from the most proximal lateral point

of the prosthesis and extend to the tip of stem. The medial zones (M1–M9) start from the most proximal medial point of the prosthesis and extend to the tip of stem. The distal zone D detects the area located distal to the stem with a determined proximal-distal expansion of 2 cm. Due to neck resection zones M1–M3 are not evaluable in neck resecting short stems.

Statistical analysis was performed using IBM SPSS Statistics Version 23.0.0.0.

HHS and NAS results were analyzed using the Wilcoxon-test.

DXA-results were analyzed using the paired-samples *t*-test.

p values <0.05 were considered significant.

3. Results

There was no evidence for aseptic loosening during follow-up period. No infection occurred, and no surgical revision had to be performed in this series. Not all patients were available for all three follow-up examinations. Therefore, the following evaluations are reported each with the corresponding sample size.

HHS significantly improved from preoperative 46.3 ± 10.6 points (*n*=48) to 95.8 ± 6.2 points (*n*=37; *p*<0.001) 6 months and 97.3 ± 6.0 points (*n*=35; *p*<0.001) 12 months postoperatively.

NAS significantly decreased from preoperative 6.9 ± 1.2 (*n*=43) to 0.2 ± 0.7 (*n*=30; *p*<0.001) 6 months and 0.4 ± 1.2 (*n*=30; *p*<0.001) 12 months postoperatively.

Compared to the preoperative BMD a significant increase of BMD was found in the lateral zones L6 and L7, as well as in the medial zone M9 six months postoperatively. A significant decrease of BMD was seen in the lateral zones L3 and L4, and in the medial-proximal zone M4. Twelve months postoperatively, BMD significantly increased in the lateral zones L1, L6, L7 and L8, as well as in the medial zone M6. A significant decrease of BMD was found in

Fig. 1. Zonal system with index-ROIs defined on the first postoperative DXA measurement (left) and transferred to the preoperative measurement (right).

the lateral zones L3 and L4, and in the medial-proximal zone M4 (Fig. 2, Table 1).

4. Discussion

The Harris Hip Score (HHS) revealed good to excellent clinical results. These are comparable to other studies using the Metha[®] stem,^{3,7,8} or other short stems.^{1,5,6}

Pain values decreased to 0.4 of 10 points. The NAS is comparable to the more often used visual analog scale (VAS).¹¹ Similar results in postoperative pain reduction are seen with the VAS in other studies using short stem implants.^{12–14}

Many studies investigating changes of bone mineral density around short stem implants use an initial postoperative measurement as baseline.^{2–5,8} This technique is based on software algorithms, which automatically exclude the area of the stem

Fig. 2. Mean DXA results at the different time points.

Table 1

Mean DXA results at the different time points and mean gain/loss of BMD compared to the preoperative measurement.

ROI	Preoperative		6 months			12 months		
	n	BMD g/cm ² (SD)	n	BMD g/cm ² (SD)	gain/loss% (SD)	n	BMD g/cm ² (SD)	gain/loss % (SD)
L1	29	0.760 (0.134)	26	0.770 (0.124)	+1.16 (12.27)	26	0.797 (0.126)	+8.64 (13.28)*
L2	29	0.885 (0.160)	26	0.874 (0.175)	−0.89 (11.68)	26	0.912 (0.165)	+4.08 (12.32)
L3	29	0.864 (0.159)	26	0.782 (0.212)	−10.47 (13.56)*	26	0.771 (0.185)	−10.08 (12.11)*
L4	29	0.974 (0.196)	26	0.861 (0.235)	−12.69 (13.25)*	26	0.827 (0.209)	−14.34 (11.60)*
L5	29	1.252 (0.227)	26	1.264 (0.265)	+0.24 (11.15)	26	1.230 (0.254)	−1.29 (10.48)
L6	29	1.641 (0.245)	26	1.816 (0.234)	+9.64 (7.61)*	26	1.856 (0.221)	+14.60 (12.06)*
L7	29	1.851 (0.254)	26	1.941 (0.239)	+5.68 (8.64)*	26	1.949 (0.222)	+8.08 (11.77)*
L8	29	2.028 (0.239)	26	2.048 (0.249)	+1.81 (7.93)	26	2.081 (0.278)	+6.08 (10.83)*
L9	29	2.116 (0.258)	26	2.175 (0.277)	+1.94 (5.79)	26	2.167 (0.255)	+4.00 (10.08)
D	29	2.125 (0.224)	26	2.113 (0.239)	−0.07 (3.47)	26	2.088 (0.252)	−0.63 (4.18)
M9	29	2.076 (0.218)	26	2.144 (0.226)	+3.38 (4.70)*	26	2.084 (0.249)	+1.80 (5.35)
M8	29	1.950 (0.230)	26	2.015 (0.238)	+2.98 (5.07)	26	1.948 (0.234)	+1.81 (5.32)
M7	29	1.709 (0.240)	26	1.782 (0.230)	+2.13 (6.37)	26	1.728 (0.205)	+2.15 (8.32)
M6	29	1.382 (0.257)	26	1.434 (0.241)	+2.62 (9.92)	26	1.428 (0.243)	+5.67 (12.97)*
M5	29	1.466 (0.327)	26	1.373 (0.313)	−5.96 (14.53)	26	1.344 (0.232)	−3.60 (16.43)
M4	29	1.585 (0.255)	26	1.360 (0.264)	−14.08 (10.53)*	26	1.341 (0.264)	−13.98 (10.28)*

ROI = region of interest; SD = standard deviation; BMD = bone mineral density; n = sample size.

* Significant change to preoperative ($p < 0.05$, paired t -test).

from measurements. In literature there are studies, using both preoperative and initial postoperative DXA measurements as well. These studies indicate an increase of BMD at early postoperative time points, compared to the preoperative BMD, especially in the lateral (Gruen zone 2 and 3) and partially in the medial (Gruen zone 5 and 6) areas around the stem.^{5,7,8} Lerch et al. assume these changes to be artificial and being created by reaming and compacting cancellous bone during stem implantation.⁷ Accordingly, there might be a bias in using postoperative measurements as baseline, which is why we prefer preoperative DXA examinations as baseline.

Using the classic DXA evaluation,^{5,7,8} a software-based algorithm excludes the area of the stem from the area of measurement at postoperative time points. DXA measurements at early postoperative time points are used as baseline values. So, this technique is available for postoperative investigations only. Preoperative DXA measurements, as used in this study, contain the whole area of the proximal femur, including the area of the later stem but also native bone density of cortical bone as baseline. Index-ROIs were defined at the first postoperative DXA image. These ROIs do not include the area of the stem. By transferring these patient-related index-ROIs to the preoperative DXA image, we are able to use preoperative and native bone density values as baseline (Fig. 1). This proceeding allows precise measurements of real BMD at all time points and minimizes the impact of surgery in the BMD values, i.e. the influence of reaming effects.

In general and compared to previous studies, we found similar increases of BMD after 12 months in the mid-medial areas of the stem (our zone M6/Gruen zone 6)^{3,5,8} and similar density decreases in the region of the greater trochanter (our zones L3 and L4/Gruen zone 1)^{3–5} and in the medial-proximal area (our zone

M4/Gruen zone 7).^{4,8} The increase of BMD in the lateral and distal areas (our zones M6–M8) was not yet described. From the clinical point of view, this result explains the not rare radiographic finding of sclerotic changes at the distal lateral aspect of the stem (Fig. 3). The reason for the missing detection of distal sclerotic changes around the stem might be the relatively extended size of ROIs in the standard Gruen system. Smaller ROIs might uncover these changes, as used in this pilot study. We do not know, what sclerotic alterations at the tip of the stem mean for stability of the stem. This finding could indicate a partial distal loading of the bone mass, which does not fit to the concept of an exclusively proximal load transfer.

Factors like gender, age and body weight may have influence on BMD but there seems to be a consensus of the fact that stem design and mode of fixation remain the major factors.¹⁵

Several studies showed relationships between distal load transfer and aseptic loosening in conventional implant designs.^{16,17} Short stem implants are designed to achieve proximal load transfer in order to avoid stress shielding. To provide evidence in what extend periprosthetic changes of BMD influence the lifetime of short stem prostheses, long-term studies are required.

A limitation of the study is our small sample size and the fact that not all patients were available for investigation at all follow-ups. A further limitation might be the limited follow-up period. Some authors suggest that the majority of bone remodeling following THA is completed within the first postoperative year.^{18,19} The duration of follow-up in our study was one year. However, other studies presume that there is a longer lasting progress of BMD changes.^{20,21}

5. Conclusion

In general, our results confirm preexisting studies using DXA measurements and support the concept of proximal load transfer of the Metha[®] short stem. Nevertheless, our data indicate a distal bony reaction. This finding fits to radiographically seen sclerotic changes at the tip of the stem.

The newly defined and smaller regions of interest should allow a more detailed insight into load transfer of a particular implant. A standardized, implant-dependent definition of regions of interest should allow comparability among similar short stem studies. Using preoperative measurements as baseline enables a precise detection of BMD changes around the implant, minimizing the impact of artificial surgery influences. Further studies are required to confirm our data and assumptions.

Conflict of interest

None.

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Fig. 3. Anteroposterior (AP) radiograph of a right femur, 6 years after Metha short stem implantation. Note the radiographic shielding in the medial-proximal area and the sclerosis in the lateral distal area of the stem.

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