A Novel Osteoporosis Screening Protocol to Identify Orthopedic Surgery Patients for Preoperative Bone Health Optimization

Elliot Chang, BA1, Brian Nickel, MD1, Neil Binkley, MD2, James Bernatz, MD1, Diane Krueger, BS2, Alec Winzenried, MD1, and Paul A. Anderson, MD1

Abstract

Introduction: Osteoporosis is highly prevalent in elective orthopedic surgery. While preoperative bone health optimization decreases osteoporosis-related complications, there is an unmet need to establish who may benefit from preoperative dual-energy x-ray absorptiometry (DXA). This study assesses a novel, simple screening protocol to identify orthopedic surgical patients for preoperative DXA. Materials/Methods: This retrospective cohort study included 628 patients undergoing total knee, hip, or shoulder arthroplasty or thoracolumbar spine fusion. Inclusion criteria were ≥40 years undergoing primary elective surgery. Screening criteria defining who should obtain DXA due to high osteoporosis risk included: female ≥65, male ≥70, fracture history when ≥50 years, or FRAX major osteoporotic fracture risk (without bone mineral density [BMD]-adjustments) ≥8.4%. Osteoporosis was defined by World Health Organization criteria [T-score ≤ −2.5], clinical National Osteoporosis Foundation (NOF) criteria [T-score ≤ −2.5, elevated BMD-adjusted FRAX risk, or prior hip/spine fracture], and modified clinical criteria [NOF criteria simplified to include any non-traumatic prior fracture and FRAX without BMD]. Results: The study included 100 TKAs, 100 THAs, 251 TSAs, and 177 spine fusions, average age 65.6 ± 9.8. DXA was available for 209 patients. Screening criteria recommending DXA was met by 362 patients. For those with DXA, screening sensitivity was .96 (CI: .78 to .99) and specificity was .19 (CI: .14 to .25) for identifying T-score osteoporosis. Similar sensitivity of .99 (CI: .91 to .99) and specificity of .61 (CI: .56 to .66) were found for modified clinical osteoporosis. For modified clinical osteoporosis, 192 patients with osteoporosis met criteria (true pos.), 1 patient with osteoporosis did not meet criteria (false neg.), 170 patients without osteoporosis met criteria (false pos.), and 265 patients without osteoporosis did not meet criteria (true neg.). Discussion/Conclusion: A simple screening protocol identifies orthopedic surgical candidates at risk of T-score or clinical osteoporosis for preoperative DXA with high sensitivity.

Keywords
osteoporosis, bone health screening, bone health optimization, bone mineral density, adult reconstructive surgery, metabolic bone disorders, fragility fractures, spine surgery

Submitted 4 May 2022. Accepted 11 July 2022

Introduction

Osteoporosis is highly prevalent in orthopedics and associated with poorer surgical outcomes, yet bone health assessment has not been widely incorporated into preoperative health optimization.1,2 For example, Edwards et al. recently identified ten medical conditions and lifestyle factors that should be assessed and
improved before total joint arthroplasty, ranging from morbid obesity to smoking to preoperative anemia, but bone health was not considered. This is not to say osteoporosis is not common in orthopedic patients. Up to 25% of patients undergoing elective total joint arthroplasty meet the National Osteoporosis Foundation criteria to receive pharmacologic osteoporosis treatment while 10% to 20% of patients undergoing elective spine surgery meet World Health Organization (WHO) bone mineral density (BMD) criteria for osteoporosis. With an aging population and 1.92 million total knee arthroplasty (TKA) and total hip arthroplasty (THA) procedures projected in 2030, the individual and systemic healthcare consequences of osteoporosis-related surgical complications will continue to grow.

Osteoporotic bone is more vulnerable to iatrogenic fracture during surgical fixation and manipulation, a consequence of its more brittle and less elastic mechanical properties. Similarly, osteoporosis reduces screw fixation due to lower resistance to pullout, while increasing the likelihood of implant subsidence. Postoperatively, osteoporosis increases the risk of periprosthetic fracture—a potentially catastrophic complication—along with aseptic loosening, the second most common cause of revision in TKA and THA. Overall, osteoporosis-related adverse events are associated with prolonged hospitalization, decreased overall function, and higher patient mortality. Mitigation of these complications with anti-osteoporotic treatment appears to be effective. For example, large registry reports show treatment of osteoporotic patients undergoing arthroplasty with bisphosphonates the reduces revision surgery rate by 50%. Preoperative bone health optimization is the process of identifying patients at high risk of poor bone health and, if warranted, treating these patients before surgery to reduce the likelihood of related surgical complications. While several professional societies and public health organizations have promoted guidelines to de

Current initiatives to assess bone health before elective surgery are based on opinion, rather than evidence. The 2019 ISCD positions note that research is needed to identify how to identify orthopedic patients who need BMD testing. Thus, the population which would benefit from preoperative BMD remains unclear. At our tertiary referral center, a screening protocol to determine which orthopedic surgical patients should undergo bone mineral density testing has been developed. The protocol is based on ISCD and the United States Preventive Services Task Force (USPSTF) recommendations for BMD testing then applied to the preoperative assessment of orthopedic surgical patients. This study’s objective is to determine the sensitivity and specificity of our simple screening protocol to identify orthopedic surgical patients at high risk of osteoporosis for preoperative DXA.

Methods

Subjects

A retrospective review of patients undergoing total shoulder arthroplasty (TSA), total hip arthroplasty (THA), total knee arthroplasty (TKA), and thoracolumbar spine fusion between January 1, 2011, to January 1, 2019, was performed. The study was granted an exemption by the Institutional Review Board under 45 CFR 46.102(d). Inclusion criteria were patients over age 40 undergoing primary elective surgery. Exclusion criteria were patients with any traumatic or oncologic conditions (e.g., fracture or tumor) or revision surgery. If a patient had multiple orthopedic procedures during the study period, only the first surgery was included.

Electronic medical records were reviewed for demographic information, preoperative osteoporosis risk factors, and DXA data. DXA was available in 209 patients. The lumbar spine, total proximal femur, femoral neck, and one-third distal radius T-scores were recorded.
Fracture Risk Assessment Tool

The FRAX fracture risk assessment tool uses clinical risk factors (Figure 2) with or without femoral neck BMD to calculate the 10-year probability of any major osteoporotic fracture [any fracture of the spine, hip, humerus, and/or wrist] and hip fracture. The FRAX major osteoporotic fracture 10-year risk with and without BMD was calculated for all patients.

Screening Protocol

The proposed screening protocol aimed to identify patients at high risk of osteoporosis for BMD testing before surgery and was developed from the 2019 ISCD Official Positions recommending bone health evaluation in orthopedic surgery and the 2018 USPSTF recommendation for using FRAX in osteoporosis screening.21,25 Meeting any one of the following four criteria was an indication for BMD testing: female ≥65 years, male ≥70 years, history of fracture when ≥50 years; or FRAX major osteoporotic fracture risk without BMD-adjustments ≥8.4%, Figure 1. The FRAX threshold is based on the USPSTF recommendation for osteoporosis screening and reflects the 10-year risk of major osteoporotic fracture in a 65-year-old female without other clinical risk factors.25,26

Osteoporosis Classification

The bone health of each patient with DXA available was classified using WHO criteria. Every patient both with and without DXA was also classified clinical osteoporosis and a modified clinical osteoporosis criteria. The WHO osteoporosis classification is based on T-score: ≥−1.0 = normal, <-1.0 and >=-2.5 = osteopenia and ≤-2.5 = osteoporosis.27 The clinical diagnosis of osteoporosis was based on the National Osteoporosis Foundation (NOF) definition and include meeting any one of the following three conditions: a lowest T-score ≤-2.5 at the hip, spine, or 1/3 radius; a T-score >-2.5 and <-1.0 at the hip or spine and a BMD-adjusted major osteoporotic fracture risk ≥20% or hip fracture risk ≥3%; or a history of hip or spine fracture.19 In cases without DXA available, the FRAX without BMD was utilized. A modified clinical osteoporosis model developed for this study adjusting the NOF criteria to include: T-score ≤-2.5 at the hip, spine, or 1/3 radius; a high FRAX risk with or without BMD-adjustment (≥20% MOF or ≥3% hip fracture); or a history of any low-energy fracture ≥50 years (excluding fractures of the hands and feet).

Statistical Analysis

For each patient, meeting or not meeting screening criteria along with an osteoporotic or non-osteoporotic classification determined true positives, false positives, true negatives, and false negatives. Sensitivity and specificity were calculated based on the WHO and clinical osteoporosis criteria. Demographic and comorbidity information was analyzed by calculation of mean, standard deviation, and frequency for each surgical group. Sensitivity and specificity 95% confidence intervals were calculated using Clopper-Pearson criteria. Statistical analyses were performed using Microsoft Excel (Redmond, WA). Receiver operator curve (ROC) analysis was performed to assess the optimal FRAX threshold for sensitivity and specificity considerations using IBM SPSS Statistics (Armonk, New York).

Figure 2. This algorithm illustrates how the 628 subjects were categorized based on screening indication and modified clinical osteoporosis criteria. In addition to age and fracture history, the FRAX risk factors listed were used to calculate 10-year fracture risk for screening determination.
Results

Demographic Data and FRAX Risk Factors

A total of 628 patients including 177 spine fusion patients, 100 TKA patients, 100 THA patients, and 251 TSA patients were evaluated. The mean age was 65.6 ± 9.8 years, and 339 patients (54%) were female, Supplemental Table 1.

A history of spontaneous fracture or a fracture arising from low-energy trauma at age 50+ was reported in 89 patients (14%) while 10 patients (1.6%) reported a parental history of hip fracture. Current smoking was present in 25 patients (4%) while an identical number reported alcohol consumption of three or more drinks per day. Rheumatoid arthritis was identified in 33 patients (5%) and 59 patients (9%) reported prior glucocorticoid (≥5 mg) usage.

Bone Health Status

Using WHO T-score bone health criteria in the 209 patients with DXA: 23 (11%) patients had osteoporosis, 104 (50%) had osteopenia, and 82 (39%) were classified as normal. Using the clinical diagnosis criteria, applied to all 628 patients, 114 (18%) patients had osteoporosis and 514 (82%) did not have osteoporosis. With the modified clinical osteoporosis criteria, 192 (31%) patients had osteoporosis and 436 (69%) did not have osteoporosis.

The average T-score of the spine was .21 ± 1.89, total femur −.58 ± 1.20, femoral neck −1.05 ± .97, and distal radius −.95 ± 1.31. The average lowest T-score was −1.23 ± 1.09. The mean FRAX major osteoporotic fracture risk without BMD was 9.2% ± 6.7% and hip was 2.3% ± 3.0%.

The mean FRAX major osteoporotic fracture risk with BMD was 12.1% ± 7.3% and hip was 2.4% ± 3.2%.

Screening Sensitivity and Specificity

A total of 362 of the 628 patients met screening criteria indicating BMD testing was indicated. Age criteria were met in 296 patients (199 female ≥65 years, 97 male ≥70 years), 89 had a historical fracture and 236 had high FRAX major osteoporotic fracture risk without BMD. Two or more screening criteria were met in 206 patients, Supplemental Table 2.

Using T-score criteria, the screening protocol to identify patients at high risk of osteoporosis for preoperative DXA had a sensitivity of .96 (95% confidence interval [CI]: .78-.99) and specificity of .19 (CI: .14-.25). With the clinical osteoporosis criteria, the screening protocol had a sensitivity of .99 (CI: .95-1.00) and specificity of .52 (CI: .48-.56). Finally, the modified clinical osteoporosis criteria resulted in a sensitivity of .99 (CI: .97-99) and specificity of .61 (CI: .56-.66), Figure 3, Table 1.

There were 170 false-positive screenings with the modified clinical osteoporosis criteria, 145 meeting age criteria, 83 having high FRAX risk, and 58 meeting multiple criteria. Alternately, there were 192 true-positive screenings when evaluating for modified clinical osteoporosis, 151 due to age criteria, 89 having a history of fracture ≥50 years, 153 having high FRAX risk, and 148 meeting multiple criteria.

ROC analysis revealed using a higher FRAX threshold of 13.5% would raise the specificity to .65 (CI: .61-.70) while also maintaining a sensitivity of .98 (CI: .96-1.00) when evaluating for the modified clinical diagnosis of osteoporosis (AUC = .937).

Discussion

Preoperative bone health optimization is an evolving concept in orthopedic surgery. Its fundamental goal is to improve outcomes, reduce costs, and avoid complications. The first steps in this process are screening patients for poor bone health, evaluating patients for potential diagnosis, and if warranted, treating the underlying condition before surgery. In this study, bone health screening to determine if further DXA testing was appropriate used the simple criteria of age, sex, fracture history, and fracture risk as predicted by FRAX without BMD. With these basic criteria, the screening protocol identified almost all osteoporotic patients for further bone health testing with a sensitivity approaching 1.0.

The ISCD recommends preoperative bone health assessment consideration for all patients before elective orthopedic and spine surgery as osteoporosis is common and associated with negative surgical outcomes. Osteoporosis is prevalent in 8% to 31% of THA and TKA patients and 9% to 51% of patients undergoing elective spinal surgery. In total joint arthroplasty, osteoporosis is associated with the inability to achieve optimal stem positioning, increased implant migration, implant loosening, and increased periprosthetic fracture risk. In spinal fusion, Bjerke et al. found periprosthetic fractures and screw loosening occurred in 50% of osteoporotic patients compared to 18% of patients with normal BMD.

Considering how prevalent and impactful osteoporosis is in orthopedic surgery, a simple and effective screening tool to preoperatively identify patients at high risk of osteoporosis for BMD testing can be expected to yield meaningful benefits. Identifying osteoporosis before surgery may lead to increased pharmacologic intervention, which improves bone quality, reduces surgical complications, and improves outcomes in arthroplasty and spine surgery. The use of bisphosphonates after THA and TKA lowers revision rates by half and helps maintain femur BMD while in spine fusion patients it improves fusion and clinical outcomes. Preoperative osteoporosis diagnosis may lead surgeons to delay surgery to pharmacologically improve bone health or influence decision making, such as the choice of implant type or use of cement. Likewise, knowledge of underlying bone disease may modify postoperative care to include osteoporosis management.
Several criteria were used to diagnosis osteoporosis. The WHO T-score is widely accepted but has poor sensitivity as less than half of patients having fragility fractures are osteoporotic. A modified version of the clinical osteoporosis criteria was developed in this study to create a more functional and clinically applicable definition that an orthopedic provider could use to assess a patient’s bone health without the need for BMD. In the modified clinical criteria, a high FRAX with or without BMD is sufficient for osteoporosis diagnosis. Additionally, the modified clinical criteria included all fracture history after age 50, an expansion from the clinical definition which is fracture history specific to the hip or spine. The rationale for this modification was two-fold. First, orthopedic surgeons manage a wide variety of fractures rather than just fractures of the hip or spine. Second, while most osteoporosis research and pharmaceutical trials are exclusive to hip and spine fractures, other fractures such as the distal radius, femur, and ulna predict refracture risk similar to fractures of the hip and spine. A 2019 report on osteoporosis in Medicare beneficiaries found 19% of patients with osteoporotic hip fracture and 15% with osteoporotic spine fracture had subsequent re-fracture or new fracture within 12 months, a proportion similar to those with fracture of the distal femur (18%), radius/ulna (17%), and distal radius/ulna (14%).

This study and its proposed screening protocol have several important strengths. The study included patients seeking spine, knee, hip, and shoulder surgery, the majority of elective orthopedic surgery cases, with minimal exclusion criteria, allowing a more representative evaluation of a true cross-section of all orthopedic patients. Additionally, the proposed screening protocol to determine if DXA is indicated can be performed in any orthopedic practice without extra imaging, radiation exposure, or additional cost. Most significantly, the screening protocol is largely straightforward, using only basic patient information and an established fracture risk assessment tool, FRAX, to stratify patients for DXA.

Table 1. Screening Protocol 2 x 2 Contingency Table. Screening protocol contingency tables evaluating for World Health Organization T-score, National Osteoporosis Foundation clinical osteoporosis, and modified clinical osteoporosis criteria.

|          | World Health Organization | National osteoporosis foundation | Modified national osteoporosis foundation |
|----------|---------------------------|----------------------------------|------------------------------------------|
|          | Osteoporosis (+) Osteoporosis (−) | Osteoporosis (+) Osteoporosis (−) | Osteoporosis (+) Osteoporosis (−)  |
| Screening (+) | 22                     | 117                             | 192                          |
| Screening (−) | 150                    | 245                             | 170                          |
|           |                         | 35                              | 265                          |
The proposed screening protocol is just the first step in the broader bone health optimization initiative. While the screening protocol in this study attempts to fill the crucial and unmet need to identify high-risk patients for preoperative DXA, what exactly needs to be done to best address the bone health of identified osteoporotic patients is the bulk effort of preoperative bone health optimization.

The screening protocol used in this study had a specificity ranging from 50-60% when using clinical criteria. The false-positive screenings—patients without osteoporosis who still met screening protocol criteria—occurred largely due to older age and high FRAX major osteoporotic fracture risk without BMD. While the screening protocol’s age threshold and FRAX major osteoporotic fracture risk without BMD threshold of ≥8.4% were adopted from the latest ISCD and USPSTF DXA testing recommendations, adjustments to these criteria to increase the screening protocol’s specificity are a potential area of future research. Analysis performed in this study suggests a FRAX major osteoporotic fracture risk 13.5% improve specificity while maintaining a high sensitivity. However, it should be emphasized the primary goal of this study was to determine if a simple screening protocol could identify patients at high risk of osteoporosis for preoperative DXA. Therefore, in our opinion, prioritizing high sensitivity—positively screening patients who indeed have osteoporosis—over specificity, is warranted to establish the first steps in developing an effective bone health screening protocol.

This retrospective study has several limitations. First, the patient population was primarily Caucasian and included a portion of patients with previous DXA scanning, both potential sources of selection bias. While some of patients in this study had a previous clinical indication for DXA, the observed distribution of T-score osteoporosis, osteopenia, and normal bone density is very similar to the rates established by many other studies of osteoporosis in the orthopedic patient population. A prospective study in which DXA is obtained for all study participants, regardless of clinical indication, is warranted to remove this bias. Additionally, the lack of available DXA restricted the application of T-score osteoporosis criteria. However, the modified clinical osteoporosis definition was not affected by this lack of DXA. Finally, the study’s patient population only included patients seeking primary elective surgery and excluded revision surgery. Future research studying this screening protocol’s efficacy within the revision orthopedic surgery population would help expand this preoperative tool to target those surgical patients who will likely most benefit from bone health optimization.

In conclusion, this study finds a simple screening protocol identifies orthopedic surgical candidates at risk of T-score or clinical osteoporosis who may benefit from preoperative DXA with high sensitivity.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

Supplemental Material
Supplemental material for this article is available online.

ORCID iD
Elliot Chang https://orcid.org/0000-0002-9715-8212

References
1. Anderson PA, Jeray KJ, Lane JM, Binkley NC. Bone health optimization: Beyond own the bone: AOA critical issues. Journal of Bone and Joint Surgery - American. 2019;101:1413-1419. doi:10.2106/JBJS.18.01229
2. Maier GS, Kolbow K, Lazovic D, Maus U. The importance of bone mineral density in hip arthroplasty: Results of a survey asking orthopaedic surgeons about their opinions and attitudes concerning osteoporosis and hip arthroplasty. Advances in Orthopedics. 2016;2016:1-5. doi:10.1155/2016/8079354
3. Edwards PK, Mears SC, Stambough JB, Foster SE, Barnes CL. Choices, compromises, and controversies in total knee and total hip arthroplasty modifiable risk factors: What you need to know. J Arthroplasty. 2018;33:3101-3106. doi:10.1016/j.arth.2018.02.066
4. Bernatz JT, Brooks AE, Squire MW, et al. Osteoporosis is common and undertreated prior to total joint arthroplasty. J Arthroplasty. 2019;34:1347-1353. doi:10.1016/j.arth.2019.03.044
5. Yagi M, King AB, Boachie-Adjei O. Characterization of osteopenia/osteoporosis in adult scoliosis: Does bone density affect surgical outcome? Spine. 2011;36:1652-1657. doi:10.1097/BRS.0b013e31820110b4
6. Wagner SC, Formby PM, Helgeson MD, Kang DG. Diagnosing the undiagnosed osteoporosis in patients undergoing lumbar fusion. Spine. 2016;41:E1279-E1283. doi:10.1097/BRS.0b013e31820110b4
7. Bjerke BT, Zarrabian M, Aleem IS, et al. Incidence of osteoporosis-related complications following posterior lumbar fusion. Global Spine J. 2018;8:563-569. doi:10.1177/2192568217743727
8. Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the U.S., 2014 to 2030. Journal of Bone and Joint Surgery - American. 2018;100:1455-1460. doi:10.2106/JBJS.17.01617
9. Grant KD, Busse EC, Park DK, Baker KC. Internal fixation of osteoporotic bone. J Am Acad Orthop Surg. 2018;26:166-174. doi:10.5435/JAAOS-D-16-00142
10. Della Rocca GJ, Leung KS, Pape HC. Periprosthetic fractures: Epidemiology and future projections. *J Orthop Trauma*. 2011;25:S66-S70. doi:10.1097/BOT.0b013e3182188c28

11. Capone A, Congia S, Civinini R, Marongiu G. Periprosthetic fractures: Epidemiology and current treatment. *Clinical Cases in Mineral and Bone Metabolism*. 2017;14:189. doi:10.11138/ccmb/2017.14.1.189

12. Bhattacharyya T, Chang D, Meigs JB, Estok DM, Malchau H. Mortality after periprosthetic fracture of the femur. *Journal of Bone and Joint Surgery - Series A*. 2007;89:2658-2662. doi:10.2106/JBJS.F.01538

13. Shields E, Behrend C, Bair J, Cram P, Kates S. Mortality and financial burden of periprosthetic fractures of the femur. *Geriatric Orthopaedic Surgery & Rehabilitation*. 2014;5:147-153. doi:10.1177/215145851452281

14. Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total hip arthroplasty in the united states. *Journal of Bone and Joint Surgery - Series A*. 2009;91:128-133. doi:10.2106/JBJS.H.00155

15. Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total knee arthroplasty in the united states. In: *Clinical Orthopaedics and Related Research*; 2010. doi:10.1007/s11999-009-0945-0

16. Teng GG, Curtis JR, Saag KG. Mortality and osteoporotic fractures: Is the link causal, and is it modifiable? *Clin Exp Rheumatol*. 2008;26:S125-S137.

17. Ro DH, Jin H, Park JY, et al. The use of bisphosphonates after joint arthroplasty is associated with lower implant revision rate. *Knee Surg Sports Traumatol Arthrosc*. 2019;27:2082-2089. doi:10.1007/s00167-018-5333-4

18. Cosman F, de Beur SJ, LeBoff MS, Lewiecki EM, Tanner B, Randall S, et al. Clinician’s guide to prevention and treatment of osteoporosis. *Osteoporos Int*. 2014;25:2359-2381. doi:10.1007/s11019-014-2794-2

19. Camacho P, Petak S, Binkley N, Diab D, Eldieri L, Farooki A. American association of endocrinologists/ American college of endocrinology clinical practice guidelines for the diagnosis and treatment of postmenopausal osteoporosis-2020 update. *Endocr Pract*. 2020;26:1-46.

20. U.S. Preventive Services Task Force. *Screening for osteoporosis: Recommendation Statement*. American family physician; 2011.

21. Anderson PA, Morgan SL, Krueger D, et al. Use of bone health evaluation in orthopedic surgery: 2019 ISCD official position. *J Clin Densitom*. 2019;22:517-543. doi:10.1016/j.jocd.2019.07.013

22. Morris MT, Tarpada SP, Tabatabaie V, Cho W. Medical optimization of lumbar fusion in the osteoporotic patient. *Archives of Osteoporosis*. 2018;13:26. doi:10.1007/s11657-018-0427-7

23. Stone MA, Jakoi AM, Iorio JA, et al. Bisphosphonate’s and intermittent parathyroid hormone’s effect on human spinal fusion: A systematic review of the literature. *Asian Spine Journal*. 2017;11:484-493. doi:10.4184/asj.2017.11.3.484

24. Maggs J, Wilson M. The relative merits of cemented and uncemented prostheses in total hip arthroplasty. *Indian J Orthop*. 2017;51:377-385. doi:10.4103/ortho.IJOrihplasty-405_16

25. Curry SJ, Krist AH, Owens DK, et al. Screening for osteoporosis to prevent fractures us preventive services task force recommendation statement. *J Am Med Assoc*. 2018;319(24):2521-2531. doi:10.1001/jama.2018.7498

26. Kanis JA, Johansson H, Harvey NC, McCloskey EV. A brief history of FRAX. *Archives of Osteoporosis*; 2018. 10.1007/s11657-018-0510-0

27. Czerwiński E, Badurski JE, Marcinowska-Suchowierska E, Osieleniec J. Current understanding of osteoporosis according to the position of the World Health Organization (WHO) and International Osteoporosis Foundation. *Ortopedia Traumatologia Rehabilitacja*; 2007.

28. Mäkinnen TJ, Alm JJ, Laine H, Svedström E, Aro HT. The incidence of osteopenia and osteoporosis in women with hip osteoarthritis scheduled for cementless total joint replacement. *Bone*. 2007;40:1041-1047. doi:10.1016/j.bone.2006.11.013

29. Chang CB, Kim TK, Kang YG, Seong SC, Kang SB. Prevalence of osteoporosis in female patients with advanced knee osteoarthritis undergoing total knee arthroplasty. *J Kor Med Sci*. 2014;29:1425. doi:10.3346/jkms.2014.29.10.1425

30. Ishii Y, Noguchi H, Sato J, Takayama S, Toyabe S. Preoperative bone mineral density and bone turnover in women before primary knee arthroplasty. *Open Orthop J*. 2016;10:382-388. doi:10.2174/1874325001610010382

31. Schmidt T, Ebert K, Rolvien T, et al. A retrospective analysis of bone mineral status in patients requiring spinal surgery. *BMC Musculoskel Disord*. 2018;19:53. doi:10.1186/s12891-018-1970-5

32. Chin DK, Park JY, Yoon YS, et al. Prevalence of osteoporosis in patients requiring spine surgery: Incidence and significance of osteoporosis in spine disease. *Osteoporos Int*. 2007;18:1219-1224. doi:10.1007/s00198-007-0370-8

33. Aro HT, Alm JJ, Moritz N, Mäkinnen TJ, Lankinen P. Low BMD affects initial stability and delays stem osseointegration in cementless total hip arthroplasty in women: A 2-year RSA study of 39 patients. *Acta Orthop*. 2012;83:107-114. doi:10.3109/17453674.2012.678798

34. Hailer NP, Garellick G, Kärholm J. Uncemented and cemented primary total hip arthroplasty in the Swedish hip arthroplasty register: Evaluation of 170,413 operations. *Acta Orthop*. 2010;81:34-41. doi:10.3109/17453671003685400

35. Teng S, Yi C, Krettek C, Jagodzinski M. Bisphosphonate use and risk of implant revision after total hip/knee arthroplasty: A meta-analysis of observational studies. *Plos One*. 2015;10(10):1-13. doi:10.1371/journal.pone.0139927

36. Bhandari M, Bajammal S, Guyatt GH, et al. Effect of bisphosphonates on periprosthetic bone mineral density after total joint arthroplasty: A meta-analysis. *Journal of Bone and Joint Surgery - Series A*. 2005;87:293-301. doi:10.2106/JBJS.D.01772
37. Buerba RA, Sharma A, Ziino C, Arzeno A, Ajiboye RM. Bisphosphonate and teriparatide use in thoracolumbar spinal fusion. *Spine*. 2018;43:E1014-E1023. doi:10.1097/brs.0000000000002608

38. Siris ES, Chen YT, Abbott TA, et al. Bone mineral density thresholds for pharmacological intervention to prevent fractures. *Arch Intern Med*. 2004;164(10):1108-1112. doi:10.1001/archinte.164.10.1108

39. Bazell C, Hansen D, Pamela Pelizzari BP. Medicare costs for osteoporosis-related fractures. *PharmacoEcon Outcomes News*. 2019;839(1):26. doi:10.1007/s40274-019-6307-6

40. Shin YH, Hong WK, Kim J, Gong HS. Osteoporosis care after distal radius fracture reduces subsequent hip or spine fractures: A 4-year longitudinal study. *Osteoporos Int*. 2020;31:1471-1476. doi:10.1007/s00198-020-05410-3