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Mid- to long-term periprosthetic bone density changes after cementless short stem hip arthroplasty in elderly: A clinical and radiological analysis

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Short stem prostheses were originally designed for younger and more active patients. In recent years, they have been increasingly offered to older patients. This study evaluates the mid-to long-term survival of a short stem prosthesis and the changes in periprosthetic bone density following implantation of a cementless short hip stem in patients over 60 years of age.
Methods: 118 patients aged over 60 received short stem prostheses. Clinical examination included Harris Hip Score (HHS) and Hip Disability and Osteoarthritis Outcome Score (HOOS). 93 patients were followed clinically for at least five years. 53 patients underwent dual-energy x-ray absorptiometry (DXA) and radiographic evaluation. Follow-up intervals were preoperative and postoperative (t_0), at approximately six months (t_1), at approximately two years (t_2), and at approximately five years or later (t_3).
Results: Over a mean 6.7-year observation period for all 118 patients, one stem revision occurred due to a traumatic periprosthetic stem fracture. The five-year survival rate for the endpoint *survival of the Metha® stem* in 95 at-risk patients is 99.2%. HHS improved significantly from t_0 55.3 ± 11.5 (range 30–79) to t_3 95.3 ± 8.6 (range 57–100) at a mean of 8.0 years ($p < 0.001$). HOOS improved significantly in each subscale ($p < 0.001$). Bone mineral density (BMD) was available for review in 53 patients after a mean of 7.1 years. BMD increased from t_0 to t_3 in region of interest (ROI) 3 (+0.4%) and ROI 6 (+2.9%) and decreased in ROI 1 (−10.3%), ROI 2 (−9.8%), ROI 4 (−5.3%), ROI 5 (−3.4%) and ROI 7 (−23.1%).
Conclusions: The evaluated short stem prosthesis shows a remarkably high survival rate in elderly patients, accompanied by excellent clinical results. Load transfer measurements show a metaphyseal-diaphyseal pattern with a trend towards increased diaphyseal transfer over the period observed.

1. Introduction

While short stem prostheses were initially recommended for younger and active total hip arthroplasty (THA) patients, this design has also been offered to older patients.[1] There are advantages of an uncemented short stem prostheses design, from which also elderly patients could benefit: A meta-analysis showed a significant lower intraoperative blood loss, a higher clinical Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and a non-significant “reduced rate of femoral fractures, dislocations and revisions” in short stem prostheses compared to the standard stem group.[2] In addition, short stem prostheses are bone sparing, generate better conditions for revision surgery, create a more physiologic load pattern, and support minimally invasive surgical techniques that preserve soft tissue.[3,4] Further, for hemiarthroplasties a shorter operation time and a lower incidence of pulmonary embolism are shown in uncemented hemiarthroplasties compared to cemented ones.[5] The uncemented short stem prosthesis has no risk for these complications.

Many short- and mid-term studies on remodeling around the Metha® short stem prostheses show the main periprosthetic bone density changes proximally.[6–12] A one-year systematic review indicates a more balanced remodeling and a shorter length over which the remodeling takes place compared to standard hip arthroplasty.[12] After one to two years, some authors report that the remodeling process is complete, while others find an increasing loss of bone density.[6–13] If these advantages can also be confirmed in an older collective has not yet been

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investigated in the mid-to long-term for the Metha® short stem prosthesis in elderly patients. The definition of elderly patients is used according to the World Health Organization (WHO), which defines elderly patients as those over 60 years of age.[14]

Beside the clinical outcome, long-term-survival and reduced need for revision surgery are crucial for patients. This study evaluates the >60-month survival, clinical outcomes and changes in bone density of a cementless short stem prosthesis in patients over 60 years of age. It was hypothesized that the periprosthetic bone density persists after postoperative remodeling indicating a metaphyseal load transfer of the Metha® prosthesis.

2. Patients and methods

2.1. Study design and demographic data

We performed a retrospective study among all patients who were surgically treated with a Metha® short stem prosthesis (B. Braun, Aesculap AG, Tuttlingen, Germany) from April 2010 to January 2017 at the Department of Orthopedics and Orthopedic Surgery at the University Hospital Giessen and Marburg (UKGM) in Giessen and met the inclusion criteria. Informed consent was required. All patients were required to be at least 60 years of age and had to undergo a bone mineral density (BMD) measurement within two weeks after surgery. Exclusion criteria were failure to provide informed consent, age less than 60 years at the time of surgery, and failure to have BMD measured around the operated hip within 14 days of surgery. The Ethics Committee of the Justus Liebig University (Giessen, Germany) approved this study under the file number 152/09. Data collection ended in February 2022.

2.2. Implants/material

The Metha® is a titanium alloy short stem prosthesis designed for cementless metaphyseal anchorage within the closed femoral neck ring, preserving its integrity. It provides primary stability through contact with the dorsolateral cortex and secondary fixation with a coated proximal surface. All patients received surgical treatment with the monobloc version of the Metha® prosthesis.

2.3. Surgical technique

Preoperative planning was performed digitally using mediCAD® (mediCAD Hectec GmbH, Altdorf, Germany). The anterolateral minimally invasive surgery (ALMIS) approach according to Basad et al. and the lateral approach according to Bauer et al. were used.[15,16]

2.4. Clinical and radiologic examination

The study used the Harris Hip Score (HHS) modified by Haddad et al. and the German version 1.0 of the Hip disability and osteoarthritis outcome score (HOOS).[17,18] HHS is widely used for assessing outcomes after total hip arthroplasty while HOOS, originally for younger, active patients, has also been applied to older patients.[19] The 2013 HOOS scoring instructions were followed, but due to a translation error, one question (number 6) from the Activities of Daily Living (ADL) subscale was counted as not answered, though it didn't affect the ADL subscale's patient count. Some patients didn't attend t_3 due to age, comorbidities, or the corona pandemic. To mitigate dropout bias, those who were unable to attend in person or whose clinical data were collected before January 2020 were interviewed by telephone. This created a discrepancy between clinical and radiological follow-up periods. Research by Sharma et al. found no significant difference between HHS results gathered in-person versus by telephone.[20] Similar findings exists for the WOMAC, upon which HOOS based.[21,22] Anterior-posterior radiographs were used for radiologic evaluation. Ectopic ossification was graded according to Brooker et al.[23] A database error caused a three-month discrepancy between one t_1 x-ray and bone density measurements. At t_3, a new radiograph was not taken twice for radiation protection, as the previous radiographs were three and six months old and there was no clinical evidence of change. All other radiographs at t_1, t_2 and t_3 were consistent with the date of the DXA.

Osteodensitometry was performed using the Lunar Prodigy Primo (General Electric, Boston, Massachusetts, USA). Dual-energy x-ray absorptiometry (DXA) is the most reliable tool for osteodensitometric measurements around THA.[24] The absorbed dose ranged from 9.0 μGy to 83.0 μGy per measured femur. Calibration was done daily using a phantom measurement as per manufacturer guidelines. Bone mineral density (BMD) in each region of interest (ROI) was measured in g/cm^2. The examination was standardized: the foot was attached to a positioning wedge perpendicular to the table and the patella was oriented straight up using another positioning aid. DXA scans were processed using enCORE® version 13.31 (Medical Systems Lunar, Madison, Wisconsin, USA). The osteodensitometric evaluation was performed by one examiner. The ROIs according to Gruen et al. were adapted to cementless short stem prostheses.[25] The longitudinal axis was placed from the prosthesis's distal tip to its lateral shoulder. ROI 6 included the lesser trochanter, while ROI 4 extended to below the prosthesis's distal tip. Care was taken to ensure ROIs excluded the pelvis and any femoral areas outside the ROI boundaries (Fig. 1).

2.5. Statistical analysis

Statistical analyses were performed using a random slope, random intercept model with SPSS® version 29.0 (IBM, New York, USA). All pairwise comparisons were Bonferroni adjusted within comparisons. Kaplan-Meier analysis was performed according to Meyers in SAS® (SAS Institute, Cary, USA).[26] The number of patients multiplied by the observation period was used to calculate person-years.[27]

3. Results

Of 192 operated patients aged 60 years and older, 118 provided informed consent and underwent BMD measurement within two weeks after surgery. 118 patients and 118 hips with diagnoses of primary coxarthrosis (87.3%), dysplastic coxarthrosis (8.5%), femoral head necrosis (1.7%), residual dysplastic coxarthrosis (0.9%), posttraumatic coxarthrosis (0.9%), and Perthes' disease (0.9%) were included. 59 patients (50%) were male and 59 patients (50%) were female. 63 hips (53.4%) were implanted on the left side, 55 (46.6%) on the right side. The mean body mass index (BMI) at the time of surgery was 27.7 ± 4.4 kg/m^2 (range 18.8–41.0). The mean age was 67.7 ± 5.3 years (range

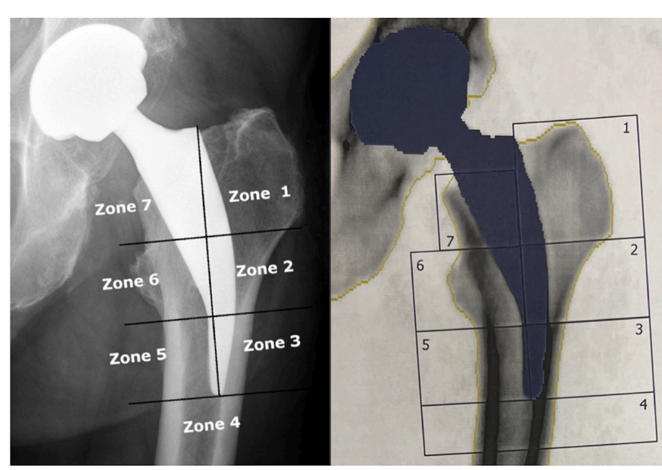

Fig. 1. ROIs adapted to cementless short stem prostheses in a radiograph (left) and in an osteodensitometric planning image (right).

60.1–82.4). There were four experienced surgeons with one surgeon (B.A.I.) performing 81.4% (96) of the surgeries. The ALMIS approach was used in 99.2% (117 cases) and the lateral approach according to Bauer et al. was used once (0.8%), including the scar of a previous operation.[15,16] The mean follow-up of all 118 patients was 6.7 years. A detailed description of the follow-up period can be found in Table 1.

3.1. Survival results

In one of 118 patients, follow-up ended due to a traumatic periprosthetic shaft fracture with loosening of the short stem prosthesis and stem replacement with a revision stem (Brehm MRP) 56 days post-surgery. Additionally, four other patients experienced complications without shaft replacement: postoperative hematoma at 5 days, deep seroma with wound healing issues at 20 days, wound healing complications with subcutaneous granulomas at 149 days, and hip endoprosthesis infection 1073 days post-surgery. Of the remaining 117 patients, 22 were deceased or could not be contacted after at least five-years postoperative. After at least five-years postoperative, the survival rate could be analyzed in 95 patients, the HOOS in 93 and the HHS in 92 patients. The BMD could be measured in 53 patients at the five-year follow-up or later. The Kaplan-Meier analysis for the Metha® stem is shown in Fig. 2.

The left Kaplan-Meier Analysis shows the endpoint *survival of the Metha® stem*. The right Kaplan-Meier Analysis shows the endpoint *no revision surgery for any cause*. The y-axis provides the survival in percent, the x-axis the patients-at-risk with time after surgery in years. The vertical lines indicate censored data points. The survival of the Metha® stem is 99.2%, the risk for *no revision surgery for any cause* is 95,8 % (mean observation time of 6.7 years for 118 patients).

3.2. Clinical results

There were four follow-up controls for clinical and radiological examination: t_0: baseline values, HHS and HOOS with preoperative values and DXA within 14 days after surgery, t_1: at approximately six months after surgery, t_2: at approximately two years after surgery and t_3: at approximately five years or later (t_3). If clinical data or radiographic measurements were not available at t_1 or t_2, the examination closest to the time of follow-up was chosen if possible. Only the included hip was evaluated. If the patient underwent surgery on both hips, a separate questionnaire was completed for each hip.

The HHS improved significantly ($p < 0.001$) from 55.3 at t_0 to all subsequent follow-up assessments. See Table 2 for detailed HHS characteristics.

The HOOS improved significantly from t_0 in each subscale and overall ($p < 0.001$). See Table 3 and Table 4 for detailed HOOS characteristics.

3.3. Radiographic osteodensitometry results

Table 5 shows the follow-up period for the 53 of the 118 patients whose radiographs and DXA were evaluated. 53 patients were evaluated at t_0 and t_3, 44 patients at t_1, and 41 patients at t_2.

All radiographs showed a properly seated prosthesis throughout follow-up. Class 1 ectopic ossification was observed in 11.4% at t_1, in 14.6% at t_2, and 17.0% at t_3. One patient had Class 2 ossification at each follow-up. No class 3 or 4 ossifications were observed. Calcar resorption was observed in 90.9% at t_1, 90.2% at t_2 and 90.6% at t_3. Calcar hypertrophy occurred in 2.3% at t_1, 4.9% at t_2 and 5.7% at t_3. Calcar femoris morphology remained unchanged in 6.8% at t_1, 4.9% at t_2, and 3.8% at t_3.

In the osteodensitometric measurements the BMD increased from t_0 to t_3 in ROI 3 (+0.4%) and ROI 6 (+2.9%), and the BMD decreased significantly ($p < 0.001$) in ROI 1 (−10.3%), ROI 2 (−9.8%), ROI 4 (−5.3%), ROI 5 (−3.4%), and ROI 7 (−23.1%). The BMD decreased from t_0 to t_1 in each ROI except ROI 6. The BMD increased from t_1 to t_2 in each ROI except ROI 7. The BMD increased from t_2 to t_3 in ROI 3 (+2.3%), ROI 4 (+0.8%), ROI 5 (+1.1%), and decreased in ROI 1 (−1.9%), ROI 2 (−3.7%), ROI 6 (−5.0%), and ROI 7 (−8.5%). See Table 6 for detailed characteristics.

4. Discussion

Short stems have been used for over 45 years, initially recommended for younger, more active patients.[1,28] Recently, this design has extended its applicability to older patients.[1] In Germany, where 79.5% of total hip arthroplasty patients are aged 60 years or above,[29] the elderly constitute the largest patient cohort. This study of 118 patients, 53 of whom underwent bone density assessments at an average of 7.1 years post-operatively, focuses on this elderly demographic. Compared to other studies of the Metha® stem using Osteodensitometry, only one included 28 elderly patients with a two-year-follow-up.[7] Osteodensitometry assessments of the Metha® stem, irrespective of age, have varied in size and duration, ranging from one to four years with sample sizes from 20 to 67 patients.[6–12] In terms of both follow-up-duration and sample size, this study ranks among the upper echelon compared to other investigations.

4.1. Clinical results

Prior investigations with mid-to long-term follow-up in diverse patient demographics have consistently shown excellent clinical results, with five-year HHS ranging from 90 to 97 points, HOOS scores of 89, and five-year survival rates between 96.7% and 98.9% for the Metha® stem.[30–32] These commendable results were reaffirmed in elderly patients within this study: Among 790.6 person-years observed, only one stem revision was necessitated due to a periprosthetic shaft fracture following a fall. The Metha® stem showed a 99.2% five-year survival rate in 95 at-risk patients. Notably, this study employed the monobloc version, eliminating reported material failures seen with the modular Metha® prosthesis.[33,34] The Harris Hip Score (HHS) exhibited a significant improvement ($p < 0.001$), increasing by 35.1 points from baseline (t_0) to immediately post-surgery (t_1). Subsequently, HHS demonstrated a non-significant continual improvement from t_1 to t_2 and t_3, culminating in a score of 95.3 points at the final assessment, averaging 8.0 years

Table 1
Clinical follow-up period.

Event (time in years)	n	Mean	SD	Min.	Q_1	Median	Q_3	Max.
Age at surgery	118	67.7	5.3	60.1	63.3	66.6	71.7	82.4
Age at last control	118	74.4	5.5	61.2	70.6	74.4	78.0	87.5
Time difference t_0-t_1	99	0.5	0.1	0.2	0.5	0.5	0.6	0.8
Time difference t_0-t_2	88	1.8	0.6	1.0	1.1	2.0	2.1	3.2
Time difference t_0-t_3	93	8.0	1.9	5.0	6.3	7.8	9.9	11.4
Time difference t_1-t_2	83	1.3	0.6	0.3	0.6	1.5	1.6	2.6
Time difference t_2-t_3	73	6.3	2.0	3.0	4.6	6.6	8.0	10.4
Time difference surgery to last x-ray	118	4.6	3.1	0.0	2.0	5.0	7.1	10.7
Time difference surgery to last control	118	6.7	3.1	0.0	5.1	7.1	9.1	11.4

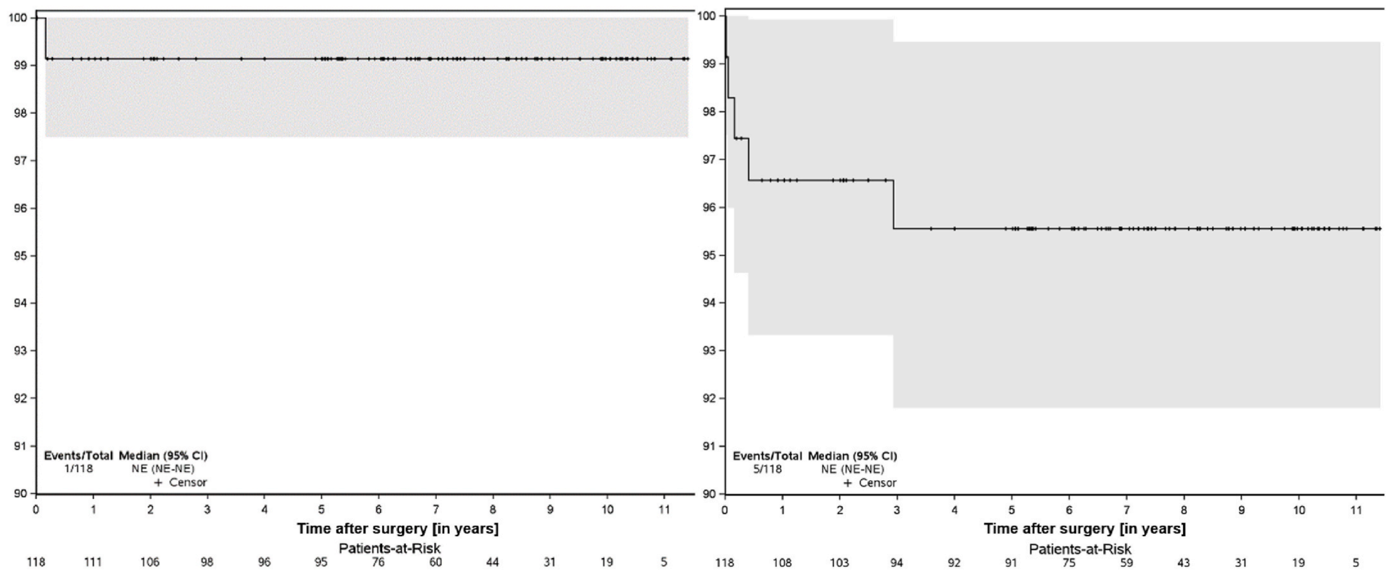

Fig. 2. Kaplan-Meier Analysis, left: endpoint survival of the Metha® stem, right: endpoint no revision surgery for any cause.

Table 2
HHS results.

t	n	mean	SD	Min.	Q_1	Median	Q_3	Max.
t_0	98	55.3	11.5	29.7	47.0	54.5	63.0	79.0
t_1	98	90.4	11.0	52.0	85.0	95.0	99.0	100
t_2	85	92.4	10.0	60.0	91.0	96.0	99.0	100
t_3	92	95.3	8.6	57.1	95.6	98.0	100	100

p-values: t_0-t_1: $p < 0.001$, t_1-t_2: $p = 0.912$, t_2-t_3: $p = 0.131$.

post-implantation. It remains uncertain whether this sustained improvement reflects enhanced functionality, psychological factors, patient acclimatization to the prosthesis, or reduced demands on the prosthesis with advancing age. The Hip disability and Osteoarthritis Outcome Score (HOOS) total score also showed significant improvement from 36.6 to 93.3 points ($p < 0.001$). Despite these promising outcomes, it's essential to acknowledge the surgeon's learning curve, where complications like intraoperative fractures may occur, especially during the initial stages.[35] Nonetheless, there are encouraging results in mitigating intraoperative fractures, particularly through the use of acoustical determination of primary stability.[35,36]

Therefore, in this investigation the prosthesis demonstrates high functionality, accompanied by excellent clinical outcomes, and a low revision surgery frequency, suggesting short stems could be a viable option even for patients aged 60 and above.

4.2. *Load transfer*

Assessing load transfer necessitates analyzing Bone Mineral Density (BMD) changes over time in specific regions of interest (ROIs). However, the lack of uniformity in ROI classification yields varied outcomes for each zone. To address this, our subdivision considers individual zones like the calcar or minor trochanter, crucial for distinct force analysis. Osteodensitometry revealed a decline in BMD across all ROIs except ROI 3 and 6 from t_0 to t_3. Between t_0 to t_1, BMD decreased across all ROIs except ROI 6. Notably, BMD in the calcar region (ROI 7) continued to decline at t_2 and t_3, reaching −23.1% at the final assessment, averaging 7.1 years. In contrast, other ROIs exhibited an increase from t_1 to t_2.

Table 4
HOOS total score (total) and questions answered (n).

t	n	mean	SD	Min.	Q_1	Median	Q_3	Max.
t_0 total	68	**36.6**	15.6	7.1	26.6	34.2	43.3	79.7
t_1 total	85	**83.1**	14.9	38.5	73.1	85.8	96.5	100
t_2 total	83	**89.4**	11.3	55.4	84.0	94.1	98.0	100
t_3 total	93	**93.3**	10.5	44.7	92.3	97.4	99.4	100
p-values	HOOS total score: t_0-t_1: $p < 0.001$, t_1-t_2: $p = 0.003$, t_2-t_3: $p = 0.093$							
t_0 n	68	37.7	3.2	24	38	39	39	39
t_1 n	85	37.0	4.0	19	37	39	39	39
t_2 n	83	37.8	2.9	24	38	39	39	39
t_3 n	93	38.2	1.2	33	38	39	39	39

Table 3
HOOS results.

t	n	mean	SD	Min.	Q_1	Median	Q_3	Max.
t_0 P/S/ADL/SRF/QOL	68/67/66/65/67	**39.9/45.3/38.2/21.9/25.9**	17.7/20.0/17.6/20.4/17.9	7.5/5.0/4.7/0.0/0.0	27.5/31.3 28.1/6.3/18.8	37.5/40.0/35.9/18.8/25.0	47.5/55.0/46.9/31.3 33.3	95.0/100/87.5/75.0/83.3
t_1 P/S/ADL/SRF/QOL	85/85/82/77/83	**86.4/84.9/84.8/73.2/73.1**	15.2/14.8/15.1/22.2/20.5	32.5/45.0/42.2/12.5/18.8	77.5/80.0/75.0/58.3/62.5	92.5/85.0/90.6/75.0/75.0	97.5/100/98.4/91.7/87.5	100/100/100/100/100
t_2 P/S/ADL/SRF/QOL	82/83/81/82/82	**91.5/90.1/91.0/82.6/83.7**	10.9/10.5/11.9/17.4/16.7	60.0/58.3 48.4/25.0/50.0	87.5/85.0/85.9/75.0/75.0	96.3/95.0/95.3/87.5/93.8	100/100/100/100/100	100/100/100/100/100
t_3 P/S/ADL/SRF/QOL	93/93/93/93/93	**94.5/93.5/94.4/90.8/88.0**	12.0/9.8/10.6/15.0/16.4	30.0/50.0/46.9/33.3/25.0	95.0/90.0/95.0/83.3/81.3	100/100/98.4/100/93.8	100/100/100/100/100	100/100/100/100/100
p-values of "mean"	P: t_0-t_1: $p < 0.001$, t_1-t_2: $p = 0.059$, t_2-t_3: $p = 0.582$ S: t_0-t_1: $p < 0.001$, t_1-t_2: $p = 0.073$, t_2-t_3: $p = 0.356$ ADL: t_0-t_1: $p < 0.001$, t_1-t_2: $p = 0.012$, t_2-t_3: $p = 0.250$ SRF: t_0-t_1: $p < 0.001$, t_1-t_2: $p = 0.003$, t_2-t_3: $p = 0.002$ QOL: t_0-t_1: $p < 0.001$, t_1-t_2: $p < 0.001$, t_2-t_3: $p = 0.240$							

P = Pain, S = Symptoms, ADL = Activities of Daily Living, SRF = Sport and Recreation Function, Q = Hip Related Quality of Life.

Table 5
DXA follow-up period.

Event	n	mean	SD	Min.	Q1	Median	Q3	Max.
Time difference surgery $DXAt_0$[a]	118	6.1[a]	2.0[a]	0[a]	5[a]	6[a]	7[a]	12[a]
Time difference surgery $DXAt_1$	44	0.5	0.1	0.4	0.5	0.5	0.6	0.7
Time difference surgery $DXAt_2$	41	2.0	0.6	0.9	2.0	2.0	2.1	3.5
Time difference surgery $DXAt_3$	53	7.1	1.6	4.9	5.6	7.0	8.1	10.7
Time difference $DXAt_0$ $DXAt_1$	44	0.5	0.1	0.4	0.5	0.5	0.6	0.7
Time difference $DXAt_1$ $DXAt_2$	40	1.4	0.6	0.3	1.4	1.5	1.6	3.0
Time difference $DXAt_2$ $DXAt_3$	41	5.3	1.9	1.8	3.4	5.0	6.5	8.7
Age of patients at surgery	53	65.7	4.5	60.1	62.3	64.2	68.2	78.5
Age of patients at $DXAt_3$	53	72.8	5.0	66.3	69.3	71.7	75.1	87.1

[a] Time in days, remaining data in years.

Table 6
DXA Results, BMD in g/cm.[2].

	t0	t1			t2					t3				
ROI	BMD	BMD	% to t0	p-value to t0	BMD	% to t0	p-value to t0	% to t1	p-value to t1	BMD	% to t0	p-value to t0	% to t2	p-value to t2
ROI 1	0.855	0.765	−10.5	<0.001	0.782	−8.5	<0.001	+2.2	0.425	0.767	−10.3	<0.001	−1.9	0.003
ROI 2	1.500	1.396	−6.9	0.001	1.405	−6.3	0.045	+0.6	1.000	1.353	−9.8	<0.001	−3.7	0.004
ROI 3	2.193	2.116	−3.5	0.031	2.152	−1.9	1.0	+1.7	0.707	2.202	+0.4	1.0	+2.3	0.310
ROI 4	2.085	1.956	−6.2	<0.001	1.958	−6.1	<0.001	+0.1	1.000	1.974	−5.3	<0.001	+0.8	0.374
ROI 5	1.942	1.834	−5.6	<0.001	1.856	−4.4	<0.001	+1.2	1.000	1.876	−3.4	<0.001	+1.1	1.000
ROI 6	1.452	1.511	+4.1	0.004	1.573	+8.3	<0.001	+4.1	0.077	1.494	+2.9	0.500	−5.0	<0.001
ROI 7	1.486	1.270	−14.5	<0.001	1.249	−15.9	<0.001	−1.7	1.000	1.143	−23.1	<0.001	−8.5	<0.001

Notably, from t_2 to t_3, BMD increased in diaphyseal regions (ROI 3–5) and decreased in metaphyseal regions (ROI 1–2, ROI 6–7), suggesting a shift in load distribution. This indicates a slightly more distal load transfer over time, significantly seen in ROI 1 ($p = 0.003$), ROI 2 ($p = 0.004$), ROI 6 ($p < 0.001$), and ROI 7 ($p < 0.001$) from t_2 to t_3. This challenges the idea that bone density stabilizes after initial remodeling, particularly in the elderly population studied here. Future research should clarify whether these changes stem from the older cohort. Short-term findings, as presented in Yan et al.'s systematic review, corroborate and align with our study's outcome, demonstrating a combined BMD loss in ROI 1 (−7.7%) and ROI 7 (−12.5%) and an increase in ROI 6 (+5.7%) at one-year follow-up.[12] In conventional stems, bone loss at ROI 1 and 7 could surpass 30% at 2 and 10 years, contrasting with our study's mean BMD loss of −10.2% and −23.1% at 7.1 years.[37] Although direct comparison is limited, the trend is clear that bone loss was lower in this study. Moreover, it's likely that the actual proximal bone loss is substantially less compared to the standard stem in Bodén et al. This is because the evaluation of the Gruen zones differed, and the lesser trochanter, typically partially located in ROI 7, relates in the short stem adapted zones to ROI 6, where an increase in bone density was noted. Furthermore, the patients in this study were older than those in Bodén et al. and age is a factor in poor bone quality.[13,37] In general, short stem prostheses typically have a smaller area for bone remodeling due to their shorter stems. Thus, evidence suggests more proximal force application and less bone density loss with the Metha® stem compared to the evaluated standard stem, advocating short stems as a potential option for patients over 60 years based on osteodensitometric results.

4.3. Limitations

This study's limitations include patient eligibility requirements for a short stem prosthesis. Severe osteoporosis or poor bone quality are exclusion criteria in short stem prosthesis. Additionally, informed consent for DXA scans and questionnaires was required. Consequently, the findings may not directly apply to the general population and cannot be generalized to the diverse array of short stem prostheses, each possessing distinct biomechanics. While data collection was prospective, the study design is retrospective with no control group or randomization. While results show efficacy, there were ongoing bone remodeling processes, so results might not extend beyond the study period. This study is unique in monitoring Metha® prosthesis bone remodeling in elderly patients, or patients in general, for an extensive duration. Clinical assessments were during COVID-19 and many elderly patients didn't attend clinic follow-ups due to pandemic-related concerns or comorbidities. The mean age at the last examination exceeded 74 years, acknowledging the inherent complexities associated with elderly patients.[38]

5. Conclusion

Existing literature has consistently highlighted excellent clinical outcomes and survival rates associated with short stem prostheses.[6,7,10–12,30–32] Similarly, our findings demonstrate comparable results, even among older patients aged 60 years and above. Consequently, age alone should not preclude consideration for short stem prosthesis implantation. Given the myriad advantages of uncemented short-shaft prostheses and the commendable long-term outcomes observed, they should be regarded as the preferred choice for hip endoprosthesis, even in elderly patients. However, it's crucial to note significant bone remodeling persists beyond two years. Our findings suggest a shift towards a metaphyseal-diaphyseal distribution of the examined Metha® prosthesis.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Ethical statement

The Ethics Committee of the Justus Liebig University (Giessen, Germany) approved this study under the file number 152/09.

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None.

Patient's consent

Informed consent was obtained.

CRediT authorship contribution statement

Max Brandl: Methodology, Investigation, Data curation, Writing – original draft. **Alexander Jahnke:** Methodology, Writing – review & editing. **Christian Fölsch:** Writing – review & editing. **Markus Rickert:** Resources, Supervision, Writing – review & editing. **Bernd Alexander Ishaque:** Conceptualization, Supervision, Writing – review & editing, Project administration.

Declaration of generative AI and AI-assisted technologies in the writing process

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Declaration of competing interest

None.

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