



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

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Elliot Chang, BA<sup>1</sup> , Brian Nickel, MD<sup>1</sup>, Neil Binkley, MD<sup>2</sup>, James Bernatz, MD<sup>1</sup>, Diane Krueger, BS<sup>2</sup>, Alec Winzenried, MD<sup>1</sup>, and Paul A. Anderson, MD<sup>1</sup>

## 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  $\geq 40$  years undergoing primary elective surgery. Screening criteria defining who should obtain DXA due to high osteoporosis risk included: female  $\geq 65$ , male  $\geq 70$ , fracture history when  $\geq 50$  years, or FRAX major osteoporotic fracture risk (without bone mineral density [BMD]-adjustments)  $\geq 8.4\%$ . Osteoporosis was defined by World Health Organization criteria [T-score  $\leq -2.5$ ], clinical National Osteoporosis Foundation (NOF) criteria [T-score  $\leq -2.5$ , 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  $65.6 \pm 9.8$ . 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

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## 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.<sup>1,2</sup> For example, Edwards et al. recently identified ten medical conditions and lifestyle factors that should be assessed and

<sup>1</sup>Department of Orthopedics Surgery and Rehabilitation, University of Wisconsin UWMF Centennial Bldg, Madison, WI, USA

<sup>2</sup>University of Wisconsin School of Medicine and Public Health Osteoporosis Clinical Research Program, Madison, WI, USA

### Corresponding Author:

Elliot Chang, BA, Department of Orthopedics Surgery and Rehabilitation, University of Wisconsin UWMF Centennial Bldg, 1685 Highland Ave, 6th Floor Madison, WI 53705-2281, USA.  
Emails: [anderson@ortho.wisc.edu](mailto:anderson@ortho.wisc.edu), [echang34@wisc.edu](mailto:echang34@wisc.edu)



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improved before total joint arthroplasty, ranging from morbid obesity to smoking to preoperative anemia, but bone health was not considered.<sup>3</sup> 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.<sup>4-7</sup> 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.<sup>8</sup>

Osteoporotic bone is more vulnerable to iatrogenic fracture during surgical fixation and manipulation, a consequence of its more brittle and less elastic mechanical properties.<sup>9</sup> Similarly, osteoporosis reduces screw fixation due to lower resistance to pullout, while increasing the likelihood of implant subsidence.<sup>9</sup> 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.<sup>10-15</sup> Overall, osteoporosis-related adverse events are associated with prolonged hospitalization, decreased overall function, and higher patient mortality.<sup>16</sup> 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%.<sup>17</sup>

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, Figure 1. While several professional societies and public health organizations have promoted guidelines to define which patients should have bone density screening for primary

preventative treatment of osteoporosis, it is still performed in less than 25% of eligible patients for whom dual-energy x-ray absorptiometry (DXA) is recommended.<sup>18-20</sup> Recently, the International Society for Clinical Densitometry (ISCD) released updated position statements emphasizing the need for expanded bone density testing before elective orthopedic surgery.<sup>21</sup> The goal is to identify patients who are likely osteoporotic so further risk stratification and treatment can be performed. Ultimately, early identification could lead to optimization of bone health preoperatively, thereby decreasing revision surgery, avoiding periprosthetic bone loss, and decreasing subsidence.<sup>22,23</sup> Additionally, preoperative knowledge of a patient's poor bone health has been shown to guide a surgeon's surgical planning, such as the use of cemented over uncemented prosthesis.<sup>2,24</sup>

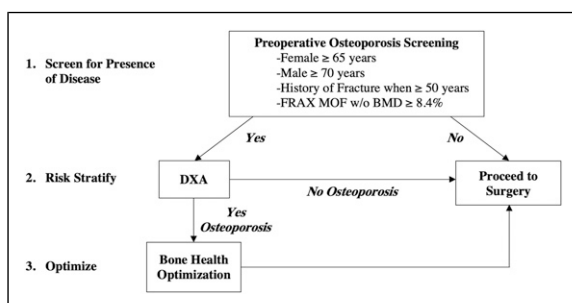
Current initiatives to assess bone health before elective surgery are based on opinion, rather than evidence. The 2019 ISCD positions note that research is needed to identify how to identify orthopedic patients who need BMD testing. Thus, the population which would benefit from preoperative BMD remains 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.<sup>21,25</sup> 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.



**Figure 1.** This algorithm outlines the proposed preoperative bone health optimization initiative, including criteria for DXA testing and how to apply results in surgical planning.

## 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.<sup>21,25</sup> Meeting any one of the following four criteria was an indication for BMD testing: female  $\geq 65$  years, male  $\geq 70$  years, history of fracture when  $\geq 50$  years; or FRAX major osteoporotic fracture risk without BMD-adjustments  $\geq 8.4\%$ , 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.<sup>25,26</sup>

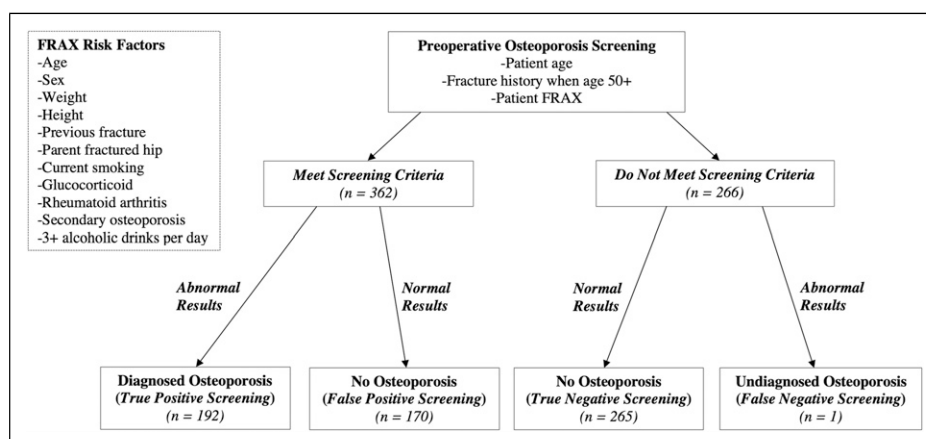
## Osteoporosis Classification

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:

$\geq -1.0$  = normal,  $< -1.0$  and  $> -2.5$  = osteopenia and  $\leq -2.5$  = osteoporosis.<sup>27</sup> 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  $\leq -2.5$  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  $\geq 20\%$  or hip fracture risk  $\geq 3\%$ ; or a history of hip or spine fracture.<sup>18</sup> 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  $\leq -2.5$  at the hip, spine, or 1/3 radius; a high FRAX risk with or without BMD-adjustment ( $\geq 20\%$  MOF or  $\geq 3\%$  hip fracture); or a history of any low-energy fracture  $\geq 50$  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  $65.6 \pm 9.8$  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 ( $\geq 5$  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  $.21 \pm 1.89$ , total femur  $-.58 \pm 1.20$ , femoral neck  $-1.05 \pm .97$ , and distal radius  $-.95 \pm 1.31$ . The average lowest T-score was  $-1.23 \pm 1.09$ . The mean FRAX major osteoporotic fracture risk without BMD was  $9.2\% \pm 6.7\%$  and hip was  $2.3\% \pm 3.0\%$ . The mean FRAX major osteoporotic fracture risk with BMD was  $12.1\% \pm 7.3\%$  and hip was  $2.4\% \pm 3.2\%$ .

### 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  $\geq 65$  years, 97 male  $\geq 70$  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  $\geq 50$  years, 153 having high FRAX risk, and 148 meeting multiple criteria.

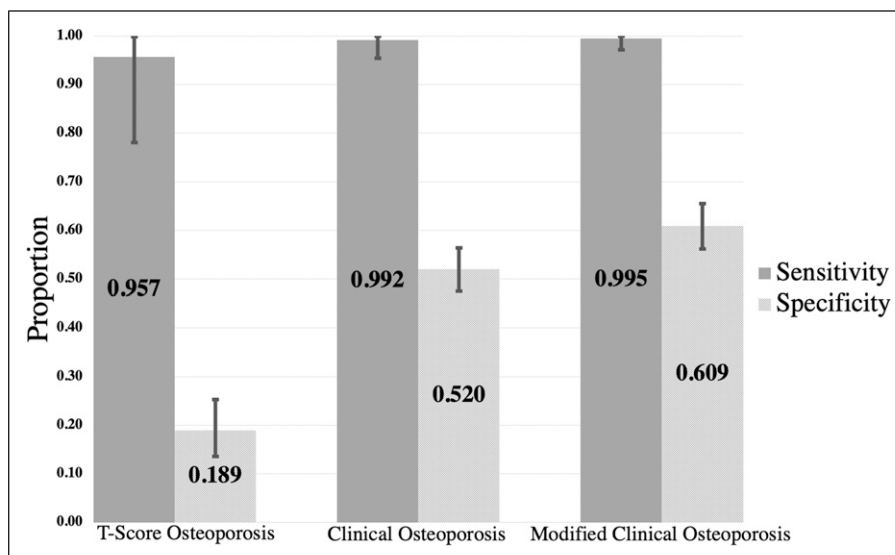
ROC analysis revealed using a higher FRAX threshold of 13.5% would raise the specificity to .65 (CI: .61-.70) while also maintaining a sensitivity of .98 (CI: .96-1.00) when evaluating for the modified clinical diagnosis of osteoporosis (AUC = .937).

## 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.<sup>21,28-32</sup> 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.<sup>33,34</sup> 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.<sup>7</sup>

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.<sup>21</sup> 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.<sup>35,36</sup> 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.<sup>35-37</sup> 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.<sup>2,24</sup> Likewise, knowledge of underlying bone disease may modify postoperative care to include osteoporosis management.



**Figure 3.** Screening protocol sensitivity and specificity when evaluating for World Health Organization T-score (n = 209), National Osteoporosis Foundation clinical osteoporosis (n = 628), and modified clinical osteoporosis criteria (n = 628). (\*Error lines represent 95% confidence intervals as calculated by Clopper-Pearson criteria.)

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.<sup>38</sup> The clinical diagnosis of osteoporosis is an improvement by including fracture history, and fracture risk. However, this includes only hip and spine fractures.<sup>18</sup> 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.<sup>39,40</sup> A 2019 report on osteoporosis in Medicare beneficiaries found 19% of patients with osteoporotic hip fracture and 15% with osteoporotic spine fracture had subsequent refracture 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%).<sup>39</sup>

This study and its proposed screening protocol have several important strengths. The study included patients seeking spine, knee, hip, and shoulder surgery, the majority

**Table I.** 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.

n = 209	World Health Organization	
	Osteoporosis (+)	Osteoporosis (-)
Screening (+)	22	150
Screening (-)	1	35

n = 628	National osteoporosis foundation	
	Osteoporosis (+)	Osteoporosis (-)
Screening (+)	117	245
Screening (-)	1	265

n = 628	Modified national osteoporosis foundation	
	Osteoporosis (+)	Osteoporosis (-)
Screening (+)	192	170
Screening (-)	1	265

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.

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  $\geq 8.4\%$  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.<sup>21,25</sup> 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.<sup>21,28–32</sup> 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

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## Supplemental Material

Supplemental material for this article is available online.

## ORCID iD

Elliot Chang  <https://orcid.org/0000-0002-9715-8212>

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