INTRODUCTION: The ideal “neck conserving” short stemmed total hip arthroplasty (THA) implant will stimulate increased bone formation around the device and its bony ingrowth by physiologic load bearing. On the basis of positive clinical results with mid- and long term follow-up using the Mayo short stem (Zimmer, Warsaw, USA) [3,5], the Metha® neck preserving stem (AESCULAP AG, Tuttlingen, Germany) was introduced.

Finite element (FE) simulations are widely accepted for estimation of bone remodeling after THA. However, the assumptions made have to be validated by direct acquisition of bone remodeling data from THA recipients. This issue can be addressed by dual-energy x-ray absorptiometry (DEXA) [2]. The stem is anchored metaphysically within the closed ring of the femoral neck. The prosthesis is made of titanium forged alloy and has a proximal rough titanium, plasma sprayed microporous hydroxyapatite coating with an additional 20 µm calcium phosphate dihydrate layer.

In this investigation we present the first numerical calculations on bone remodeling after THA with the Metha® short stem and its validation by DEXA.

METHODS: A Surface Triangulation Language model of a physiological left femur based on computer tomography data of an average weight male patient was generated by means of a 3D image processing and software. A solid FE model was built based on ten-noded tetrahedral elements. The apparent bone density (ABD) distribution from the measured Hounsfield Unit (HU) values was calculated according to Rho et al. [6]. The stem was optically measured with the 3D coordinate measurement system. To simulate the physiological loading situation of the femur, the boundary conditions according to Speirs et al. were chosen [8]. For the loading history, the whole gait cycle (the most frequent dynamic activity of a patient after THA [4]) was examined in order to regard all the different load cases of the cycle in the simulation. The physiological loading pattern in the junction between the femur under the considered loading history was calculated in one cycle. The changes in material properties of the bone after THA were determined. This iterative simulation process ends when the change in the bone mass converges. Bone remodeling was calculated by quantifying the change in the ABD using a bone adaptation law [1].

For the clinical validation a consecutive series of 25 patients were included in a prospective study. The number of patients was calculated by a power-analysis performed by our institute for biometry. This was required by our institute’s institutional review board committee to obtain approval for this study (Ethic Committee No. 4226). The patients underwent DEXA examinations preoperatively and after 1 week, 6 months, 12 months and 2 years of implantation (9 (36%) female and 16 (64%) male). Conventional Gruen’s zones were adapted to the short stem design [3,7,9]. Each patient’s individual regions of interest (ROI) were saved on the Hologic system and were used for all subsequent measurements to reduce bias. According to the routine clinical follow-up radiographs were taken preoperatively, intraoperatively, 1 week after surgery, 3 months and 1 year postoperatively.

The Shapiro-Wilk-tests did not show a normal distribution for the DEXA measurements; the Wilcoxon signed-ranks test was used to statistically compare the density changes. P < 0.005 was considered significant. Data analysis was performed using SPSS (11.05 SPSS Inc., Chicago, Illinois).

RESULTS: FEA Bone remodeling was mostly found in the very proximal part of the calcar and in the greater trochanter. In the diaphyseal/distal region, no change in the ABD could be proven and thus no bone remodeling was estimated. A spot of increase in bone density was found at the junction between the rough proximal part of the stem and the smooth distal portion. A slight increase was seen at the medial aspect of the prosthesis in the lesser trochanter region. A bone mass decrease of 4.1% for the whole femur was estimated until convergence was reached. Clinical validation Six patients were excluded from the study. No infection, loosening, or periprosthetic fracture occurred in the remaining patients. In the first 12 months the decrease in BMD was 9.5% in R7 (calcar region), but recovered in the following year to 0.06 g/cm² over baseline value. The highest decrease in BMD was seen in the greater trochanter region (R1). Only in R6 the BMD did increase statistically significant after 2 years. No statistical significant differences between the regions were observed. Only in R7 the measured area decreased significantly (p < 0.001).

DISCUSSION: The numerical and DEXA investigations show that stress shielding and bone mass loss occurs in the proximal regions of the femur. The overall femoral bone mass loss is little after implantation of the Metha® short stem and the diaphysis is not compromised after implantation. The numerical investigations can be confirmed in terms of proximal bone mass loss and distal bone conservation.

The FE calculations differ from the DEXA results in terms of an observed increase in BMD in the minor trochanter region. To some extent, the differences can probably be ascribed to the known influence of the proximal diaphyseal phosphate layer on periprosthetic bone remodeling. Due to a strong calcar resorption calculated in R7, the Hologic system only detects the remaining bone close to the minor trochanter where stress transfer increases bone mass, leading to a false increase in BMD in the DEXA analysis.

The used short stemmed implant seems to enhance a physiological load distribution to the proximal femur. Further clinical studies are warranted to assess the efficacy of this relatively new implant.

SIGNIFICANCE: The aim to develop a FE model of the femur-stem composite with the used stem was achieved and successfully clinically validated. The study reveals a physiological load distribution to the metaphyseal portion of the femur, thus preserving periprosthetic bone in the proximal and medial regions.

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