Periprosthetic Bone Remodeling Around Short Stem

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Total hip arthroplasty (THA) has become standard treatment for advanced degenerative changes of the hip. A few studies have reported promising clinical outcomes with the Metha stem fixated by metaphyseal anchoring. This study evaluated early bone remodeling around the Metha stem during 12 months of follow-up. The study population included 36 patients (18 women and 18 men) with a mean age of 50.4 years who underwent THA between 2009 and 2011 for advanced degenerative changes of the hip with the Metha stem. Patients were evaluated on the day of surgery, 10 days postoperatively, and then at 3, 6, and 12 months postoperatively. Evaluation included Harris Hip Score and dual-energy x-ray absorptiometry (DEXA) scanning in 7 Gruen zones. At 12 months postoperatively, Harris Hip Score increased significantly by 38 points. A significant change in bone mineral density (BMD) was found immediately after surgery; this change was most pronounced in Gruen zone 3 (+36%), followed by Gruen zones 2 and 5. The smallest postoperative BMD increase was observed in Gruen zone 7 (+3.66%). In contrast, at 3 months postoperatively, a trend toward decreased BMD was observed in all Gruen zones. At 6 months postoperatively, mean BMD decreased in all Gruen zones except for Gruen zone 6. At 12 months postoperatively, mean BMD increased in Gruen zones 2 through 6, with the highest value (30%) observed in Gruen zone 3; in Gruen zones 1 and 2, mean BMD decreased. Short-term assessment of periprosthetic bone remodeling after uncemented Metha stem implantation revealed different host-bone responses. Apparently, the Metha stem can reduce BMD loss in the proximal femur. DEXA is a precise method for assessing BMD changes around implanted Metha stem.
Osteoarthritis is a World Health Organization-acknowledged disease that poses serious, interdisciplinary challenges for health care providers, as well as for affected patients. According to various sources, it is estimated that osteoarthritis affects from 25% to 80% of the adult population, with disease-related disability posing a significant medical and social problem. The health problems associated with osteoarthritis rank second behind spine degenerative disease in the number of admissions at orthopedic departments.

In advanced stages of osteoarthritis, conservative approach often is not sufficient, and surgical intervention, including joint arthroplasty, is the only solution to help patients regain or improve their functional ability. In consideration of these problems, combined with the inevitability of several operations throughout life, especially for younger patients, new therapeutic solutions are being sought, surgical techniques are being improved, and newer and better implant designs are implemented.

Total hip arthroplasty (THA) currently is the surgical standard for osteoarthritis of the hip and is performed worldwide. A few reports have described promising clinical outcomes with the use of the Metha (B. Braun, Aesculap, Tuttingen, Germany) implant with metaphyseal anchorage and encouraged the current authors to launch a study project supported by densitometric scanning that could help explain the dynamics of early stem healing process into the osseous bed.

Uncemented stems are used more often in THA because both surgeons and manufacturers believed they offer reliable, long-term fixation. Uncemented short stem implants also are used because they may stimulate physiological bone remodeling while reducing stress shielding. However, periprosthetic bone remodeling is still a subject of investigations. The current study sought to evaluate early bone remodeling around the Metha stem during 12 months of postoperative follow-up.

MATERIALS AND METHODS

Thirty-six patients (18 women and 18 men) who underwent THA between 2009 and 2011 for advanced degenerative changes in the hip joint using the Metha stem comprised the study group. Inclusion criteria were body mass index between 20 and 30, and ≥65 years old.

Mean patient age was 50.4 years (range, 21 to 65 years). In 3 patients (2 men and 1 woman), the Metha stem was implanted bilaterally with a minimum 1-year interval between the operations. Only 1 patient was younger than 40 years of age; this patient was a woman who underwent bilateral THA at 21 and 22 years of age for avascular necrosis due to treatment of leukemia. Other degenerative changes originated from underlying hip joint dysplasia in childhood (5 hips), Perthes’ disease (3 hips); in the remaining cases idiopathic osteoarthritis was the cause of the degenerative changes.

In all cases, THA was performed by the same surgeon (MS), and a modular stem (monoblock or modular neck with 130° head-neck-shaft [caput-collum-diaphyseal] angle and 0° anteversion) was implanted. A no-screw cup press-fit acetabular component was implanted, and 28- or 32-mm ceramic heads were inserted with a medium neck in 36 cases, a short neck in 6 cases, and a long neck in 2 cases. In 13 cases, an asymmetric polyethylene acetabular cup was used; in the remaining 23 cases, ceramic articulation was applied. No intraoperative fracture of the femoral bone occurred in any of the patients. The average hospital stay was 7 days, and patients began rehabilitation on the first postoperative day after drains were removed. All patients were allowed full weight bearing postoperatively.

Patients agreed to participate in the study by providing a written and signed consent form. The study protocol was approved by the Bioethical Commission (protocol number RNN/66/11/KE 12 April 2011).

Patient Assessment

In addition to standard radiographs, preoperative evaluations included hip joint range of motion, and Harris Hip Score. Bone mineral density (BMD) also was assessed using dual-energy x-ray absorptiometry (DEXA).

On the 10th postoperative day after surgery, only densitometry of the operated hip joint was performed; neither hip joint range of motion or the patient’s quality of life were evaluated. Patients then underwent clinical follow-up, including DEXA evaluation, at 3, 6, and 12 months postoperatively.

Densitometric Evaluation

Proximal femur bone densitometry was performed before surgery, on the 10th postoperatively, and at 3, 6 and 12 months postoperatively using a Lunar Prodigy scanner (GE Healthcare Lunar, Madison, Wisconsin) with dedicated enCore software (C 10/2003 version). The scanner was standardized daily following the manufacturer’s recommendations. The operative limb was stabilized with a special adapter in 20° of internal rotation to ensure the same, repeated limb position in each scanning.

The first densitometry scan was performed on the day of the patient’s admission as part of the preoperative assessment. Subsequent densitometric scanning was performed 10 days postoperatively, using the orthopedic program, in which the scanner automatically designated 7 Gruen zones around the implanted stem, following an optional adjustment of the long stem axis in the program. Gruen zones were adapted to the short stem design (R1-R7).

The obtained stem images were plotted on the preoperative scan, it first converted to the orthopedic format. That approach enabled a direct comparison of the dynamics of postoperative changes in particular Gruen zones and also with...
preoperative baseline BMD values. All measurements were stored as enCore files and also as hard copies.

**Statistical Analysis**

Statistical analysis of obtained results included the elements of descriptive statistics (mean, median, standard error, and minimum and maximum), and the average changes for selected features were calculated. The $t$ test was used for associated trials in cases of normal distribution, the Wilcoxon test was used in opposite cases, and the Shapiro-Wilk test was used for the assessment of conformity of distribution in case of an analyzed feature versus normal distribution. The level of statistical significance was set at $\alpha=.05$. All calculations were supported by the R environment for statistical calculations, version for Microsoft Windows by GNU License (Free Software Foundation).

**RESULTS**

All of the patients completed the study assessments according to schedule. No signs of radiographic stem migration or radiolucent lines around the stem were observed. During the postoperative course, considerable differences were found in the dynamics of changes around the stem, should the point of reference be the preoperative (baseline) status or the postoperative status (10 days after), which leads to different results in statistical analysis. Surgical technique, which could compress the bone, may influence postoperative BMD. When analyzing the percentage changes in particular time intervals, there was a significant BMD change immediately after THA. This change was most pronounced in Gruen zone 3 (+36%) and consecutively in Gruen zones 2 and 5 (+30% and +22%, respectively) and could be attributed to the highest compression of the spongy bone in those zones during the stem implantation. The smallest postoperative BMD increase was noted in Gruen zone 7 (+3.66%).

One patient, who underwent bilateral THA at 21 and 22 years of age because of avascular necrosis of the femoral head due to leukemia treatment, had similar bone density parameters around the Metha stem as older patients. The authors believe this finding, which was comparable to the findings of the older patients in the study, was influenced by this patient’s previous leukemia treatment.

**Clinical Evaluation and Harris Hip Score**

Range of motion was compared preoperatively and at 3, 6, and 12 months postoperatively using the Harris Hip Score. At final follow-up, the Harris Hip Score increased significantly by 38 points (Table 1).

**Densitometry Results**

Evaluation concentrated on the mean quantitative results of DEXA measurements in particular Gruen zones, the percentage changes in the time intervals between subsequent controls and the dynamics of the changes in selected observation periods. The dynamics of metabolic processes around the stem were evaluated postoperatively and compared with the preoperative findings (Table 2). During the course of the study, considerable differences were found in the dynamics of changes around the Metha stem, depending on whether the reference point was the preoperative status or the status on the 10th day after the operations, which leads to different results in statistical analysis. Analyzing the percentage changes in particular time intervals, a big change can be observed in BMD immediately after the surgery. This change was most pronounced in Gruen zone 3 (+36%) and consecutively in Gruen zones 2 and 5 by 30% and 22%, respectively. This change possibly may be attributed to the highest compression of the spongy bone in these zones during stem implantation. The smallest postoperative BMD increase was noted in Gruen zone 7 (+3.66%).

Three months postoperatively, bone density demonstrated an overt dropping tendency at all of the studied zones. That phenomenon of “osteolysis” varied from $-1.2\%$ at Gruen zone 6 up to $-17\%$ at Gruen zone 7. Three months postoperatively, further BMD decrease was observed at all Gruen zones except for zone 6, but with lower dynamics and varying from $-5.8\%$ at Gruen zone 7 to $+0.6\%$ at Gruen zone 6. The second half-year postoperatively manifested a reversal of this tendency, with mean BMD values increasing at particular areas in Gruen zones 1 to 6. Those values varied from $0.9\%$ at Gruen zone 4 to $3.3\%$ at Gruen zone 1; only Gruen zone 7 demonstrated further BMD decrease by $1.9\%$. At 12 months postoperatively, increased bone

<table>
<thead>
<tr>
<th>Time</th>
<th>No. Cases</th>
<th>Mean Score</th>
<th>Median Score</th>
<th>SE</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>36</td>
<td>56.2</td>
<td>52</td>
<td>3.0</td>
<td>30</td>
<td>86</td>
</tr>
<tr>
<td>Postoperative</td>
<td>36</td>
<td>89.6</td>
<td>90</td>
<td>1.6</td>
<td>61</td>
<td>100</td>
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<tr>
<td>3 months</td>
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<td>96.2</td>
<td>97</td>
<td>0.7</td>
<td>87</td>
<td>100</td>
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<td>6 months</td>
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<td>94.1</td>
<td>100</td>
<td>1.6</td>
<td>55</td>
<td>100</td>
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</tbody>
</table>

Table 1

**Table 1**

Preoperative and Postoperative Harris Hip Scores

**Abbreviation:** SE, standard error.
Feature Article

Density values were observed at Gruen zones 2 through 6, with the highest increase at Gruen zone 3 (30%). At Gruen zones 1 and 7, BMD decreased during the year after surgery compared with preoperative values by $-2.7\%$ and $-20.5\%$, respectively.

In addition, at 12 months postoperatively, mean BMD values decreased at all but Gruen zone 6 compared with BMD values on the 10th day postoperatively, with the highest drop at Gruen zone 7 (23.2%). At Gruen zones 3 through 5, the decrease in mean BMD values varied within 4% to 5%. At Gruen zone 6, there was a small but noticeable BMD increase during the year compared with BMD values on the 10th day postoperatively ($+1.8\%$). Changes were statistically significant after 6 months and 1 year (baseline versus 6 and 12 months postoperatively, $\alpha=0.05$).

**DISCUSSION**

Total hip arthroplasty is currently standard treatment in cases of advanced degenerative changes of the hip joint. This surgical procedure poses the highest challenge for orthopedic surgeons when performed in young patients who are in the period of their highest social and professional activity. The orthopedic surgeon must implant the most suitable prosthesis for these patients. Currently, there is a large number of available stem models, ranging from standard designs, through hip resurfacing, to metalseal stems, which have been gaining more advocates in the world of orthopedic surgery. In all cases, the most important issue is optimal healing of the implants into the patient’s osseous bed. For this reason, this study was undertaken to evaluate early bone remodeling process around the Metha stem during the first 12 months after implantation.

The uncemented Metha stem is made of a titanium forged alloy (Ti6Al4V/ISO 5832-3), with a 0.35-mm proximal microporous titanium, plasma-sprayed coating and with an additional 20-µm dicalcium phosphate dehydrate layer that is applied electrochemically. The sizes in the implant (the smallest 9.75 cm, and the largest 12.25 cm) increase in increments of 1.5 mm in the anteroposterior and 1.2 mm in the lateral views. Anchorage in the femoral neck is supported by the conical shape in the lateral projection. The difference in nominal length between the smallest and largest stem is only 2.5 cm. The Metha stem can be used both with a modular neck (0° and 7.5° of retroversion or anteversion) or as a monoblock (120°, 130° or 135° and 0° anteversion neck angle).

Periprosthetic bone loss is the main problem in patients undergoing THA. In certain studies, the factors of bone remodeling after THA have been analyzed and evaluated. In the current study, early periprosthetic bone behavior around the Metha stem was observed and its relationship with preoperative BMD was investigated in the femoral metalseal area. DEXA is considered the most reliable tool to evaluate bone remodeling after THA with different stem designs.

In recent years, a number of reports have been published with evaluation of bone remodeling processes at stem implantation areas. Lerch et al evaluated bone density around Bicontact stems; Albanese et al analyzed CFP, Mayo, and IPS stems; and Zeh et al made Nanos stems their issue of interest.

The analysis of Gruen zones is the most commonly used method to evaluate bone remodeling or aseptic loosening after implantation of femoral stems. According to reports in the literature, conventional Gruen zones were adapted to the short stem design.

Several reports in the literature present bone remodeling around implanted stem in long-term follow-up. The current authors believe observation of bone tissue remodeling around the implanted stem is most important in the early, postoperative period; therefore, similarly as in the study by Mulier, this study evaluated bone remodeling

### Table 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Gruen Zone 1</th>
<th>Gruen Zone 2</th>
<th>Gruen Zone 3</th>
<th>Gruen Zone 4</th>
<th>Gruen Zone 5</th>
<th>Gruen Zone 6</th>
<th>Gruen Zone 7</th>
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<tr>
<td>Preoperatively</td>
<td>0.79184</td>
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<td>1.56712</td>
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<td>1.55144</td>
<td>1.24824</td>
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<td>Postoperatively</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 days</td>
<td>0.860964</td>
<td>1.303643</td>
<td>2.126464</td>
<td>2.044464</td>
<td>1.891036</td>
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<td>1.229821</td>
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<tr>
<td>3 months</td>
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<td>6 months</td>
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<td>1.181483</td>
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<td>12 months</td>
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<td>2.039724</td>
<td>1.947793</td>
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<td>1.524345</td>
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</tbody>
</table>
around the Metha stem at 10 days postoperatively, as well as at 3, 6, and 12 months postoperatively.

No other factors were analyzed in the current study, which may have had an influence on bone tissue remodeling around the Metha stem. It does not appear from the available literature whether factors such as sex, body weight, or the type of implanted stem play any significant role in bone tissue remodeling around the Metha stem.17,19

Another important issue in the current study was the reference of BMD changes around the stem to their preoperative (baseline) values and to their status at 10 days postoperatively. The changes in bone density, which occur in the metaphyseal part of the femoral bone, are associated with the surgical technique of site compacting to implant the Metha stem. Similar observations were made by Leichtle et al,11 although they claim that results from experimental studies indicate compacting of trabecular bone or bone loss due to rasping are not the main causes of density changes, while bloodstream disorders after femoral preparation may affect some Gruen zones, causing bone density to drop in the first several months postoperatively.

DEXA is considered the most reliable tool for the evaluation of bone remodeling after THA using different stem designs. This method is applied not only for evaluation of bone remodeling around the stem but also of the cup.20 The shape and length of the Metha stem with its unique coating offers great potential for bone remodeling around this stem. Although the position of the Metha stem ensures primary load stability, the additional circumferential Plasmapore μ-CaP coating of the entire proximal surface supports rapid secondary fixation, has an osteoconductive effect, and accelerates contact between the bone and the prosthesis stem.

Clinical values may be attributed to considerations on the dynamics of metabolic processes versus their postoperative status. This is so because after surgery, there is an “artificial” increase of bone density in particular zones, created as a result of the surgical technique itself (ie, compacting the spongy bone to obtain an appropriate site in the femur bone for stem implantation). Further deliberations have been based on that premise, namely, that the “independent” bone metabolism around the stem should be evaluated in observations of the status soon after surgery (10 days). Nevertheless, interesting information can be found in the data by comparing the mean BMD in Gruen zones 1 through 7 at 10 days postoperatively to preoperative values. The data provide a picture of BMD changes in these areas, induced by the operative technique, where the highest postoperative BMD increase is observed in the lateral (Gruen zones 2 and 3) and medial (Gruen zones 5 and 6) regions.4,21

This study demonstrated a slow BMD drop in all Gruen zones during the first 3 months postoperatively after the surgery. After 4 months, the BMD decreasing trend continued in the observed zones but at a slower pace. From the 7th month postoperatively, a gradual increase in BMD was noted in the observed zones.

One year after THA, increased BMD values were observed at Gruen zones 2 through 6, with a peak increase observed at Gruen zone 3, where the BMD exceeded the baseline levels by 30%. Similar observations have been made by other authors.10,11 In their study, Rahmy et al22 demonstrated higher BMD loss in cases with anatomical and standard stems. In a recent study by Zah et al.,8 who used a Nanos stem, DEXA scanning showed a significant and relevant increase in Gruen zone 6 (12%) and a decrease in Gruen zone 1 (15%), Gruen zone 2 (5%), and Gruen zone 7 (12%), which was interpreted as reflecting a distal load transfer in the metaphysis of the femur.

Similar observations were made by Albanese et al.7 In their evaluation of CFP, IPS, and ABG stems, they showed decreased BMD in Gruen zone 1. In another study comparing the Mayo, IPS, and Alloclassic stems, a decrease was observed in Gruen zone 7.7 Stukendorf-Colsman et al23 also reported the greatest decrease in BMD occurred in the greater trochanter (−11%) and the calcar region (−12%).

In a study by Lerch et al.,9 the overall bone mass loss was 2.8% in the entire femur. Bone mass decrease occurred primarily in the proximal part of the calcar and in the greater trochanter, probably leading to stress shielding. Pitto et al10 reported a 39.6% cortical bone mass decrease in the calcar and trochanteric region 5 years after implantation of a tapered uncemented stem in a quantitative computed tomography investigation. Albanese et al7,23 reported BMD loss in Gruen zone 7 as a known issue because of stress shielding in the very proximal portion of the femur.

The current study confirms the results obtained by other authors in studies evaluating BMD levels around the femoral stem.8,10,18,21,22 This study also confirmed that the DEXA method is a reliable procedure to determine periprosthetic mineral density and may become a useful tool to study bone response to particular THA options.

**Conclusion**

The assessment of periprosthetic bone remodeling 12 months after uncemented Metha stem implantation revealed a different host-bone response. The Metha stem can reduce BMD losses in the proximal femur. DEXA is a precise evaluation technique that is ideal for assessing small BMD changes around the Metha stem. These data further highlight the crucial role of mechanical stress in BMD maintenance.
REFERENCES


