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POSITION PAPER

Evidence-based joint statement position of perioperative bone optimization in the arthroplasty candidate, from FEMECOT, AMMOM, ACOMM, SCCOT, SECOT, SEFRAOS, SEIOMM

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Abstract

Background The prevalence of patients living with joint replacements is increasing. Nearly two-thirds of patients undergoing elective arthroplasty procedures have low bone mineral density (LBMD), defined as osteopenia in 38.5% and osteoporosis in 24.8%; among those with osteoporosis, only 32.8% received treatment at the time of surgery.

Materials and methods A group of 7 national societies (FEMECOT, AMMOM, ACOMM, SCCOT, SECOT, SEFRAOS, SEIOMM) developed a joint statement position on the diagnosis of osteoporosis and perioperative bone optimization in candidates for arthroplasty "Arthroplasty Bone Optimization." We performed a scoping review of the available literature, followed by a systematic review and meta-analysis. Subsequently, a Delphi-modified method was used to gather the different positions.

Results After analyzing the literature, we came up with five recommendations: (1) Patients scheduled for elective arthroplasty should undergo a bone health assessment (BHA). (2) If poor bone quality is observed during surgery and a bone health assessment has not been conducted promptly, a complete BHA, including a DXA scan, is imperative. (3) In the arthroplasty candidate, if LBMD or osteoporosis are noticed, bone loss–related factors should be corrected, and appropriate treatment for osteoporosis should be started before or right after arthroplasty. The use of anti-resorptive and bone anabolic agents has been shown to reduce periprosthetic bone loss, complications, and non-septic revision rates after joint arthroplasty. (4) In arthroplasty candidates, the diagnosis of osteoporosis or low bone mineral density (LBMD) should not delay the surgery. (5) Monitoring central and periprosthetic bone mineral density through DXA protocols can help identify bone loss in central and periprosthetic areas in patients with risk factors or osteoporosis.

Conclusions Perioperative bone optimization should be considered in all patients who are candidates for arthroplasty. The orthopedic surgeon and multidisciplinary team should be encouraged to diagnose and treat the arthroplasty candidates' bone by screening for bone loss-related factors and diagnosing osteoporosis and starting treatment according to the current international guidelines. Following these recommendations could reduce periprosthetic bone loss, complications, and aseptic revision rates following arthroplasty surgery. More research is needed to understand the implications of osteoporosis and its treatment for joint replacement outcomes and long-term survival.

Keywords Arthroplasty · Bone loss · Bone optimization · Osteoporosis · Revision arthroplasty

Introduction

Arthroplasty is a common and increasingly performed surgical procedure for joint diseases; the estimated prevalence of knee arthroplasties in the US rose from 0.05% in 1990 to 4.55% in 2010; for hip arthroplasties, the prevalence increase from 0.07% of the population of 50 years old and older in 1990 to 2.34% in 2010, respectively, amounting to approximately 7 million people in total [1]. The incidence of shoulder arthroplasty is also increasing and is expected to grow between 67 and 235% from 2017 to 2025 [2].

The total amount of annual total hip arthroplasty (THA) and total knee arthroplasty (TKA) in the USA are expected

Level of evidence: V.

Extended author information available on the last page of the article

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to grow by 2060, 659%, and 469%, respectively, based on 2019 volume counts of procedures [3].

Nearly two-thirds of patients undergoing elective arthroplasty procedures have low bone mineral density (LBMD), definable as osteopenia in 38.5% and osteoporosis in 24.8%; of those with osteoporosis, only 32.8% receive treatment at the time of surgery [4].

While the treatment of osteoporosis is well established and protocolized for patients with fractures as a means of secondary fracture prevention, there are currently no universal guidelines for assessing osteoporosis in candidates for arthroplasty. In recent years, evidence that defines osteoporosis as a risk factor for arthroplasty complications has emerged. However, it has not affected the perioperative osteoporosis treatment rate. In a recent investigation, 77% of orthopedic surgeons performing elective arthroplasty stated that LBMD could change their choice of implant when asked, but only 4% measured bone mineral density (BMD) preoperatively [5]. Bone quality is underestimated and undertreated prior to elective arthroplasty [6, 7].

In shoulder arthroplasty, one in three elective arthroplasty patients meet the criteria to receive osteoporosis medications, but only 20% receive therapy [8].

Furthermore, the role of osteoporosis medications in managing peri-prosthetic bone loss remains uncertain. Some meta-analyses state that antiosteoporosis medications can lower the risk of revision and periprosthetic fractures, but they neither discern the appropriate candidates or indications nor they define the appropriate treatment duration. [9–12]. Some excellent protocols and initiatives to start diagnosing and treating osteoporosis before arthroplasty also exist under the term "Bone Health Optimization" [13–15], albeit with a low evidence base.

Consequently, the role of LBMD in periprosthetic bone loss (PPBL) after arthroplasty needs to be established, as well as the link between the LBMDs and differences in the effect of the stress shielding between patients with LBMD and those with normal bone density. Analyzing the impact of LBMD on arthroplasty revision and aseptic complication rates could clarify which arthroplasty patients could benefit most from anabolic or antiresorptive medications after an arthroplasty.

Therefore, it is crucial to determine whether diagnosing LBMD and performing perioperative bone optimization in candidates for joint replacement would be a practical and recommended approach to reducing PPBL, arthroplasty revision, and aseptic complication rates.

The objective is to provide evidence-based recommendations for perioperative bone optimization in arthroplasty candidates to improve patient outcomes and reduce PPBL.

Methodology

Given the potential beneficial effect of evaluating and addressing bone quality in patients undergoing arthroplasty, several Spanish-speaking scientific societies involved in bone metabolism, osteoporosis, and joint replacement surgery decided to develop a joint statement position on the diagnosis of osteoporosis and perioperative bone optimization in candidates for arthroplasty.

A group of 24 experts from seven national societies was created: AMMOM, Mexican Association of Bone and Mineral Metabolism; ACOMM, Colombian Association of Osteoporosis and Mineral Metabolism; FEMECOT, Mexican Federation of Colleges of Orthopedics and Trauma; SCCOT, Colombian Society of Orthopedic Surgery and Trauma; SECOT, Spanish Society of Orthopedic Surgery and Traumatology; SEFRAOS, Spanish Society of Osteoporotic Fractures; SEIOMM, Spanish Society of Bone and Mineral Metabolism Research, to develop the Joint Position Statement. Experts were selected based on their expertise in treating osteoporosis, performing elective hip and knee arthroplasties, and their involvement in clinical research, including twenty orthopedic surgeons, two endocrinologists, one geriatrician, and one clinical densitometrist. All experts submitted signed data privacy and conflicts of interest statements. None of the experts declared conflicts of interest regarding this research.

A comprehensive literature review was conducted, focusing on local changes in bone mineral density following arthroplasty, the presence of adverse outcomes among LBMD patients, the effect of anabolic and antiresorptive bone medications on the changes in periprosthetic bone density following arthroplasty, and the effect of anabolic and antiresorptive bone medications on the rate of revisions and aseptic complications related to arthroplasty. **A combination of search techniques was used to obtain as much information as possible.**

A scoping review of the available literature was followed by a systematic review and meta-analysis, which were registered in PROSPERO (CRD42022301231). Due to high heterogeneity in trial designs and insufficient reporting of factors influencing bone mass in most trials, we conducted a random-effects meta-analysis.

To gather comprehensive information, we employed a combination of search techniques. Initial searches were conducted in August 2022 using PubMed, Scopus, Web of Science, and ScienceDirect databases. MeSH terms proposed by the experts were utilized, and publications between 2000 and 2022 in English and Spanish were included (Table 1). The scope encompassed patients followed for at least 24 months after primary hip or knee joint replacement surgery, focusing on bone loss,

Table 1 Search strategies

Data source	Search date	Number of items	Query syntax
PubMed	10 ago 2022	139	("knee arthroplasty" OR "hip arthroplasty" OR "shoulder arthroplasty" OR "periprosthetic") AND (alendronate OR etidronate OR etidronic OR Risedronate OR Risedronic OR Ibandronate OR Ibandronic OR Zoledronate OR Zoledronic Acid OR Pamidronate OR Pamidronic OR bisphosphonates OR biphosphonates OR Denosumab OR Teriparatide OR Abaloparatide OR Romosozumab) AND ("bone mineral density" OR "Bone mineral content" OR "bone mass" OR dxa OR dexa OR "Bone loss" OR bmd) Filters: from 2000 to 2022
Scopus	11 ago 2022	98	TITLE-ABS-KEY (("knee arthroplasty" OR "hip arthroplasty" OR "shoulder arthroplasty" OR "periprosthetic") AND (alendronate OR etidronate OR etidronic OR risedronate OR risedronic OR ibandronate OR ibandronic OR zoledronate OR zoledronic AND acid OR pamidronate OR pamidronic OR bisphosphonates OR biphosphonates OR denosumab OR teriparatide OR abaloparatide OR romosozumab OR raloxifene) AND ("bone mineral density" OR "Bone mineral content" OR "bone mass" OR dxa OR dexa OR "Bone loss" OR bmd))
Web of Science	11 ago 2022	162	ALL = (("knee arthroplasty" OR "hip arthroplasty" OR "shoulder arthroplasty") AND (alendronate OR etidronate OR etidronic OR Risedronate OR risedronicum OR Ibandronate OR Ibandronic OR Zoledronate OR Zoledronic Acid OR Pamidronate OR pamidronat OR bisphosphonates OR bisphosphonates OR Denosumab OR Teriparatide OR Abaloparatide OR Romosozumab OR Raloxifene) AND ("bone mineral density" OR "Bone mineral content" OR "bone mass" OR dxa OR dexa OR "Bone loss" OR bmd OR "periprosthetic"))
ScienceDirect	11 ago 2022	88	Title, abstract, or author-specified keywords: (arthroplasty OR periprosthetic) AND (bisphosphonates OR alendronate OR zoledronate OR Denosumab OR Teriparatide OR Abaloparatide OR Romosozumab)

osteoporosis, low bone mineral density, aseptic complications, revision rates, and anti-osteoporotic medications. Additionally, an exhaustive search was conducted using digital tools such as "LitMaps," "Research Rabbit," and "Elicit" to identify related studies not captured in the initial database search. Relevant studies not found in the initial search were identified through the reference lists of retrieved reviews and meta-analyses.

All experts actively reviewed the analysis results. Upon identifying gaps in the literature, the research team adopted a Delphi approach [16] following the guidelines for conducting and reporting a Delphi method [16–18].

After analyzing the literature review and meta-analysis results, the survey's statements were defined, and the steps mentioned in (Table 2) were completed**.** The replies were given through an online platform and were blinded to the research team. The final 54 closed questions questionnaire had three answering options: (a) agree, (b) partially agree, and (c) disagree. The threshold for expert agreement on a given statement was over 70%. Statements without an agreement below the 70% threshold were not included in the statements.

For the given recommendations and statements, all available evidence in the search fingings were considered, together with the last (International Society for Clinical Densitometry) ISCD 2023 recommendations for adult Bone Mineral Density Testing [19].

Results and recommendations

Recommendation 1: Patients scheduled for elective arthroplasty should undergo a bone health assessment (BHA)

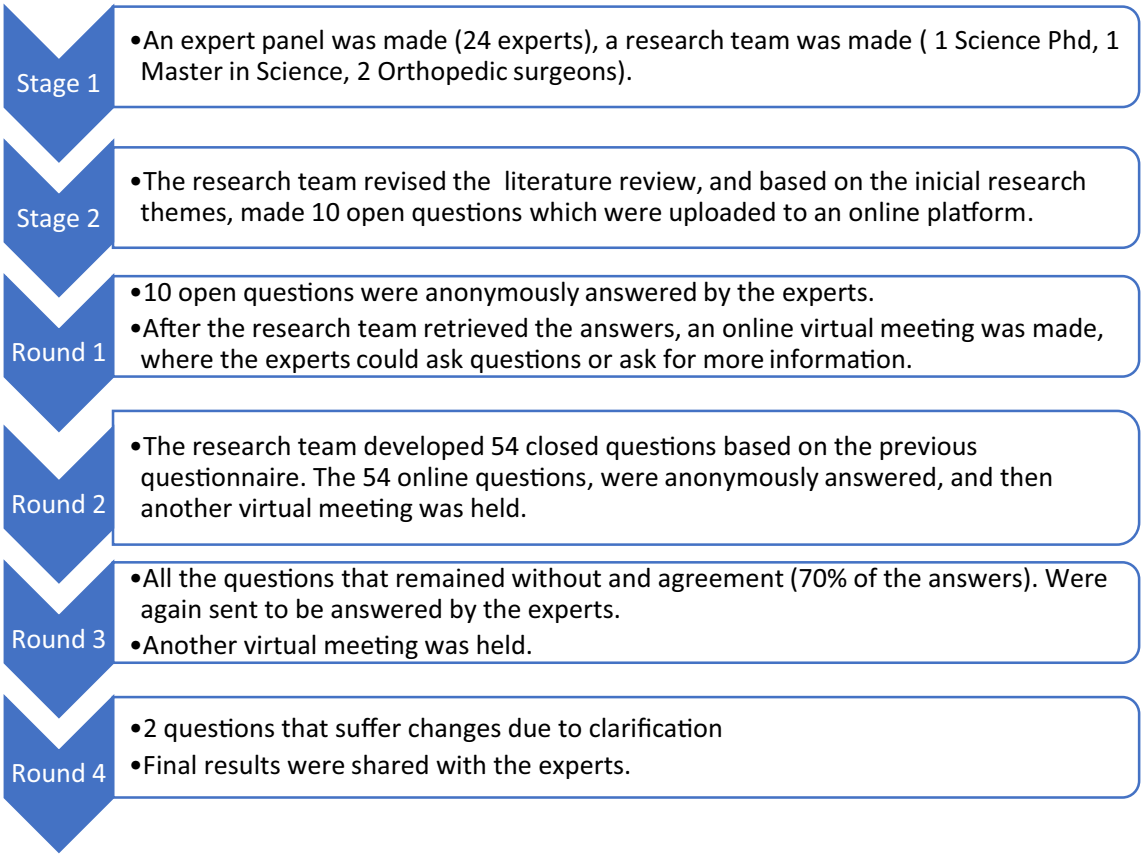
Experts' agreement: 100%

This assessment should evaluate risk factors and clinical signs of osteoporosis and low bone quality. Additionally, a bone mineral density (BMD) DXA scan should be performed for those with one or more risk factors for osteoporosis, meeting ISCD or regional indications for DXA testing.

A growing body of evidence supports that osteoporosis results in more frequent complications and revision rates following arthroplasty. Osteoporosis has been associated with multiple complications in arthroplasty, such as component malposition, periprosthetic fractures, subsidence, delayed osteointegration, and aseptic loosening [4, 5, 13, 15, 20]. Therefore, all arthroplasty candidates should be assessed for factors associated with bone loss and impairment of bone quality.

Caps et al. analysed a cohort of 17,287 patients, comparing osteoporotic and non-osteoporotic patients, to investigate the association between LBMD and

Table 2 Delphi phases and rounds



arthroplasty complications in shoulder arthroplasties and found that the presence of osteoporosis increased the likelihood of periprosthetic fracture (OR 1.86 (IC 1.49–2.32, $P = 0.001$)), dislocation (OR 1.16 (IC 0.96–1.34, $P = 0.138$)), and revision rates (OR 1.42 (IC 1.26–1.6, $P = 0.005$)) [21].

Andrew B Harris et al. performed a nationally based study in the USA including 418,054 patients. Of these, 41,760 (10%) of which had osteoporosis. The 5-year incidence of revision surgery was examined for all causes.

Osteoporosis was independently associated with PJI and aseptic loosening at a higher rate in obese patients. Patients with osteoporosis had a higher 5-year rate of revision surgery for all causes (HR 1.1, 95% CI 1.0 to 1.2), and the risk of revision was even higher for PPF (HR 1.8, 95% CI 1.6 to 2.1). After controlling for age, sex, and comorbidities, patients who had osteoporosis have a nearly twofold increased risk of 5-year revision for PPF after TKA [22].

Periprosthetic fractures (PPF) have also been described as an opportunity to diagnose and treat osteoporosis [23]. However, osteoporosis should ideally be treated before PPF occurs. Paul S Whiting et al. [24] analyzed a case series of 115 PPF fractures and found that before the fracture 67% of the patients with PPF could have been diagnosed with osteoporosis before the fracture occurred. However, only 26% had received anti-osteoporosis treatment before the fracture.

An extensive clinical history must be carried out; this must include familiar history and personal risk factors associated with bone loss and impairedbone quality; therefore, it is essential to explore lifestyle factors such as alcohol abuse, active or passive smoking, high salt consumption, immobilization, lack of adequate physical activity, deficient protein intake, and low calcium intake; endocrine disorders such as diabetes mellitus (type 1 and 2), hyperparathyroidism, thyrotoxicosis, early menopause (< 40 years), Cushing's syndrome; rheumatological and autoimmune diseases such as rheumatoid arthritis, systemic lupus; gastrointestinal disorders such as celiac disease, pancreatic disease, primary biliary cirrhosis, bariatric surgery; and use of medications such as corticosteroids, aromatase inhibitors, proton pump inhibitors, anticonvulsants (e.g., phenobarbital, phenytoin, valproate), androgen deprivation therapy, among others.

DXA scans, including the lumbar spine and hip, should be considered in all *women aged 65 or older*, *men* 70 or older [25–29], and women and men younger than 65 and 70 if they have a risk factor for low bone mass such as low body weight, prior fracture, high-risk medication use

(e.g., exposed to chronic corticosteroids (≥ 5 mg/day for three or more months of treatment)), disease or condition associated with bone loss or high risk of fracture [30, 31].

Forearm distal third BMD is recommended when the spine or the hip is inaccessible, and in those awaiting shoulder arthroplasty, bone density should be measured using forearm DXA in the distal third of the radius [32].

Lab tests and other paraclinical procedures must be carried out according to each patient's clinical condition, and they must include those intended to evaluate the metabolic condition that potentially impacts bone metabolism.

In patients having hip replacement surgery, preoperative planning can detect further patients in whom preoperative DXA testing can be obtained may be indicated, such as those with a Dorr C femoral classification or a CC (canal to calcar isthmus ratio) of more than 0.75 measured comparing the inner cortical width at the isthmus level (10 cm below the lesser trochanter) and the metaphyseal level (inner cortical width at the mid lesser trochanter level) [33].

In patients undergoing proximal humerus arthroplasty, The deltoid tuberosity index (DTI), can be applied, which is the ratio between the outer cortical and inner endosteal diameter measured immediately above the upper end of the deltoid tuberosity, where the outer cortical borders become parallel. [34]. The DTI strongly correlates with the proximal humerus BMD ($r = 0.80$; 95% CI, 0.63–0.90; $P = 0.001$). Using a cutoff value of less than 1.4 of DTI, has a sensitivity of 0.88 and a specificity of 0.80 to detect low BMD at the proximal humerus. [34]. DTI also has a significant correlation with the hip (correlation with the hip ($r = 0.549$, $P < 0.001$), and spine BMD ($r = 0.461$, $P < 0.019$), and total ($r = 0.555$, $P < 0.001$) T-scores, having a correlation coefficient 0.69 [35, 36].

Furthermore, knowledge of a patient's bone density can influence surgical planning, implant choice, type of fixation, or surgical technique to minimize the risk of implant-related complications. Hip arthroplasty in patients with a Dorr type C femur (CC more than 0.75) correlated with an increased risk of periprosthetic fractures, subsidence, or stem loosening in uncemented stems; thus, using a cemented stem and doing a bone health complete assessment are strongly recommended in these patients [33, 37–39].

Measurement of the trabecular bone score (TBS) should be obtained in patients with comorbidities that can cause further deterioration of the trabecular bone structure, such as diabetes [4, 5, 13, 15].

Recommendation 2: If poor bone quality is observed during surgery and a bone health assessment has not been conducted promptly, a complete BHA, including a DXA scan, is imperative

Experts' agreement:71.4%

In some cases, bone quality can be readily distinguished during surgery, highlighting the possibility of low bone mineral density (LBMD). However, despite visible signs of LBMD during surgery, this condition is often overlooked, and no further action is taken (Fig. 1).

Some studies have evaluated surgeons' perceptions of vertebral bone strength using an Intraoperative Physician Assistant (IPA) approach during posterior thoracolumbar surgeries. In these studies, participants provided intraoperative feedback, and each patient's bone quality was graded on a 5-point Likert scale. The surgeon assessment of bone correlated with VBQ ($\tau = 0.15$, $P = 0.07$), CT HU ($\tau = -0.31$, $P < 0.01$), lowest DXA T-score ($\tau = -0.47$, $P < 0.01$), and

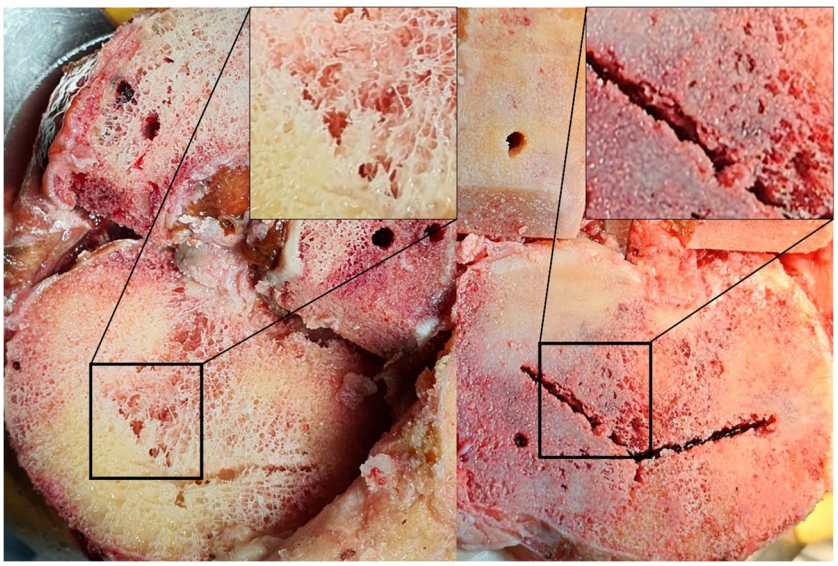


Fig. 1 Difference in bone quality observed during knee arthroplasty. Left image: osteoporotic proximal tibia bone arthroplasty cut, of a patient with a femoral neck T-score of − 5.9 measured by DXA. Right image: healthier proximal tibial bone cut, of a patient with a femoral neck T-score of − 1.2 measured by DXA

TBS ($\tau = -0.23$, $P = 0.06$) [40]. This gives a statistical significance to the surgeon's bone feeling during surgery.

Another study of 70 patients in TKA compared the intraoperative physician assessment (IPA) of the bone in TKA to distal femur BMD and hip and spine T-scores in a scale of 1–5, where lower IPA vaules correlates with bad bone quality during surgery. With a mean value was 2.74, and no osteoporotic patient had IPA above 2.74, and IPA correlated with the lowest T-score ($R = 0.511$) and distal femur BMD ($R = 0.603$–0.661) [41]. Another retrospective study comparing IPA and proximal femur T-scores in patients undergoing THA showed similar results, making IPA the only grading measuring our feeling when broaching or reaming the bone during arthroplasty [42].

Along with IPA, some other indicators highlight the possibility of low bone mass and the necessity for further investigation: thin cortical bone, poor screw purchase, soft bone texture, unintended intraoperative fractures, difficulty achieving stable fixation, and significant bone cavities after reaming.

Therefore, to ensure early detection and treatment of osteoporosis, it is highly recommended that patients suspected intraoperatively of having poor bone quality undergo a DXA scan and a complete bone health assessment (BHA).

Recommendation 3: In the arthroplasty candidate, if LBMD or osteoporosis are noticed, bone loss–related risk factors should be corrected, and appropriate treatment for osteoporosis should be started before or right after arthroplasty

Experts' agreement: 90.5%

The use of anti-resorptive and bone anabolic agents has been shown to reduce periprosthetic bone loss, complications, and non-septic revision rates after joint arthroplasty.

Periprosthetic bone loss and its contributing factors

Periprosthetic bone mineral density (PPBMD) decreases significantly within the first 24 months following hip and knee joint replacements, particularly in metaphyseal regions [49–52]. This PPBL has been attributed to stress shielding and is influenced by implant characteristics, fixation methods, implant stability, surgical technique, and patient-related factors. These factors include increased age, low bone mass, comorbidities, use of osteotoxic medications, alcohol abuse, smoking, and a sedentary lifestyle, all of which can affect implant-related complications and revision rates.

Studies measuring PPBL via quantitative computed tomography (qCT) and dual-energy X-ray absorptiometry (DXA) have reported substantial losses in specific areas. For example, the metaphyseal lateral proximal femur experienced up to 22.1% bone loss, while the medial side showed a 16.2% reduction. Mean femoral cortical density decreased by 15.5% at the medial calcar after 1 year, and acetabular cancellous BMD dropped by up to 30% after 3 years [49–52]. Around the knee, PPBL reached 15.8% at 12 months and persisted for up to 24 months, especially in metaphyseal regions [53].

Despite the growing evidence, most studies fail to report preoperative BMD, osteoporosis status, or bone loss-associated factors, limiting the ability to evaluate the relationship between osteoporosis and PPBL. This gap underscores the need for preoperative bone health assessment and targeted interventions in arthroplasty candidates.

Impact of antiosteoporosis treatment on periprosthetic bone loss

Several studies have examined the role of antiosteoporosis treatment in mitigating PPBL. However, the design of clinical trials varies widely.

We conducted a random-effects meta-analysis of 29 studies involving 1182 adult patients with elective total hip arthroplasty (THA), in which patients were followed up for at least 24 months and had at least two periprosthetic bone mineral density (BMD) DXA scans. Given the lack of control or description of various factors in most studies, we adjusted for heterogeneity in our analysis. After a full review text, our study comprised 1182 adult patients: 614 who underwent elective total hip arthroplasty (THA) and received postoperative antiosteoporosis treatment and 568 controls.

Our meta-analysis revealed a consistent trend of BMD reduction in Gruen zones among untreated patients, with significant effect sizes supporting the efficacy of antiosteoporosis therapies in preserving periprosthetic BMD across specific zones. Notably, in Gruen Zones 1, 2, 5, 6, and 7, antiresorptive treatments were associated with statistically significant BMD preservation at multiple time points during the 24-month follow-up period, However, this effect was inconsistent across the entire duration (Fig. 2). In Zones 1 and 2, a notable decrease in bone loss rate was observed within the first 12 months post-surgery ($d = 0.82$, 95% CI 0.45–1.20; $d = 0.72$, 95% CI 0.80–1.35), although this effect diminished by 18 months. As illustrated in the subgroup analysis, this decrease in effect may be partly due to the small number of trials with follow-up periods longer than 12 months (Fig. 3).

We observed high heterogeneity among the included studies ($I^2 = 69\%$), likely due to variations in study design, baseline osteoporosis status, and preoperative BMD at the lumbar spine and hip. A funnel plot (Fig. 4) was used to

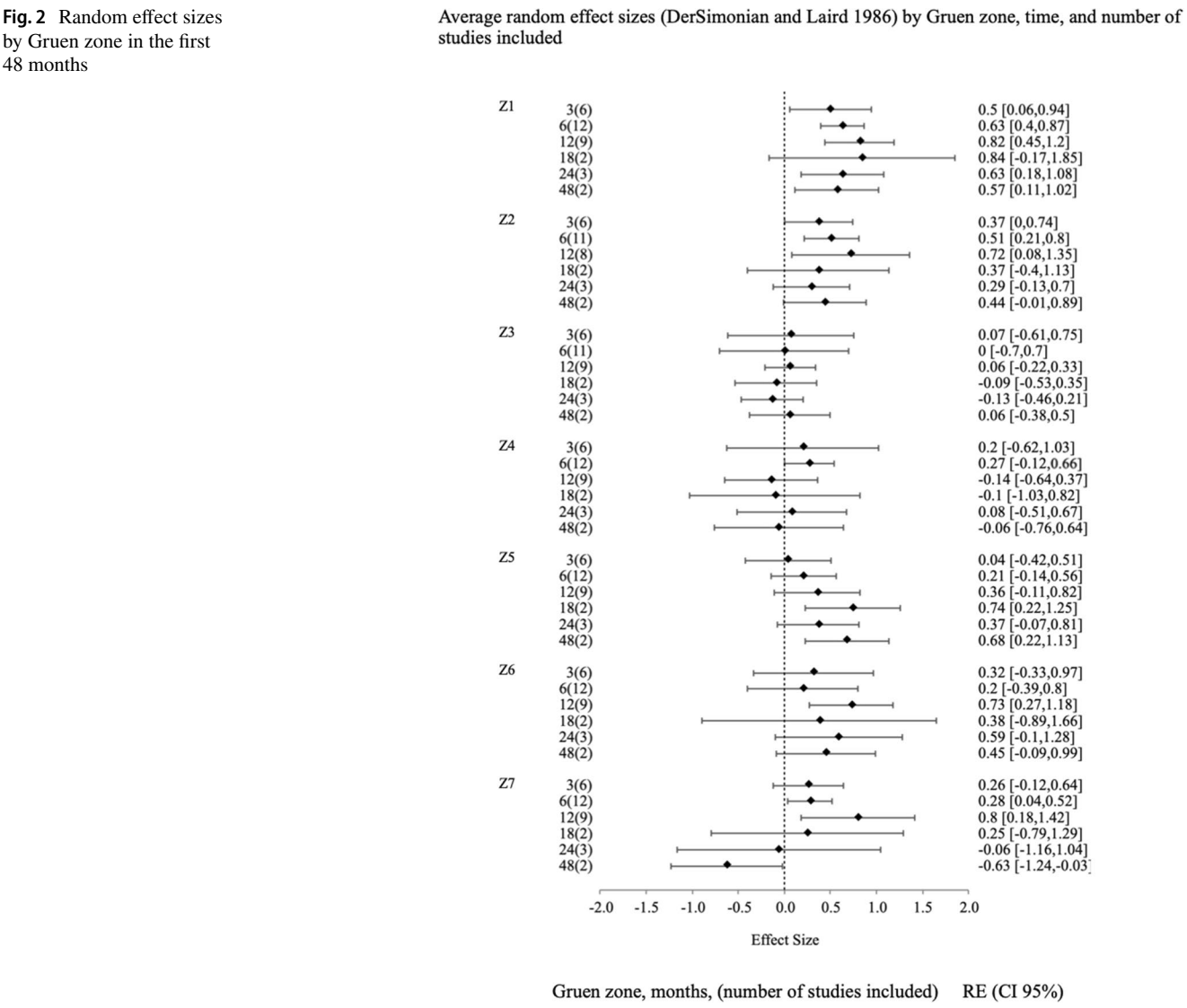


Fig. 2 Random effect sizes by Gruen zone in the first 48 months

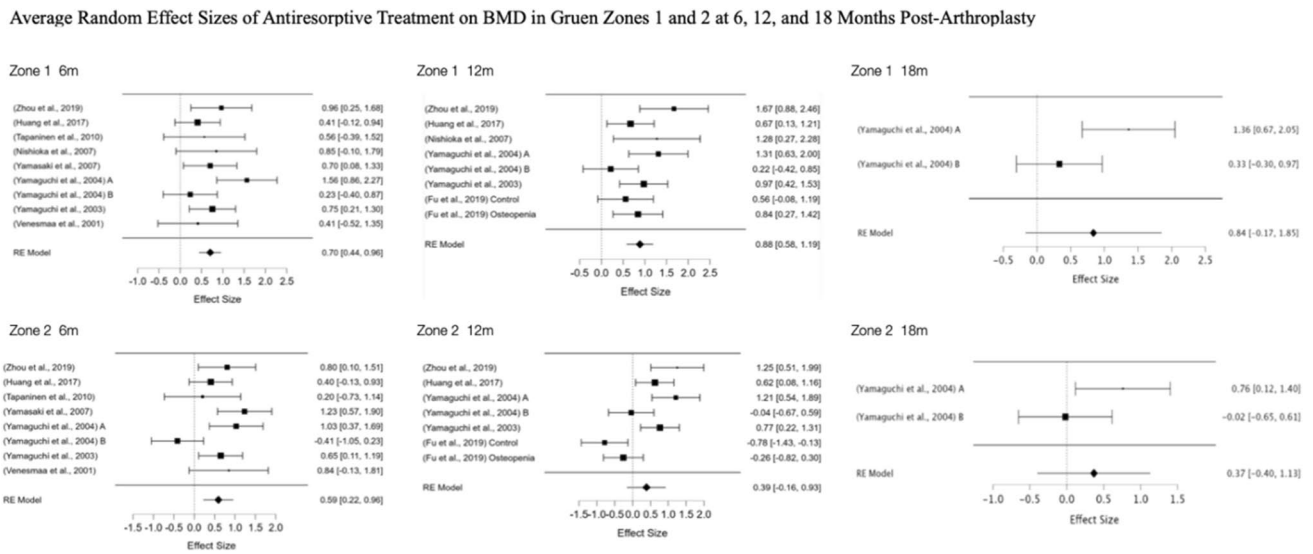
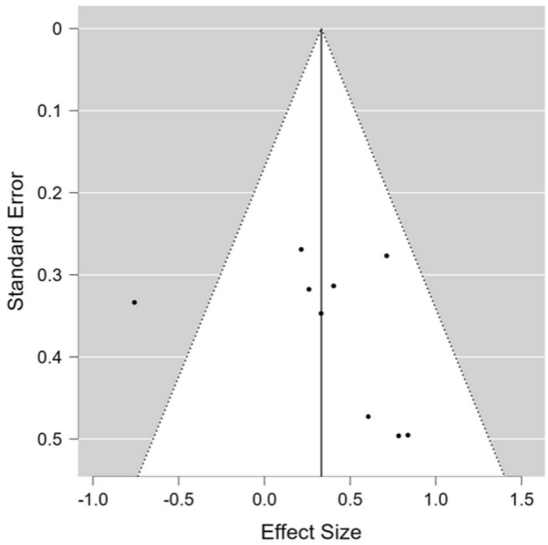


Fig. 3 Forest plot showing the effect size by Gruen zone



Heterogeneity of effect sizes for antiresorptive treatment on bone loss in Gruen Zone 7
There is some spread of data points across the x-axis (effect size), which could indicate heterogeneity in the effect sizes. This variability might result from differences in study designs, patient characteristics, or variations in how antiresorptive treatments were administered.

Fig. 4 Example of the high heterogeneity between the different studies

assess potential publication bias, revealing a broad distribution of effect sizes that may limit the generalizability of the findings.

Additionally, inconsistent documentation of baseline patient characteristics and differences in protocols for measuring periprosthetic BMD contributed to this heterogeneity.

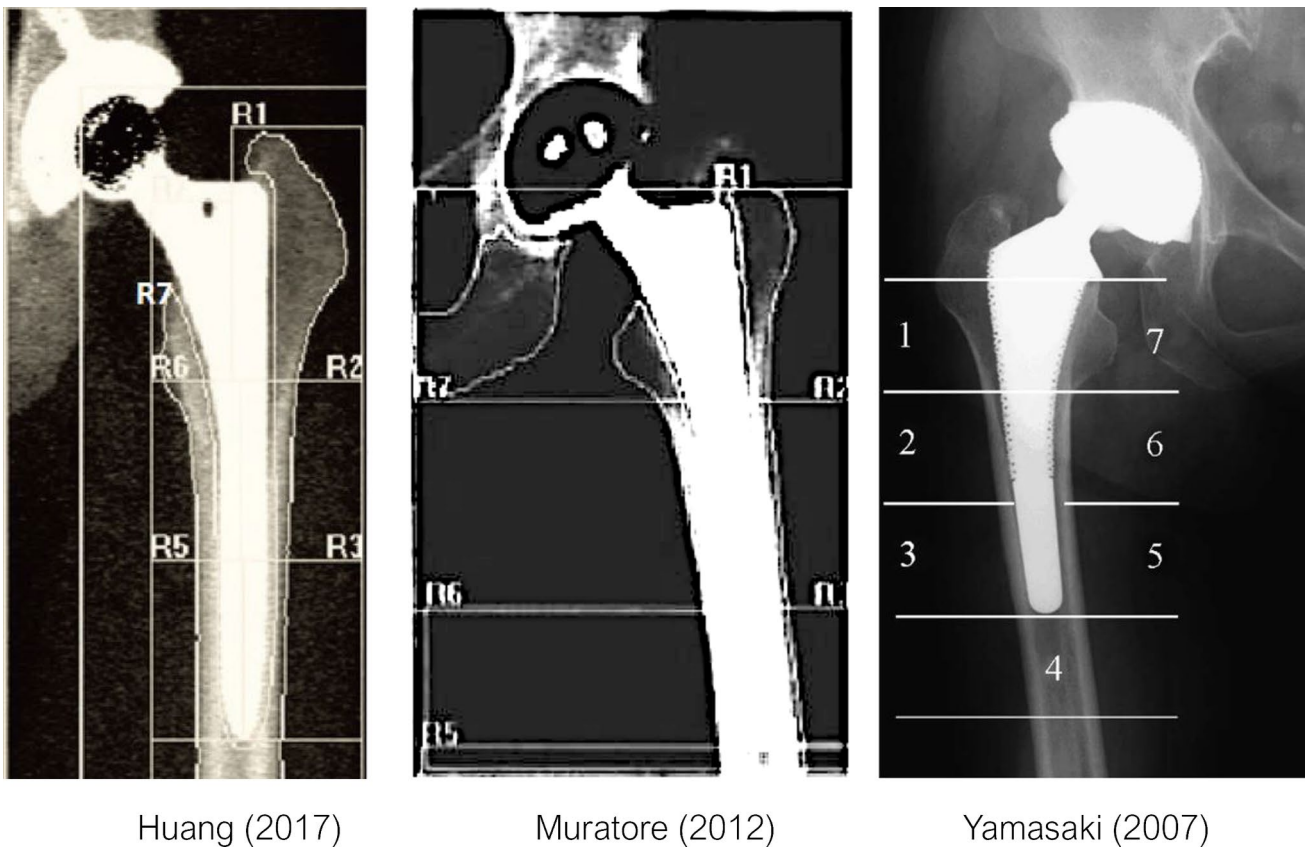


Fig. 5 Differences in periprosthetic DXA measurement protocols

For example, we observed significant variations in the regions of interest (ROI) and techniques used to acquire and analyze periprosthetic DXA scans. Representative DXA images (Fig. 5) highlight these protocol differences, likely influencing the study results [54–56].

Different placements of the Gruen zones in the proximal femur peri-prosthetic DXA scans were used in the studies cited, especially for Zones 1 and 7. These differences make the interstudy comparison challenging or even inappropriate [54–56].

Standardization will help ensure the results are comparable and reliable, allowing for a more accurate interpretation of the findings. Implementing standardized protocols for data acquisition, analysis, and reporting is crucial to enhancing the reproducibility of the results across different studies.

Clinical implications of antiresorptive and anabolic treatments after a joint arthroplasty

Antiresorptive and bone anabolic agents are recommended in patients with medical indications for treating osteoporosis and other bone fragility conditions. Additionally, evidence suggests that antiresorptive therapies (e.g., bisphosphonates) reduce implant-related complications and reduce revision rates. Therefore, assessing bone density preoperatively and addressing any underlying bone health issues can improve surgical outcomes and reduce the risk of implant-related complications.

Along with the review, we studied the effect of the use of antiresorptive medications on revision or complication rates following joint replacement, including five studies (Table 3), with 447,117 patients who had undergone hip and knee

Table 3 Bisphosphonate use after arthroplasty and its impact on revision rates at 24 months

Research article	Joint	Outcome	Number of patients	Groups	Number of revision cases	Revision risk	Relative risk (IC 95%)
Ro et al., 2019 Bisphosphonates (BP) Type: Prospective	Knee	All cause revisión	Total 331,660 Male = 39,349 Female = 292,311	BP users = 75,919 Non-BP users = 25,5741	Total = 8447 BP users = 1064 Non-BP users = 7383	All patients = 2.55% BP users = 1.40% Non-BP users = 2.89%	0.49 (0.43–0.54)
Ro et al., 2019 Bisphosphonates Type: Prospective	Hip	All-cause revision	Total 56,043 Male = 30,361 Female = 25,682	BP users = 5756 Non-BP users = 50,287	Total = 2851 BP users = 162 Non-BP users = 2689	All patients = 5.09% BP users = 2.81% Non-BP users = 5.35%	0.50 (0.38–0.64)
Namba et al., 2016 Bisphosphonates Type: Prospective	Knee	All-cause revision	Total 34,116 Male = 12,616 Female = 21,500	BP users = 6692 Non-BP users = 27,424	Total = 800 BP users = 49 Non-BP users = 751	All patients = 2.34% BP users = 0.08% Non-BP users = 2.74%	0.41 (0.16–0.58)
Kathod et al., 2015 Bisphosphonates Type: Retrospective	Hip	All-cause revision	Total 12,878 Male = 5461 Female = 7416	BP users = 2292 Non-BP users = 10,586	Total = 259 BP users = 29 Non-BP users = 230	All patients = 2.01% BP users = 1.27% Non-BP users = 2.17%	0.49 (0.29–0.71)
Prieto-Alhambra et al., 2014 Bisphosphonates Type: Retrospective	Hip and knee	Prosthetic removal	Total 10524 Male = 2574 Female = 7950	BP users = 1558 Non-BP users = 8966	Total = 426 BP users = 27 Non-BP users = 399	All patients = 4.05% BP users = 1.73% Non-BP users = 4.45%	0.45 (0.20–0.65)
Thillemann et al., 2010 Bisphosphonates Type: Prospective	Hip	All-cause revision	Total 1896 Male = 525 Female = 1371	BP users = 201 Non-BP users = 1695	Total = 632 BP users = 72 Non-BP users = 560	All patients = 33.33% BP users = 35.82% Non-BP users = 33.04%	Unclear methodology due to group overlap

arthroplasty—92,418 (20.1%) of whom were taking bisphosphonates before and after the surgery. In patients receiving bisphosphonate therapy, the aseptic revision rate was half of those without treatment, with relative risks between 0.26 and 0.58 (95% CI 0.20–0.85) during the first 24 months after surgery, except for one study including 1896 patients (0.4% of total) including 272 (0.06%) taking bisphosphonates, in which the methodology was not transparent due to group overlap mixing case and control groups [57].

Most clinical trials with antiresorptive or anabolic treatment have a 2- to 4-year follow-up at most; after that period, treatment was dropped, leading to the rapid bone loss that occurs when discontinuing some treatments. Also, some complications, such as periprosthetic fractures, increased in the younger patients with normal BMD who received bisphosphonates after arthroplasty [58]. Consequently, the use of antiresorptive and bone former agents to prevent periprosthetic bone loss after arthroplasty in patients with normal BMD and no osteoporosis risk factors is not indicated.

Recent evidence is open to discussion; while some large nationally based series (6485 THA and 20,920 TKA) suggest that the preoperative use of bisphosphonates (BF) decreased the revision rate when compared with non-BF users (0.54 and 0.53 for THA and TKA, respectively) [59], others say that BF use could increase the risk of periprosthetic fractures in the osteoporotic patient [60, 61]. However, none of these studies considered preoperative BMD, severity of osteoporosis, number of years under bisphosphonate treatment, or the type of arthroplasty fixation. The decision to initiate osteoporosis therapy should be based on a careful assessment of the individual patient's fracture risk, bone health status, and potential benefits and risks of treatment.

Also, some other periooperative decisions can change if surgeons are aware of the diagnosis of osteoporosis beforehand, such as the type of hip stem, type of fixation and intraoperative measures to avoid fractures (e.g. clamping the bone while broaching the canal).

Recommendation 4: In arthroplasty candidates, the diagnosis of osteoporosis or low bone mineral density (LBMD) should not delay the surgery

Experts' agreement: 100%

In the arthroplasty candidate in whom osteoporosis or bone loss–related factors are diagnosed, regardless of the initiation time for osteoporosis treatment, the surgery should not be delayed.

We encourage initiating treatment preoperatively or in the first weeks after surgery, as per local and international guidelines for the diagnosis and treatment of osteoporosis [27, 28, 43, 44]. None of the available evidence showed any adverse effect of the antiresorptive medications on uncemented arthroplasty integration.

There is no evidence to recommend delaying arthroplasty surgery while waiting for the effect of anti-osteoporotic medication on bone density. This decision should be left to the interdisciplinary medical team tailored to each patient. Delaying surgery can produce more deteriorating effects on bone and muscle due to the patient's expected pain, leading to inactivity and lower workload, and joint function deteriorates with every day awaiting surgery [45]. Furthermore, the patient's perception of delaying surgery is generally negative [45]. Studies have shown patients are reluctant to delay surgery even when offered physical therapy, due to a lack of perceived efficacy in providing long-term symptom relief. [46].

The American College of Rheumatology and the American Association of Hip and Knee Surgeons recommend against delay in patients who have severe deformity or bone loss [47].

In spine surgery, some bone health optimization protocols have pointed out the importance of early osteoporosis treatment intervention in osteoporotic patients, leaving the decision of delaying surgery to the multidisciplinary team [48].

The decision to initiate osteoporosis therapy should be based on a careful assessment of the individual patient's fracture risk, bone health status, and potential benefits and risks of treatment.

In addition to pharmacologic interventions, strategies to optimize bone health in patients undergoing arthroplasty may include adequate nutrition, weight-bearing exercise, smoking cessation, and optimization of perioperative care.

Recommendation 5: Monitoring central and periprosthetic bone mineral density through DXA protocols can help identify bone loss in central and periprosthetic areas in patients with risk factors or osteoporosis

Experts' agreement: 83.3%

By comparing the results of lumbar, hip, and forearm follow-up DXA scans and PPBMD to the baseline measurement, clinicians can identify any significant changes in bone density and adjust treatment plans accordingly.

Evaluating BMD changes over time allows for prompt intervention to prevent further bone loss and reduce the risk of fractures in patients undergoing arthroplasty. Accordingly, PPBMD DXA and hip and spine DXA scans should be read for a proper evaluation.

The choice of imaging modality (e.g., DXA, CT, MRI) and its parameters can impact measurement accuracy and reliability. In PPBMD measurement, variations in the region of interest (ROI) and follow-up protocols may lead to differences in BMD values and interpretation.

Hence, standardizing acquisition and analysis protocols is imperative to ensure that the observed values accurately

reflect the evolution of the PPBMD, devoid of any influence from measurement technique noise (Fig. 6). Also, using a DXA scan to evaluate PPBMD could be more demanding in cemented hip arthroplasties.

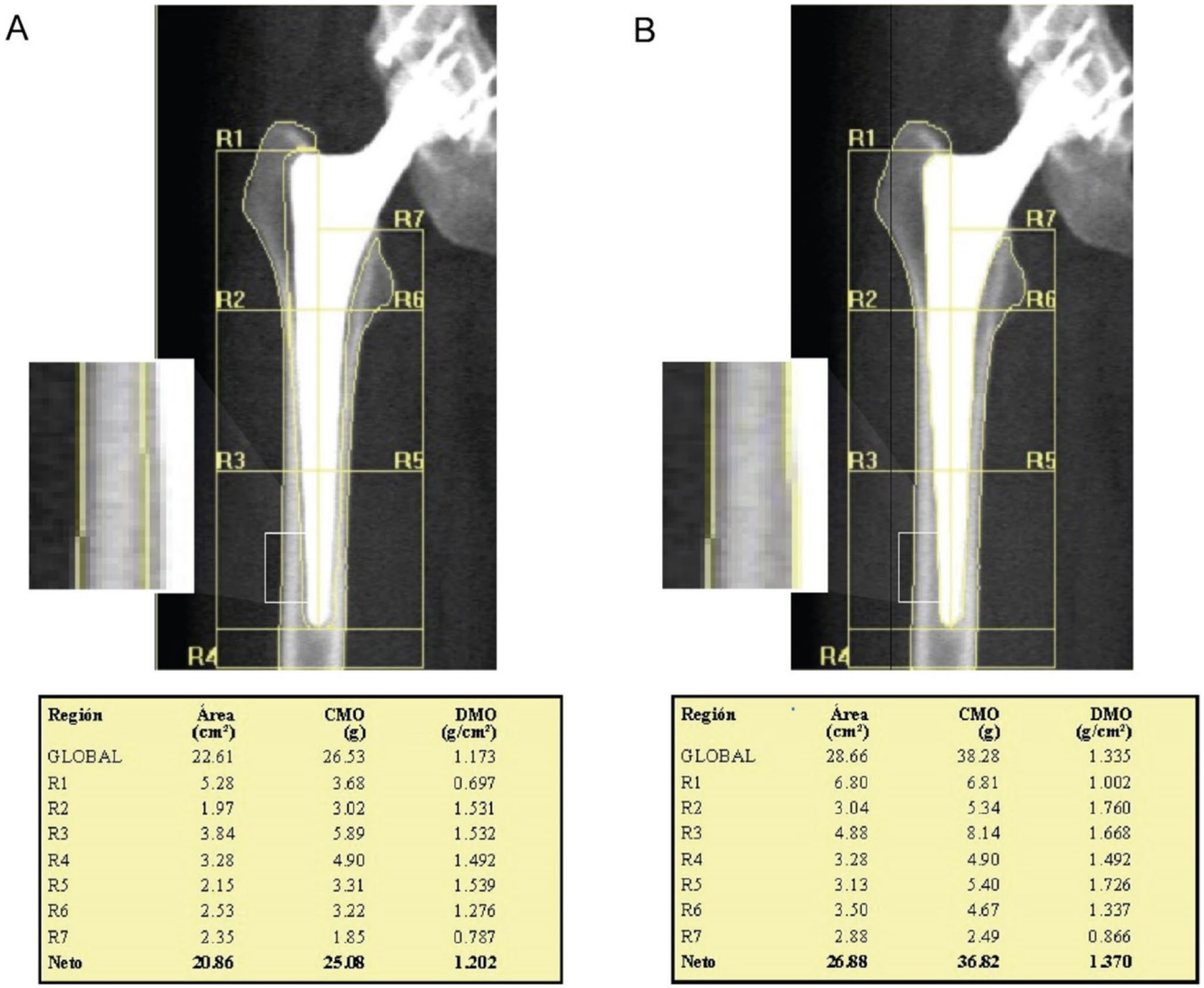
Since the BMD baseline reference point is based on the first periprosthetic DXA scan, it is recommended to take the first periprosthetic DXA in the first weeks after the surgery. The frequency of PPBMD scans remains to be determined. In the available studies, the most common protocol to track changes in bone density was to measure every 6 months for the first 2 years. However, it is necessary to consider the least significant change (LSC) for each DXA facility, which can widely differ; differences in software algorithms, analysis methods, calibration, and standardization across imaging centers can introduce variability in BMD measurements.

Future directions

We encourage arthroplasty surgeons according to the following algorithm (Fig. 7) to start diagnosing and treating osteoporosis and detecting bone loss-related factors, to have more structured evidence about perioperative bone optimization protocols in the future, and to measure the role of osteoporosis and PPBL in our patient outcomes.

The evolution of periprosthetic bone mass evaluated via DXA and other technologies can offer relevant insights into bone intervention approaches to improve outcomes.

Due to the high heterogeneity in periprosthetic DXA scans, the methods to measure periprosthetic bone density should be standardized, including protocols that consider the



Región	Área (cm²)	CMO (g)	DMO (g/cm²)
GLOBAL	22.61	26.53	1.173
R1	5.28	3.68	0.697
R2	1.97	3.02	1.531
R3	3.84	5.89	1.532
R4	3.28	4.90	1.492
R5	2.15	3.31	1.539
R6	2.53	3.22	1.276
R7	2.35	1.85	0.787
Neto	**20.86**	**25.08**	**1.202**

Región	Área (cm²)	CMO (g)	DMO (g/cm²)
GLOBAL	28.66	38.28	1.335
R1	6.80	6.81	1.002
R2	3.04	5.34	1.760
R3	4.88	8.14	1.668
R4	3.28	4.90	1.492
R5	3.13	5.40	1.726
R6	3.50	4.67	1.337
R7	2.88	2.49	0.866
Neto	**26.88**	**36.82**	**1.370**

Fig. 6 Variability in DXA acquisitions, leading to different results. Variability in the region of interest (ROI) definition during periprosthetic bone density acquisition could give different BMD results. **A** The bone edge line of the bone map is 1–2 pixels separated from the prosthesis. **B** The bone edge line of the bone map is adjacent to the prosthesis stem

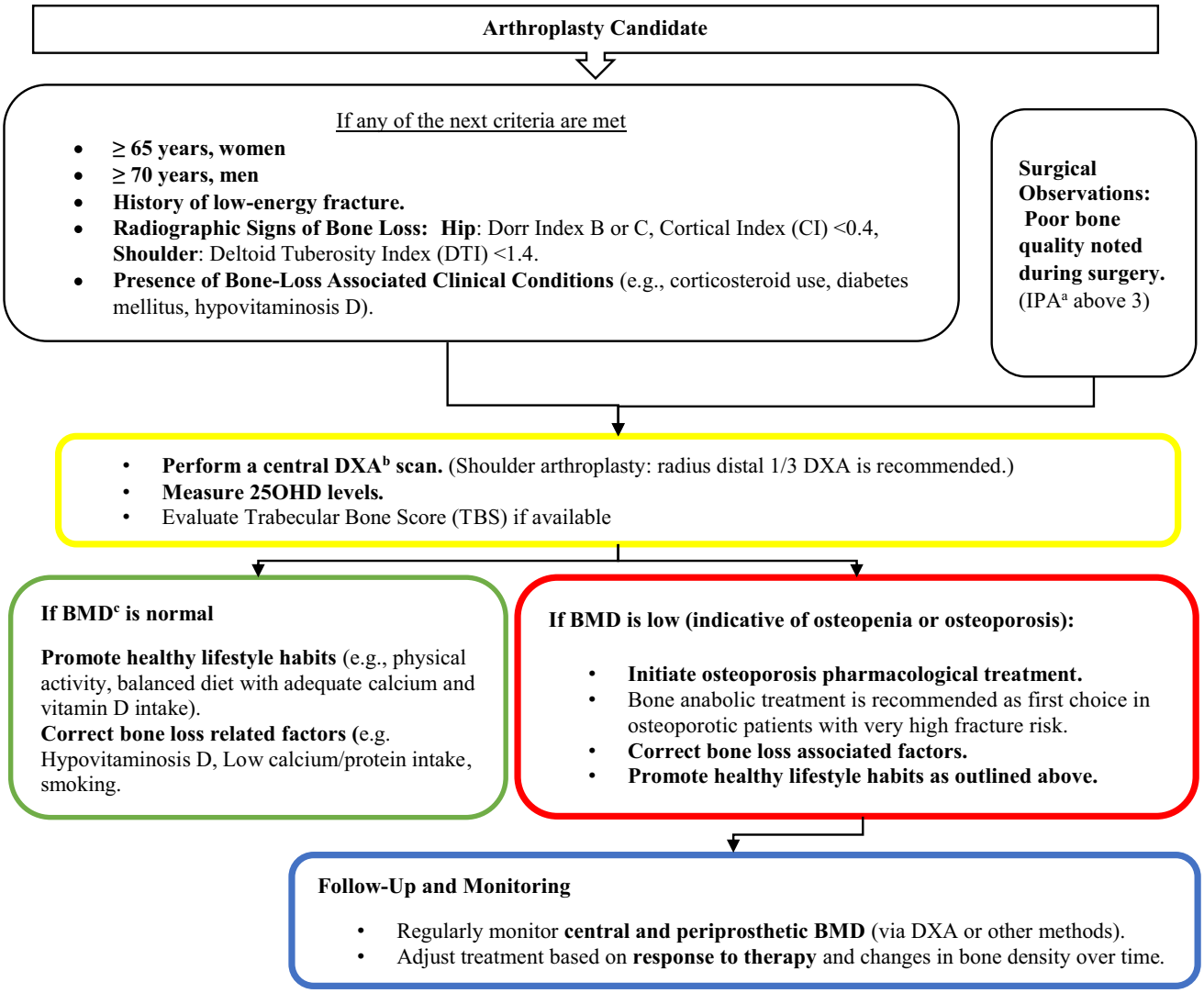


Fig. 7 Arthroplasty bone optimization algorithm. [a]IPA, intraoperative physician assessment; [b]DXA, bone density scan. [c] BMD, bone mineral density. *The treatment selection should be directed by objectives and individualized for each patient

different types of arthroplasty fixation methods, designs, and adjacent devices such as screws, cables, or other implants. We still need a standardized method to replicate this measurement in the different centers, software, and world regions.

Conclusions

Perioperative bone optimization is an approach that should be considered in all patients who are candidates for arthroplasty. We encourage the orthopedic surgeon and multidisciplinary team to diagnose and treat the arthroplasty candidate's bone by screening for bone-loss-related factors, diagnosing osteoporosis, and starting treatment according to the current international guidelines. Following these recommendations could lower PPBL, complications, and aseptic revision rates after an arthroplasty.

Several technologies, such as quantitative computed tomography, are available to assess bone mass, and they should also be explored to monitor the evolution of PPBMD.

Further research is necessary to understand the effects of osteoporosis, bone loss-related factors, and osteoporosis medications on PPBL after arthroplasty and their impact on complication rates. Following cases for extended periods will allow us to see the evolution of the periprosthetic BMD throughout the implant's lifetime. Researchers are encouraged to standardize the methodology for periprosthetic DXA analysis and register relevant variables.

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Declarations

Conflict of interest None.

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