



High prevalence and undertreatment of osteoporosis in elderly patients undergoing total hip arthroplasty

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Abstract

Summary We detected a high prevalence of low bone mineral density assessed by DXA in 268 elderly patients with end-stage osteoarthritis scheduled for total hip arthroplasty (18% osteoporosis, 41% osteopenia). Therefore, and due to the identified concomitant undertreatment, routine DXA measurements should be considered in elderly patients prior to surgery.

Introduction Bone quality represents a decisive factor for osseointegration, durability, and complications of an implanted prosthesis. Although the risk of osteoporosis increases with age and the assessment of bone mineral density (BMD) prior to total hip arthroplasty (THA) is recommended in elderly patients, a systematic, unbiased analysis of such patients is not available in the literature.

Methods In this retrospective study, we examined 268 elderly patients (age ≥ 70 years) who underwent dual-energy X-ray absorptiometry (DXA) within 3 months prior to primary THA. Demographics, medical history, radiographic OA grade, and stem fixation method (i.e., cemented or cementless) were obtained.

Results In total, 153 (57%) cemented and 115 (43%) cementless stem fixations during THA were performed. Forty-nine patients (18%) were diagnosed with osteoporosis (T-score ≤ -2.5), 110 patients (41%) with osteopenia (T-score ≤ -1.0), and 109 patients (41%) with normal BMD (T-score > -1.0). Importantly, 36/49 patients (73%) with osteoporosis were not diagnosed before, resulting in a relevant undertreatment. Female sex and low body mass index (BMI) were the main factors negatively influencing the bone mineral density (BMD).

Conclusions Due to a high incidence of undiagnosed and untreated osteoporosis in elderly patients with potential effects on the success of osseointegration as well as other clinical outcomes, DXA measurements should be included in the clinical routine for these patients prior to THA.

Keywords Arthroplasty · Bone mineral density · DXA · Osteoarthritis · Osteoporosis

Introduction

Total hip arthroplasty (THA) is a highly successful surgical intervention to restore the function of the hip joint and to relieve pain in patients with symptomatic end-stage osteoarthritis (OA) of the hip [1]. As age represents not only one of the most relevant risk factors for OA but also for osteoporosis,

there is a general recommendation from the International Society for Clinical Densitometry (ISCD) to assess bone mineral density (BMD) in women aged ≥ 65 years and men aged ≥ 70 years prior to THA [2]. Nonetheless, an implementation of this recommendation is not consistently carried out in clinical routine. Namely, although it is generally considered as relevant and 60% of the orthopedic surgeons previously stated that a low BMD represents a reason to reconsider their choice of prosthesis fixation during THA, only 4% performed BMD measurements preoperatively [3]. At present, the decision whether to perform cemented or cementless fixation during THA usually depends on the surgeon's preference, region-specific standards, the age of the patient, as well as the intraoperative impression of bone quality [4], but is usually not based on bone mineral density (BMD) in a standardized or routine manner.

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In patients with OA, a high frequency of osteopenia and osteoporosis has previously been reported, but limited patient numbers, restriction to one sex, and lack of differentiation between hip or knee arthroplasty were limiting factors [5–8]. Patients with low BMD possess increased risks for major potential complications in the context of a THA: intraoperative fractures, periprosthetic fractures, stem subsidence, and aseptic loosening [9–12].

In the present study, we analyzed the BMD assessed by dual-energy X-ray absorptiometry (DXA) in elderly OA patients aged ≥ 70 years scheduled for THA. We hypothesized that osteoporosis is a relevant and frequent finding, which may underline the need for routine BMD measurements prior to surgery. An additional aim was to investigate the relevance of potential influencing factors on BMD in these patients.

Methods

Study cohort

We retrospectively included 268 consecutive elderly patients aged ≥ 70 years who underwent THA in our department due to end-stage OA in the years 2018 and 2019. The only exclusion criteria were active cancer with skeletal metastases and inoperability due to severe medical conditions. We assessed demographic parameters (sex, age, and BMI) as well as the preoperative BMD determined by DXA as a part of the routine workup in all patients. In patients diagnosed with osteoporosis and/or indication for specific osteoporosis drug treatment such treatment was initiated or recommended according to the German osteoporosis guidelines [13]. Furthermore, the detailed medical history with primary focus on relevant clinical risk factors for osteoporosis and increased fracture risk was obtained. These risk factors included the presence of previous fractures, rheumatoid arthritis, oral intake of glucocorticoids for longer than 3 months in the past or at present, as well as regular consumption of alcohol (more than three units per day) and tobacco. The presence of diabetes mellitus was also recorded. Regarding the severity of OA, the Kellgren-Lawrence score was determined in preoperative radiographs [14]. Moreover, we evaluated the type of femoral stem fixation (cemented or cementless). Either the CORAIL stem (Depuy Synthes, Raynham, MA, USA; cemented or cementless) or the Müller Geradschaft (cemented)/CLS Spotorno (cementless) (Zimmer-Biomet, Warsaw, IN, USA) was implanted. The acetabular cup was implanted without the use of bone cement (cementless) in all cases. The orthopedic interventions were performed by senior surgeons only. Preoperative DXA results were not included in the surgeon's decision to perform cemented or

cementless stem fixation in a routine or standardized manner. This multifactorial process was based on age, sex, BMD, femur geometry, and intraoperative impression of bone quality. The present study is in accordance with the guidelines of the local ethics committee. Since a retrospective chart analysis with anonymized data was performed in all study patients, the need for ethical approval was waived.

Dual-energy X-ray absorptiometry

We assessed the bone mineral density (BMD) at the left and right proximal femur and the lumbar spine (L1–L4) by using dual-energy X-ray absorptiometry (DXA) within 3 months before surgery (Lunar Prodigy enCore 2007, GE Healthcare; Madison, WI, USA). This instrument-based assessment was performed according to the German osteoporosis guidelines (DVO). The T-scores representing the BMD standard deviations above or below the mean for young, sex-matched healthy adults were generated by the manufacturer's software. In accordance with the guidelines of the World Health Organization (WHO), we diagnosed osteoporosis and osteopenia on the basis of the T-score (osteoporosis T-score ≤ -2.5 , osteopenia T-score $> -2.5 \leq -1.0$, normal T-score > -1.0).

Statistical analysis

We used SPSS® statistical program (version 26.0, IBM, Armonk, NY, USA) and GraphPad Prism® (version 7.0, GraphPad Software, La Jolla, CA) for statistical analyses. Continuous variables are expressed as mean \pm standard deviation (SD), while categorical variables are expressed as number and percentage. Evaluation of normality of data distribution was tested with the Shapiro-Wilk test. For determining the age-dependent development of T-scores, we performed linear regression analysis and determined the *p*-value, the coefficient of determination R^2 , and the 95% confidence interval (CI) of the respective regression slopes. Group differences were tested for significance using unpaired two-sided *t*-test for normally distributed data and Mann-Whitney *U* test for non-normally distributed data. Differences of more than two groups were analyzed by one-way ANOVA with Tukey's post hoc analysis for multiple comparisons in the case of normally distributed data. For non-normally distributed data, the Kruskal-Wallis test with Dunn's post hoc test for multiple comparisons was performed. To determine the influence of age, sex, BMI, or Kellgren-Lawrence score on BMD T-score, a multivariate regression model was performed. The regression used the "Enter" method to examine the significant impact of all variables simultaneously. *P*-values < 0.05 (2-tailed) were considered statistically significant.

Results

The study collective of hip OA patients undergoing cemented or cementless THA ($n=268$) consisted of 90 (34%) male and 178 (66%) female patients (Fig. 1a–c). Male and female patients were similar in age, but the BMI values differed significantly between the sexes, with values of 28.0 ± 3.0 kg/m² for male patients and 27.2 ± 4.6 kg/m² for female patients ($p=0.029$) (Table 1). Regarding the relevant clinical risk factors for osteoporosis, no differences were present between male and female patients. A total of 15 (5.6%) patients had previously suffered from a fragility fracture (24 fractures in total). Of these, 10/24 fractures occurred at a peripheral site, while 14/24 were vertebral fractures. Furthermore, 17 patients (6.3%) had a confirmed diagnosis of rheumatoid arthritis, while 13 patients (4.9%) were exposed to oral glucocorticoids for longer than three months in the past or present. Thirty-nine patients (14.6%) with diabetes mellitus were identified.

Regarding tobacco and alcohol consumption, 19 patients stated to drink more than three units of alcohol per day, while 27 patients were currently smoking.

To determine the skeletal status, we measured the BMD and the associated T-scores by DXA of both hips and the lumbar spine. An overview of the demographic and disease-specific characteristics, medical history including risks factors, and DXA results for female and male patients is given in Table 1. Importantly, of the 268 patients analyzed, 49 patients (18%) were diagnosed with osteoporosis, while 110 patients (41%) had T-scores in the range of osteopenia, resulting in a total number of 159 patients (59%) with reduced BMD (Fig. 1d). Of the 49 patients with osteoporosis, only 13 (27%) had already been diagnosed with osteoporosis before (Fig. 1e). Of note, only 18 (37%) patients received vitamin D (25(OH)D₃) supplementation (Fig. 1f), and an antiresorptive treatment had been prescribed to only eleven (22%) patients (Fig. 1g), indicating relevant undertreatment.

Table 1 Demographic and disease-specific characteristics, medical history, and DXA evaluation in the OA patient collective scheduled for THA ($n=268$)

| | Female Mean (SD) or <i>n</i> (%) | Male Mean (SD) or <i>n</i> (%) | <i>p</i> -value |
|--|-------------------------------------|-----------------------------------|---------------------------|
| Total | 178 (66%) | 90 (34%) | |
| Patient characteristics | | | |
| Age (years) | 78.6 (4.7) | 77.6 (5.0) | 0.076 |
| Height (cm) | 163.8 (5.9) | 174.0 (7.5) | <0.0001 |
| Weight (kg) | 73.4 (14.7) | 85.1 (11.3) | <0.0001 |
| BMI (kg/m ²) | 27.2 (4.6) | 28.0 (3.0) | 0.029 |
| Kellgren-Lawrence Score | 3.1 (0.6) | 3.3 (0.5) | 0.068 |
| Cemented femoral stem fixation | 111/178 (62.4%) | 42/90 (46.7%) | 0.014 [#] |
| Medical history and risk factors | | | |
| Previous fractures | 11/178 (6.2%) | 4/90 (4.4%) | 0.559 [#] |
| -Peripheral | 6/178 (3.4%) | 2/90 (2.2%) | |
| -Vertebral | 5/178 (2.8%) | 2/90 (2.2%) | |
| Rheumatoid arthritis | 8/178 (4.5%) | 9/90 (10.0%) | 0.081 [#] |
| Diabetes mellitus | 24/178 (13.5%) | 15/90 (16.7%) | 0.485 [#] |
| -Type 1 | 3/178 (1.7%) | 0/90 (0%) | |
| -Type 2 | 21/178 (11.8%) | 15/90 (16.7%) | |
| Glucocorticoids | 9/178 (5.1%) | 4/90 (4.4%) | 0.825 [#] |
| Three or more units alcohol/day | 10/178 (5.7%) | 9/90 (10.0%) | 0.186 [#] |
| Current smoking | 17/178 (9.6%) | 10/90 (11.1%) | 0.688 [#] |
| DXA results | | | |
| T-score hip (min.) | -1.5 (1.3) | -0.7 (1.3) | <0.0001 |
| T-score affected hip | -1.0 (1.3) | -0.3 (1.3) | <0.0001 |
| T-score unaffected hip | -1.1 (1.3) | -0.4 (1.3) | 0.001 |
| T-score lumbar spine | -0.7 (1.8) | 0.8 (2.1) | <0.0001 |
| Osteoporosis (T-score ≤ -2.5) | 41/178 (23%) | 8/90 (9%) | 0.005 [#] |
| Osteopenia (T-score $\leq -1.0 > -2.5$) | 81/178 (46%) | 29/90 (32%) | 0.037 [#] |
| Normal (T-score > -1.0) | 56/178 (31%) | 53/90 (59%) | <0.0001 [#] |

[#] Determined by the chi² test. Bold indicates significant differences ($p < 0.05$).

THA total hip arthroplasty, BMI body mass index, SD standard deviation, *n* number of patients, *min.* minimum

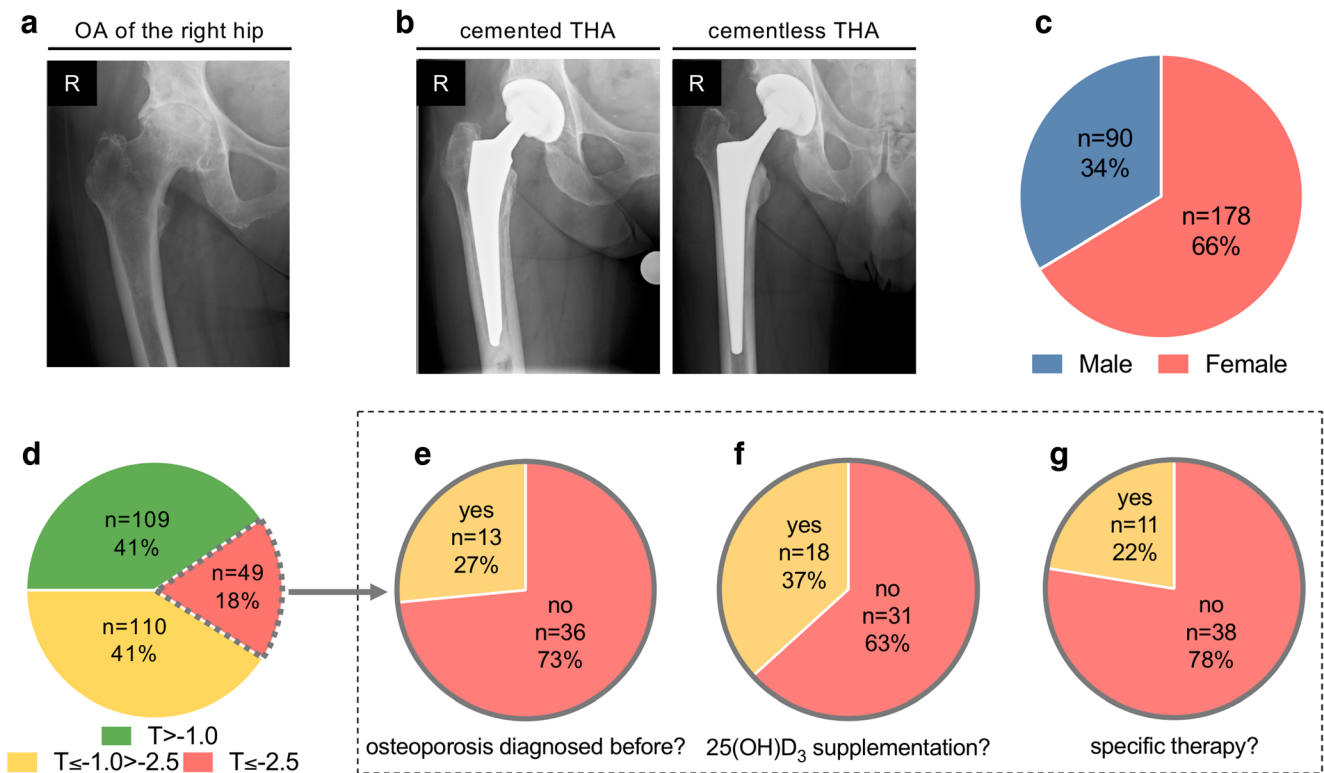


Fig. 1 Overview of the study collective and DXA results in THA patients aged ≥ 70 years. **a** Representative preoperative radiograph (right hip AP) of an OA patient included in this study. **b** Postoperative radiographs (right hip AP) of a cemented and a cementless THA. **c** Sex distribution of the study population. **d** Pie charts showing DXA results and categorization in

osteoporosis, osteopenia, or bone mineral density within the reference range based on the $T\text{-score}_{\text{min}}$. A detailed description of the osteoporosis patients concerning **e** an existing diagnosis of osteoporosis, **f** the current supplementation of vitamin D, and the **g** application of a bone-specific therapy

Analyzing the influencing factors of BMD, especially of the hips as the region of interest in THA, the sex-specific distribution of BMD showed significantly higher T-scores in male individuals compared to females ($p < 0.0001$; Fig. 2a), resulting in a lower frequency of low bone mass (i.e., osteoporosis) than in females. Namely, osteoporosis by $T\text{-score}_{\text{min}}$ was observed in only 8/90 (9%) of the male and 41/178 (23%) of the female patients (Table 1). When examining a possible

age-related BMD loss of the hips in our patient collective, linear regression analysis revealed a weak negative association of age with T-scores in the hip ($R^2 = 0.033$; $p = 0.003$, slope (95% CI) = -0.084 to -0.018 T-score per year) (Fig. 2b). However, a moderate positive association was found with relation to BMI with an increased T-scores of the hips in patients with a higher BMI ($R^2 = 0.209$; $p < 0.0001$, slope (95% CI) = 0.114 to 0.185 T-score per kg/m^2 ; Fig. 2c). No

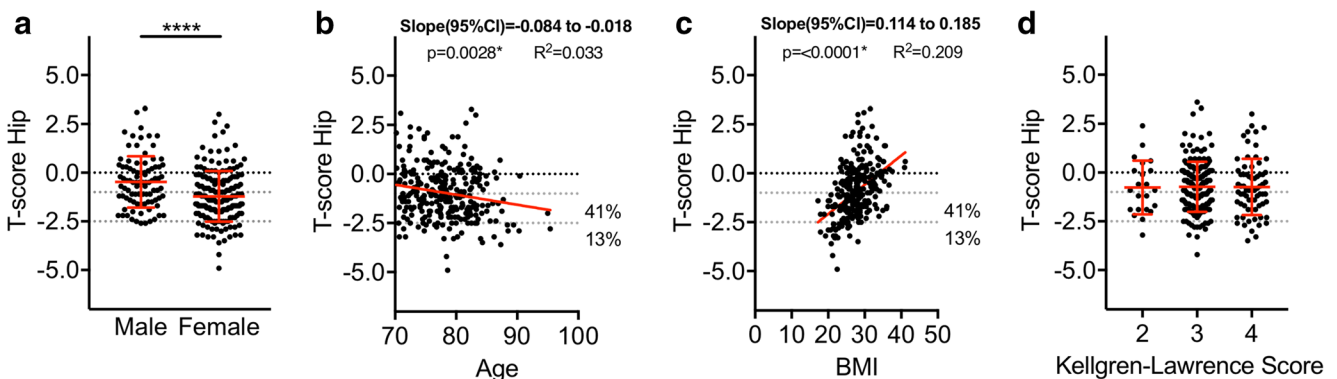


Fig. 2 Influencing factors on BMD values at the hip. **a** In the patient collective of OA patients ≥ 70 years, significantly lower T-scores at the hip could be revealed in females compared to males (Mann-Whitney U test). **b** Furthermore, age (years) showed a weak negative association with the T-score at the hip (linear regression). **c** A moderate positive

association was detected between BMI and T-score at the hip (linear regression). **d** T-scores of the affected hip were not different between the different OA grades determined by the Kellgren-Lawrence scores (Kruskal-Wallis test). **** $p < 0.0001$

Table 2 Multivariate regression model analyzing the independent factors influencing BMD

| | T-score _{min} | | | T-score _{aff.} | | | T-score _{LS} | | |
|--------------------------------|------------------------|---------------|------------------|-------------------------|---------------|------------------|-----------------------|---------------|------------------|
| | β | <i>T</i> | <i>p</i> | β | <i>T</i> | <i>p</i> | β | <i>T</i> | <i>p</i> |
| Hip | | | | | | | | | |
| (Intercept) | | −0.488 | 0.626 | | 0.015 | 0.998 | | −0.174 | 0.862 |
| Age | −0.087 | −1.552 | 0.122 | −0.105 | −1.793 | 0.074 | −0.052 | −0.908 | 0.365 |
| Sex | −0.255 | −4.639 | <0.001 | −0.223 | −3.890 | <0.001 | −0.308 | −5.458 | <0.001 |
| BMI | 0.357 | 6.439 | <0.001 | 0.308 | 5.314 | <0.001 | 0.293 | 5.161 | <0.001 |
| KLS | −0.041 | −0.740 | 0.460 | 0.001 | 0.026 | 0.980 | 0.017 | 0.303 | 0.762 |
| <i>R</i> ² adjusted | 0.22** | | | 0.169** | | | 0.2** | | |

Bold indicates significant independent predictors

***p* < 0.001 for the multivariate ANOVA regression model

T-score_{min} minimum T-score of both hips, *T-score_{aff.}* T-score of the affected/operated hip, *T-score_{LS}* T-score lumbar spine, *KLS* Kellgren-Lawrence score, *BMI* body mass index

differences in T-scores were found between the groups of different OA severity grades classified according to the Kellgren-Lawrence score (Fig. 2d).

In line to these results, a multivariate regression analysis to determine the influence of age, sex, BMI, and Kellgren-Lawrence score on BMD indicated that sex and BMI were statistically significant independent factors influencing the T-score in our elderly patient collective with OA (Table 2). Specifically, female sex and low BMI predicted lower T-scores in total, in the affected hip and in the lumbar spine (*p*<0.001). Age and the severity of OA did not represent independent determinants.

Discussion

During the process of osseointegration of implants, which is based on bony ingrowth in the porous surface of the implant, the bone quality and remodeling capacities are of great importance [15]. In the case of reduced BMD, extensive micromovements and the risk of increased migration with subsequent loss of optimal implant position can decisively impair osseointegration leading to implant failure [16, 17]. In cementless THA, especially the initial stem stability is an essential factor in forming a sufficient fixation between the bone and the prosthesis [18]. Other potential complications of reduced BMD in the context of cementless THA are the increased risk of intraoperative periprosthetic fractures and aseptic loosening [12, 19, 20]. A substantial influence of the BMD on the success or failure of the cementless THA appears therefore evident. Furthermore, large registry studies previously showed that the risk of intraoperative periprosthetic fracture is markedly higher in cementless stems [21, 22]. Nonetheless, and despite recommendation from the International Society for Clinical Densitometry (ISCD), in women aged ≥ 65 years and men aged ≥ 70 years, BMD

measurements are not usually implemented in routine examinations prior to THA and consequently are not included in the decision-making process whether to perform cemented or cementless fixation in THA. In the present study, we demonstrated that osteoporosis assessed by DXA is highly prevalent and undertreated in elderly patients undergoing THA.

From the 268 patients included, 49 (18%) had osteoporosis and 110 (41%) had osteopenia expressed by a T-score of ≤ -2.5 and ≤ -1.0 , respectively. Previous studies also analyzed the BMD of patients undergoing total joint arthroplasty by DXA with an osteoporosis frequency of 25–33%. However, these previous studies were limited to low patient numbers, the examination of exclusively female patients scheduled for cementless THA, or a lack of differentiation between hip and knee arthroplasty [5–8]. Since we have measured a consecutive series of patients ≥ 70 years of age using DXA, we believe that the detected osteoporosis and osteopenia frequency of 18% and 41% shown here reflects a realistic prevalence of elderly OA patients in central Europe affected by osteoporosis. Global differences in the incidence of osteoporosis must be considered.

Analyzing the potential risk factors, sex and BMI were the main factors influencing BMD in our patient collective, as confirmed by the multivariate regression analysis. Therefore, especially women with low BMI were at high risk of having a low BMD within our elderly patient collective of OA patients. Interestingly, and despite the fact that osteoporosis risk is known to increase with age, age had no effect on BMD in the patient collective of OA patients ≥ 70 years, possibly because of the opposing effects of decreasing BMD and increasing degeneration (which positively affects DXA results) with age in this selected group.

Our results are primarily important as 36 (73%) of the 49 patients with osteoporosis had not been diagnosed with osteoporosis before, strengthening the need for routinely performed DXA measurements before surgery. Furthermore,

the observed problematic undertreatment of patients with osteoporosis regarding vitamin D supplementation (63% without vitamin D supplementation) as well as bone-specific treatment (78% without bone-specific treatment) became apparent, as all patients with osteoporosis fulfilled the indications for such treatment. The results of the present study have several clinical implications in line with previous studies. Besides the increased risk for atraumatic or low-energy fractures in patients with osteoporosis, the osseointegration of a cementless femoral stem can be impaired by poor bone remodeling capacities [17]. On the other hand, it has already been shown that the treatment with antiresorptive agents such as bisphosphonates and denosumab reduces the risk for an early femoral stem migration in the context of a THA [23–25]. Moreover, both bisphosphonates and denosumab had a significant positive effect on the reduction of periprosthetic bone loss and consequently on the revision rates [19, 23, 26, 27]. In patients with osteoporotic bone, an antiresorptive treatment could therefore be a decisive factor for either success or failure of osseointegration as well as rates of loosening [28]. Based on these collective findings, it appears crucial to identify OA patients undergoing THA with low BMD, in order to initiate adequate treatment. Overall, it is interesting to note that the use of bisphosphonates does not appear to have a significant effect on the progression of the OA of the hip or the risk of undergoing a THA in patients with hip OA [29]. Nevertheless, in the case of knee OA, it has been shown that bisphosphonates seem to delay the progression of OA and reduce the risk of a total knee arthroplasty [30, 31]. Besides, it should be noted that with the existing endemic vitamin D deficiency in northern Germany [32], vitamin D supplementation is indispensable for osteoporosis therapy to allow balanced calcium homeostasis. Although we were not able to assess preoperative vitamin D levels in all our patients, it is highly likely that vitamin D deficiency was present in the majority of patients. Patients with low BMD were recommended to attend our outpatient clinic for skeletal diseases, where extensive laboratory tests are carried out before initiation or adjustment of vitamin D supplementation as well as bone-specific treatment.

The decision whether to perform cemented or cementless fixation during THA is subject to ongoing discussion and is also influenced by geographical factors. In Germany, the endoprosthesis registry was able to show in over 150,000 included patients that the probability of early failure in patients ≥ 75 years is significantly higher in patients with cementless compared to cemented stems, while in patients < 75 years, both fixation methods showed similar results [33]. One of the reasons for this difference could be a higher incidence of low BMD in patients of advanced age. Here, BMD measurements by DXA prior to THA could possibly identify patients who are suitable for cementless implants despite advanced age. In this regard, it is interesting to note that implanting a

cemented stem was associated with a 25% higher load-to-failure force compared to the cementless equivalent in a previous cadaveric study [34]. Considering the high incidence of reduced bone quality in elderly patients in combination with the relevant therapeutic consequences, a general DXA measurement before the surgery in patients ≥ 70 years of age is likely beneficial to improve short- and long-term treatment outcomes.

Conclusion

In the present patient collective of end-stage OA patients aged ≥ 70 years scheduled for THA, there was a high frequency of reduced BMD (i.e., osteoporosis). The majority of these cases had not been diagnosed with osteoporosis before leading to a crucial rate of undertreatment. A general assessment of BMD prior to THA should be considered in patients over 70 years to optimize treatment and outcome, which includes the prevention of complications such as intraoperative periprosthetic fractures and aseptic loosening, and likely also to assist the surgeon's decision to perform cemented or cementless fixation. However, longitudinal studies should assess the effects of low BMD on these complications.

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Declarations

Ethical approval A retrospective chart analysis was conducted in all study patients. Data were anonymized before analysis. Therefore, the need of ethic approval was waived.

Informed consent The authors declare that informed consent was obtained in all patients.

Conflicts of interest None.

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