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Primary Hip and Knee Arthroplasty

Total Joint Arthroplasty and Osteoporosis: Looking Beyond the Joint to Bone Health

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ABSTRACT

Background: Metabolic bone diseases in the total joint arthroplasty (TJA) population are undertested and undertreated, leading to increased risk of adverse outcomes such as periprosthetic fractures. This study aims to better characterize the current state of bone care in TJA patients using Fracture Risk Assessment Tool (FRAX) score risk stratifications.

Methods: In total, 505 consecutive TJA patients who meet the Endocrine Society guidelines for osteoporosis screening were included for review. They were divided into a high risk or low risk group depending on FRAX scores and were compared based on screening, diagnosis, and treatment of metabolic bone disease. Logistic regression models were used to analyze factors influencing screening and treatment. A population analysis involving 2,000 TJA patients, and a complication analysis involving 40 periprosthetic fracture patients were conducted.

Results: Among high risk patients undergoing TJA, 90% did not receive any pharmacological treatment for osteoporosis, 45% were not treated with vitamin D or calcium, and 88% did not receive bone density testing in the routine care period. Among patients with pre-existing osteoporosis undergoing TJA, 80% were not treated with any osteoporosis medications and 33% of these patients were not taking vitamin D or calcium. Female gender and past fracture history contributed to whether patients received screening and treatment. Patients with periprosthetic hip fractures have significantly higher FRAX scores compared to control THA patients.

Conclusion: There are significant gaps in metabolic bone care of the geriatric TJA population regarding both screening and treatment. Metabolic bone care and risk identification with FRAX should be highly considered for TJA patients.

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are among the most common orthopedic procedures in the United States [1]. Osteoporosis is a major risk factor for arthroplasty surgery-related complications including intraoperative fractures, aseptic loosening, and postoperative periprosthetic fractures [2]. Importantly, the incidence of osteoporosis is high in total joint arthroplasty (TJA) patients with 1 study estimating that up to 36.7% of well-functioning TKA patients have osteoporosis and up to 28% of patients undergoing THA have osteoporosis [3,4]. Patients undergoing TJA have an additional increased risk for osteoporosis-related complications due to postoperative bone loss, with studies estimating up to 20% bone loss following TJA around the surgical site [5,6].

There is some evidence suggesting that pharmacologic treatment could reduce bone loss post-TJA [7–10]. In a recent large retrospective cohort study, Ro et al [11] found that among 331,660 TKA patients, those who took bisphosphonates had a significantly lower revision rate compared to untreated patients (1.5% versus 2.9%). Similarly, THA patients who took bisphosphonates also had lower revision rates compared to those without treatment (2.8% versus 5.3%) [11]. A prior meta-analysis in 2015 also showed similar results with a roughly 50% reduction in revision rates when treated with bisphosphonates [12].

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Although osteoporosis is common among the TJA population and studies suggest that treatment is effective, osteoporosis in this population is likely to be underdiagnosed and undertreated, despite official guidelines recommendations [13–17]. A 2018 American Orthopaedic Association (AOA) survey showed that only 10% of surgeons reported regularly measuring bone mineral density (BMD) despite 78% of surgeons indicating that osteoporosis would influence surgical decision making [18]. One study by Bernatz et al [13] demonstrated underutilization of dual-energy X-ray absorptiometry (DXA) scans in the preoperative period and lack of medication up to 6 months postoperatively. However, the prevalence of osteoporosis screening and treatment for TJA patients as well as the risk profiles of the patients and the roles of the arthroplasty surgeons in patients' metabolic bone care are still understudied. To address this, our study looked at the metabolic bone care of TJA patients in 2 different risk groups across a wide time range. We hypothesize that there are significant gaps in metabolic bone care in the TJA population in terms of both screening and treatment. We will also test the utility of the Fracture Risk Assessment Tool (FRAX) to identify the TJA patients at highest risk of requiring medical intervention.

Methods

A population survey including age, diagnosis of osteoporosis/osteopenia, periprosthetic fractures, and screening eligibility was performed on 2,000 adult patients (500 of each male TKA, female TKA, male THA, female THA) who received surgery at a single tertiary-care center between January and March 2019.

Retrospective chart reviews were conducted on 505 consecutive THA and TKA patients (250 THAs, 255 TKAs). These patients were a subset of the patients included in the population survey above. They were chosen consecutively based on their time of surgery starting from January 1, 2019 with the earliest 250 THA and 255 TKA surgeries included. The inclusion criteria included any patient over the age of 50 with primary THA or TKA from the population survey who satisfied the Endocrine Society screening guidelines which recommends osteoporosis screening for all females above age 65, all males above age 70, and everyone age above 50 with a history of low energy fracture. Exclusion criteria included patients under the age of 50 or have a history of cancer. The study was not powered as it was designed to elucidate a clearer picture regarding the current state of metabolic bone care in THA and TKA patients and was not designed to show correlation. A convenience sample size of 505 was selected to provide better statistical significance and broader representation of the population compared to prior studies looking at osteoporosis in the TJA population, which had sample sizes of 100-300 patients [3,13,16,19].

Demographic variables including age, gender, race, and ethnicity, medical history of metabolic bone disease, previous fractures, risk factors, postsurgical complications, DXA records, and osteoporosis medication use were collected through a retrospective chart review of the electronic medical record (EMR). For each patient, data were collected for both the routine care period and the surgical period. The routine care period was defined as any time before the time of admission for surgery. The surgical period was defined as 1 year following the admission for surgery. For each follow-up visit during the surgical period, medication changes, additional DXA scans, and complications were recorded. For patients who have records of DXA scans, the results and the dates of the DXA scans were extracted to determine prior diagnosis of osteoporosis and osteopenia. Patients were classified as treated for osteoporosis if they are taking any of the following: hormones for the treatment of osteoporosis, bisphosphonates, estrogen agonist, denosumab, parathyroid hormone analogs, romosozumab, or calcitonin. Calcium or vitamin D (VD) usage was recorded separately and did not count toward osteoporosis medications.

The FRAX score was used to determine patients' risks for developing fractures. FRAX scores were calculated with BMD (if available) or without BMD using the race-specific US databases. The patients were categorized as having either high risk or low risk of developing osteoporosis-related complications according to the FRAX score. High risk was defined as having a >20% 10-year risk of major osteoporotic fracture or >3% 10-year risk of hip fracture. This criterion was selected because it is the established standard FRAX cutoff for initiating osteoporosis treatment according to the American Association of Endocrinology [20].

Additionally, FRAX scores and osteoporosis screening eligibility of 40 THA patients who had periprosthetic hip fractures in the past 2 years were extracted through review of the EMR using the same guidelines and cutoffs described above.

The study was approved by the institution's Institutional Review Board. Study data were collected using REDCap [21,22]. This study was not supported by external funding.

Statistical Analysis

The mean and standard deviations of demographic variables and FRAX scores were calculated and compared between the high risk versus the low risk group and the periprosthetic fracture group versus THA patients without periprosthetic fractures using 2-sample *t*-tests. Chi-squared tests were performed on categorical values including DEXA screening, osteoporosis-related medication usage, VD and calcium usage, and diagnosis of osteoporosis/osteopenia. Multivariable logistic regressions were performed to determine the effects of demographic variables and risk factors on DXA screening, osteoporosis medication usage, and VD/calcium usage for both the routine and surgical periods. For the regressions, race and ethnicity was simplified to whether the patient was White or non-White. Alpha was set to 0.05 for all tests. Statistical analysis was performed using Matlab 2021a.

Results

Demographics and Risks

The population characteristics of 2,000 patients are summarized in Table 1.

In total, 214 patients were categorized as low risk and 291 patients were categorized as high risk. The high risk group was significantly more likely to be female ($P < .001$) and have a significantly lower BMI ($P < .001$). The racial and ethnic distribution of the high risk group was significantly different from the low risk group (Table 2).

Bone Density Testing

During the routine care period, 7.5% of the low risk group and 12.4% of the high risk group received at least 1 DXA scan ($P = .074$). During the surgical period, 0.5% of the low risk group and 2.4% of the high risk group received at least 1 DXA scan ($P = .085$) (Fig. 1, Table 3). For those who have received DXA scans, the average time from the most recent routine care period scan to the date of the operation was 3.0 and 3.5 years for the low and high risk groups, respectively ($P = .140$) (Table 3).

Pharmacological Treatment

During the routine care period, 2.3% of the low risk group and 8.9% of the high risk group received an osteoporosis medication

Table 1
Population Characteristic.

Gender	Surgery	Age (y), Mean ± SD (Range of Age)	Osteoporosis Diagnosis by Prior DXA (%)	Osteopenia Diagnosis by Prior DXA (%)	% Meeting Endocrine Society Screening Guideline	Surgery-Related Periprosthetic Fracture (%)
Male	TKA	65.66 ± 9.43 (24-91)	4.4	3.8	35.8	0.6
Female	TKA	67.20 ± 9.09 (26-89)	22	16.2	62.6	0.4
Male	THA	62.45 ± 11.14 (20-94)	4.4	4.4	27.6	0.2
Female	THA	65.54 ± 10.57 (27-91)	26	16	57	0.8

n = 500 for each combination of gender and surgery. Osteoporosis/osteopenia diagnosis: patients with a prior diagnosis of osteoporosis/osteopenia in the EMR at the time of surgery. Surgery-related periprosthetic fracture: percentage of patients with documented periprosthetic fracture related to their arthroplasty surgery at the time of chart review.
SD, standard deviation; DXA, dual-energy X-ray absorptiometry; THA, total hip arthroplasty; TKA, total knee arthroplasty; EMR, electronic medical record.

($P = .005$), while 51.9% of the low risk group and 53.6% of the high risk group received VD and/or calcium ($P = .700$). During the surgical period, 0.9% of the low risk group and 4.5% of the high risk group received an osteoporosis medication ($P = .021$), while 50.9% of the low risk group and 55.3% of the high risk group received VD and/or calcium ($P = .328$) (Fig. 2, Table 3).

Diagnosis of Osteoporosis and Osteopenia

Overall, 19.8% (n = 100) of all patients had a diagnosis of osteoporosis on file and 12.1% (n = 61) had a diagnosis of osteopenia on file. The high risk group was significantly more likely to have a diagnosis of osteoporosis (28.2% versus 8.4%, $P < .001$) and osteopenia (13.7% versus 9.8%, $P < .001$) when compared to the low risk group. Medical intervention rates, VD and calcium treatment rates, and DXA screening rates of patients based on metabolic bone diagnosis are summarized in Table 4.

Adjusted Analysis—Multivariate Logistic Regression

Multivariate logistic regression shows that when adjusted for all other demographic and risk factors, history of previous fractures significantly increases the probability of receiving osteoporosis medications during both the routine care ($P < .001$) and surgical period ($P = .005$), female sex significantly increases the probability of receiving VD or calcium during both the routine care ($P = .026$) and surgical period ($P = .010$) as well as the probability of receiving DXA scan during the routine care period ($P = .004$) (Table 5).

Complications

There was a total of 5 (1%) periprosthetic fractures and 4 (0.8%) revision surgeries in the study population across the 1-year surgical period with no significant differences between the 2 groups.

Forty THA patients with periprosthetic fractures in the past 2 years were identified through chart review. Patients with periprosthetic fractures had significantly higher FRAX scores compared to the population of 250 chart reviewed THA patients (major osteoporotic fracture risk 18.73% ± 11.54% versus 15.03% ± 7.94%, $P = .012$; hip fracture risk 8.25% ± 8.3% versus 5.28% ± 4.65%, $P = .001$). Both male and female periprosthetic fracture patients had higher FRAX scores compared to their nonfracture counterparts. Comparisons of characteristics of periprosthetic fracture patients versus THA patients without periprosthetic fractures are shown in Table 6.

Discussion

Osteoporosis is a common and growing concern in the United States [23], and it is a particularly relevant diagnosis for patients undergoing arthroplasty as it can increase the risk of complications. There is increasing evidence suggesting that osteoporosis is

Table 2
N, Age, Gender, Race, Ethnicity, BMI, FRAX Risk Factors, FRAX Scores of High Versus Low Risk Group.

Variables of Interest	Risk Group		
	Low Risk	High Risk	*P* Value
N (%)	214 (42%)	291 (58%)	
Mean age (y), mean ± SD	70.1 ± 4.3	75.5 ± 5.5	.401
Gender, n (%)			**<.001**
Male	79 (37%)	40 (14%)	
Female	135 (63%)	251 (86%)	
Race and ethnicity			**<.001**
White non-Hispanic	172 (80%)	280 (96%)	
Hispanic	22 (10%)	5 (2%)	
Black	12 (6%)	3 (1%)	
Asian	8 (4%)	3 (1%)	
BMI, mean ± SD	32.2 ± 6.5	26.9 ± 5.0	.59
Previous fractures, n (%)	27 (13%)	113 (39%)	**<.001**
Parent hip fracture, n (%)	0	6 (2%)	.346
Currently smoking, n (%)	2 (1%)	4 (1%)	.652
Glucocorticoid use, n (%)	0	9 (3%)	**.010**
Rheumatoid arthritis, n (%)	12 (6%)	31 (11%)	**.045**
Alcohol use of ≥3 units/d, n (%)	0	1 (<1%)	.391
FRAX major (10 y %risk)	8.5 ± 3.1	19.1 ± 7.3	**<.001**
FRAX hip (10 y %risk)	1.9 ± 0.7	7.3 ± 4.8	**<.001**

Previous fractures: a previous low-energy fracture in adult life; parent hip fracture: history of hip fracture in either parent; glucocorticoid use: current use of oral glucocorticoid or has been exposed to oral glucocorticoids for more than 3 mo at a dose of prednisolone of 5 mg daily or more (or equivalent doses of other glucocorticoids); rheumatoid arthritis: confirmed diagnosis of rheumatoid arthritis; alcohol use 1 unit = 1 drink as documented by physicians; *P*-values <.05 are bolded.
BMI, body mass index; FRAX, Fracture Risk Assessment Tool; SD, standard deviation.

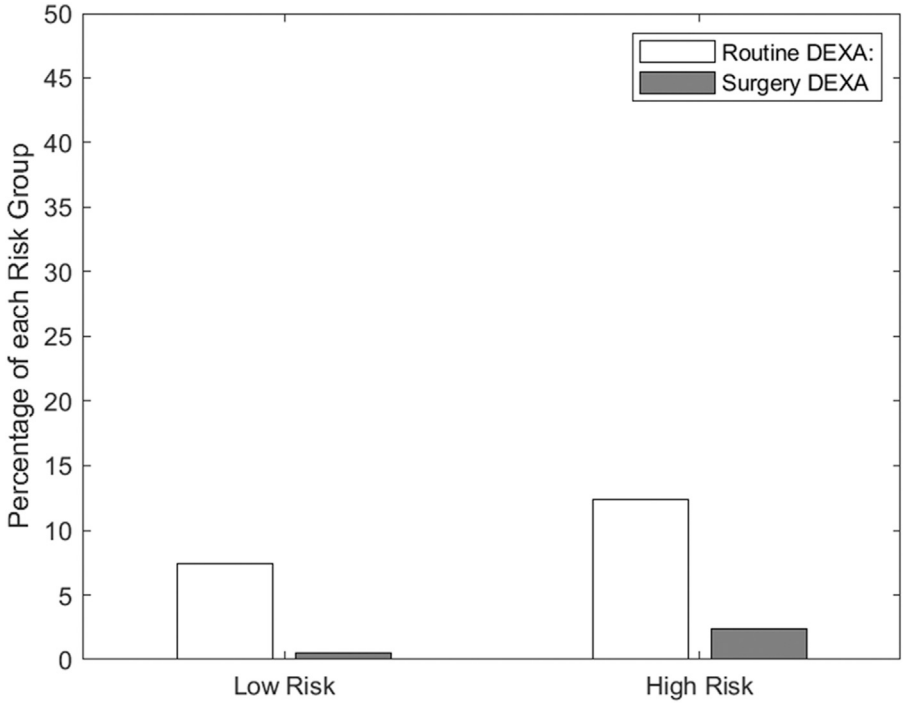

Fig. 1. Prevalence of DEXA scans in the low and high risk groups during the routine period and the surgical period. Routine DEXA, %patients with at least 1 DEXA scan on file during the routine care period. Surgery DEXA, %patients receiving at least 1 DEXA during the surgical period. DEXA, dual-energy X-ray absorptiometry.

undertreated and undertested [3,13]. However, there are few studies evaluating the extent to which such gaps exist in patients undergoing TJA [24]. In this study, we found that for high risk patients undergoing TJA, 90% did not receive any pharmacological treatment for osteoporosis and 88% did not receive bone density testing in the routine care period, with even lower rates of screening and treatment in the surgical period. We also found that patients with existing osteoporosis undergoing TJA are undertreated, as 80% of these patients were not treated with any osteoporosis medications and 33% of these patients were not taking VD or calcium. These findings suggest that there are significant gaps in both screening and treatment in the TJA population, especially among patients who are at high risk for fractures.

One of the most important findings of this study is that patients undergoing TJA are severely under-screened for osteoporosis in both periods, particularly in the high risk group. Our population analysis reveals that most female patients and a large portion (>25%) of male patients meet the criteria for osteoporosis screening. Although the high risk group as determined by FRAX received higher rates of DXA screening in the routine care period compared to the low risk group (12.4% versus 7.5%), the difference is not significant, and the absolute rates of screening are inadequate for all patients who satisfy the osteoporosis screening guidelines. High risk patients should also receive DXA screening during the surgical period due to bone loss during the postoperative period around the surgical site [9]. However, the rates of DXA during the surgical period up to 1 year of follow-up showed that very few patients (<2.5%) were screened. Furthermore, all patients whose charts were reviewed met the Endocrine Society criteria for osteoporosis screening as part of the inclusion criteria, indicating that rates of adequate screening for osteoporosis were likely much lower in the general arthroplasty population. The screening gap we demonstrated indicates that BMD measurement is not a standard of care in the current clinical environment for TJA patients. Since the FRAX can be performed without DXA, those patients with a high risk score require a formal DXA and medical intervention.

Besides low screening rates, we also found that the TJA population have low rates of treatment for osteoporosis. Only half of all

Table 3
Bone Density Testing and Pharmacological Treatment of Low Risk Versus High Risk Groups.

Variables of Interest	Risk Group		
	Low Risk	High Risk	*P* Value
N (% total population)	214 (42%)	291 (58%)	
Routine care DXA scan, n (%)	16 (8%)	36 (12%)	.074
Surgical period DXA scan, n (%)	1 (1%)	7 (2%)	.085
Routine care osteoporosis medication, n (%)	5 (2.3%)	26 (9%)	**.005**
Surgical period osteoporosis medication, n (%)	2 (1%)	13 (5%)	**.021**
Routine care VD/Ca, n (%)	111 (52%)	156 (54%)	.699
Surgical period VD/Ca, n (%)	109 (51%)	161 (55%)	.328

VD/Ca: patient taking either VD or Ca during the routine care or surgical period. *P*-values <.05 are bolded.
DXA, dual-energy X-ray absorptiometry; VD, vitamin D; Ca, calcium.

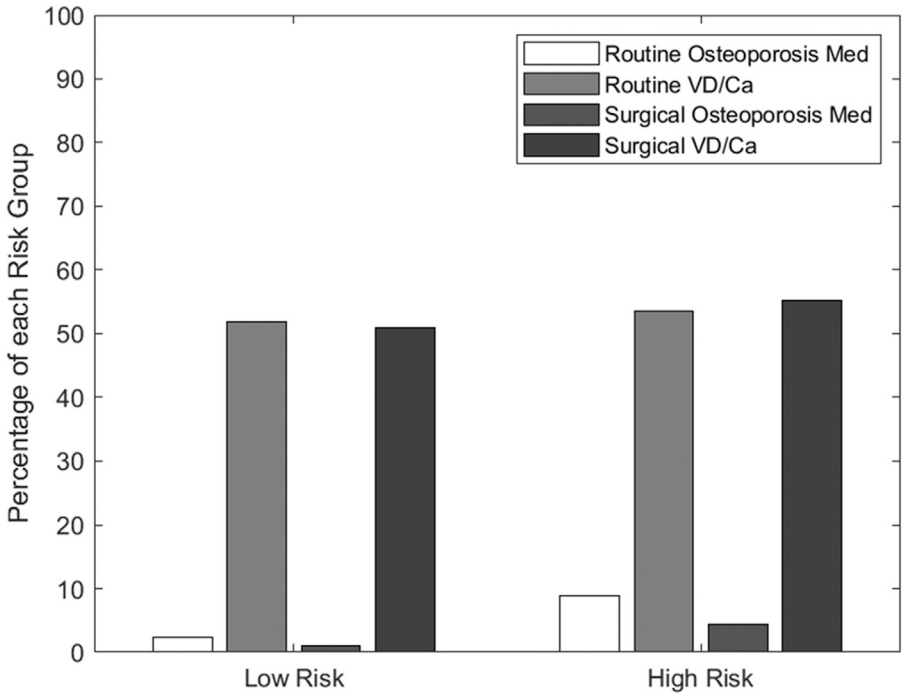

Fig. 2. Osteoporosis medication usage in the low and high risk groups during the routine and the surgical period. Routine Osteoporosis Med, % patients taking any osteoporosis medication during the routine care period. Routine VD/Ca, % patients taking VD and/or calcium during the routine period. Surgical Osteoporosis Med, % patients taking any osteoporosis medication during the surgical period. Surgical VD/Ca, % patients taking VD and/or calcium treatment during the surgical period. VD, vitamin D, Ca, calcium.

patients in both the high and low risk groups received VD and calcium treatment during the routine care or the surgical care period. VD levels are not routinely screened in arthroplasty patients, but evidence suggests that VD and calcium deficiencies are common and associated with worse functional outcomes post arthroplasty [25,26]. Therefore, all high risk patients undergoing TJA should be either treated with VD/calcium or screened for VD deficiency. Although VD and calcium are important parts of osteoporosis treatment and prevention [27], many patients, particularly the high risk group, who meet the criteria of treatment per FRAX score, should also receive targeted osteoporosis medications to further decrease their risk of fractures [28,29]. This is especially relevant given recent evidence suggesting surgical outcome benefits with bisphosphonate treatment [11,12] and our finding that 75% of patients who suffered recent periprosthetic fractures would be classified as high risk at the time of their fracture and should have received pharmacological treatment based on FRAX. In addition, patients with periprosthetic fracture following THA had significantly higher FRAX scores compared to THA patients without periprosthetic fractures which further emphasizes the need for screening and treatment. In contrast, we found that <10% of patients during the routine period for either risk group and <5% of patients during the surgical period received any osteoporosis medication. This demonstrates a severe deficiency in treating metabolic bone disease in high risk patients and represents a missed opportunity to prevent worsening bone health.

Additionally, the pattern of under-treatment persists even in patients who have an established diagnosis of osteoporosis. We found that about 80% of all patients with a diagnosis of osteoporosis, and 90% of all patients with a diagnosis of osteopenia, are not being treated with osteoporosis medications during the study period. Additionally, less than two-thirds of patients with a diagnosis of osteoporosis or osteopenia were taking VD and calcium during the study period. Engaging these patients with osteoporosis/osteopenia treatments, BMD evaluations, VD and calcium supplements, or referring them to a metabolic bone specialist may reverse the course of deteriorating bone health and prevent future complications.

This study also identified that female gender and a history of previous low energy fractures were independently associated with higher rates of screening and treatment. Multivariate logistic regression analysis demonstrated that after adjusting for other

Table 4
Bone Density Testing and Pharmacological Treatment Profile of TJA Patients According to Metabolic Bone Disease Diagnosis.

Variables of Interest	Metabolic Bone Diagnosis			
	Osteoporosis	Osteopenia	Neither	*P* Value
N (% total population)	100 (20%)	61 (12%)	344 (68%)	
Received medical intervention, n (%)	20 (20%)	6 (10%)	5 (1%)	**<.001**
Received VD/Ca, n (%)	67 (67%)	36 (59%)	176 (51%)	**.016**
Received DXA scan, n (%)	25 (25%)	7 (11%)	24 (7%)	**<.001**

Received medical intervention: patients who received osteoporosis medication during either the routine care or the surgical period. Received VD/Ca: patient taking either VD or calcium during the routine care or surgical period. Received DXA: patient who received DXA scan during either the routine care or the surgical period. *P* values were calculated using chi-squared test. *P*-values <.05 are bolded.
TJA, total joint arthroplasty; DXA, dual-energy X-ray absorptiometry; VD, vitamin D; Ca, calcium.

Table 5
Coefficients (*B*) of Multivariate Logistic Regression Models of Medication Usage and Bone Density Testing Versus Demographic and Risk Factors.

Regression Variables	Routine Care Period Osteoporosis Medications	Surgical Period Osteoporosis Medications	Routine Care Period VD/Ca	Surgical Period VD/Ca	Routine Care Period DXA	Surgical Period DXA
Intercept	−31.9	−28.8	−0.9	−0.9	−3.6	−274.8
White race	23.7	22.2	0.4	0.5	0.7	104.4
Age	0.1	0.0	0.0	0.0	0.0	0.0
Gender	1.1	1.4	**0.5**	**0.6**	**2.1**	173.3
BMI	0.0	−0.1	0.0	0.0	0.0	−0.1
Previous fx	**1.4**	**1.6**	0.2	0.2	0.4	0.3
Parent hip fx	0.7	−31.7	0.4	0.3	−31.7	**−34,805.0**
Smoking	−29.8	−29.2	1.7	1.7	−31.4	**−110,449.1**
Glucocorticoid	0.2	1.1	−0.9	−0.4	0.2	**−102,476.7**
RA	0.3	0.7	0.3	0.3	0.2	0.8
Alcohol	−27.1	−25.6	29.7	29.8	−25.7	148.4

Each column represents a separate multivariate logistic regression model while each row represents each independent variable; White race: whether the patient's race and ethnicity was White; previous fx: a previous low energy fracture in adult life; parent fx: history of hip fracture in either parent; glucocorticoid use: current use of oral glucocorticoid or has been exposed to oral glucocorticoids for more than 3 mo at a dose of prednisolone of 5 mg daily or more (or equivalent doses of other glucocorticoids); RA: confirmed diagnosis of rheumatoid arthritis; alcohol: >3 or more units/d; *P*-values <.05 are bolded.
DXA, dual-energy X-ray absorptiometry; VD, vitamin D; Ca, calcium; BMI, body mass index; fx, fracture; RA, rheumatoid arthritis.

variables, having a history of low energy fractures are significantly associated with an increased probability of receiving osteoporosis medications. In addition, being female significantly increases the chance of receiving VD/calcium and DXA scan during the routine care period. Although the model also shows that a history of parental hip fractures, current smoking, and alcohol usage are very strong predictors of receiving DXA during the surgical period ($B > 10{,}000$), these effects are unreliable due to the small sample size in this subgroup ($N = 8$). Whether the patient was White or not does not have any significant effects on treatment or screening. These results demonstrate that While clinicians were able to identify some risk factors, many other factors were overlooked. This further supports the usage of FRAX scores as a discrimination tool for physicians to parse out high versus low risk patients.

Limitations of this study include its retrospective nature, the limited time frame of study, and the use of EMR. Furthermore, due to the limitation of COVID-19 preventing us from having accurate follow-up data past March 2020, we were not able to study more recent patients beyond March 2019, although we used the most recent data possible for the most accurate clinical picture.

Conclusion

There are significant gaps of care in the TKA and THA population regarding both screening and treatment. Particularly, only <10% of high risk patients received any pharmacological treatment and only 12% of them received DXA screening. Additionally, among patients with existing osteoporosis, 80% were not treated with osteoporosis medications and one-third were not taking VD or calcium. Multivariate regression analysis demonstrated that many risk factors were likely overlooked in clinical decision making. Although the incorporation of metabolic bone care for TJA patients has become more common, the currently low rates of screening and treatment suggest that there are still potential financial barriers or structural rigidities that prevent patients from accessing appropriate metabolic bone care. Periprosthetic fracture is largely a product of metabolic bone disease as demonstrated by the fracture group's significantly higher FRAX scores. Thus, incorporation of metabolic bone care and risk identification should be highly considered for TJA patients, and awareness of metabolic bone diseases among this patient population should be increased.

Table 6
N, Age, Gender, Race, Ethnicity, BMI, FRAX Scores of Periprosthetic Hip Fracture Cohort, and THA Review Cohort.

Variables of Interest	Risk Group		
	PPFRX	Review Cohort	*P* Value
N	40	235	
Mean age (y), mean ± SD	73.1 ± 11.43	73.5 ± 6.05	.741
Gender, n (%)			**.023**
Male	17 (42%)	59 (25%)	
Female	23 (58%)	176 (75%)	
Race and ethnicity			
White non-Hispanic	35 (88%)	212 (90%)	
Hispanic	0 (0%)	4 (2%)	
Black	3 (8%)	15 (6%)	
Asian	0 (0%)	4 (2%)	
Other	2 (2%)	0 (0%)	
BMI, mean ± SD	26.2 ± 4.5	27.7 ± 5.8	.121
FRAX MOF (10 y % risk)	18.7 ± 11.5	15.0 ± 7.9	**.012**
Male	12.5 ± 6.0	8.6 ± 3.1	**<.001**
Female	24.9 ± 11.0	17.2 ± 7.9	**<.001**
FRAX HF (10 y % risk)	8.3 ± 8.3	5.3 ± 4.7	**.001**
Male	4.9 ± 4.6	3.2 ± 2.1	**.035**
Female	11.2 ± 9.2	6.0 ± 5.0	**<.001**

PPFRX cohort is a group of 40 patients diagnosed with periprosthetic hip fractures at our institution following previous THA. Review cohort consists of the 250 patients with THA analyzed in this study minus 15 patients that overlapped with the PPFRX cohort due to subsequent fracture around their THA.
P-values < .05 are bolded.
BMI, body mass index; FRAX, Fracture Risk Assessment Tool; THA, total hip arthroplasty; PPFRX, periprosthetic hip fracture; SD, standard deviation; MOF, major osteoporotic fractures; HF, hip fractures.

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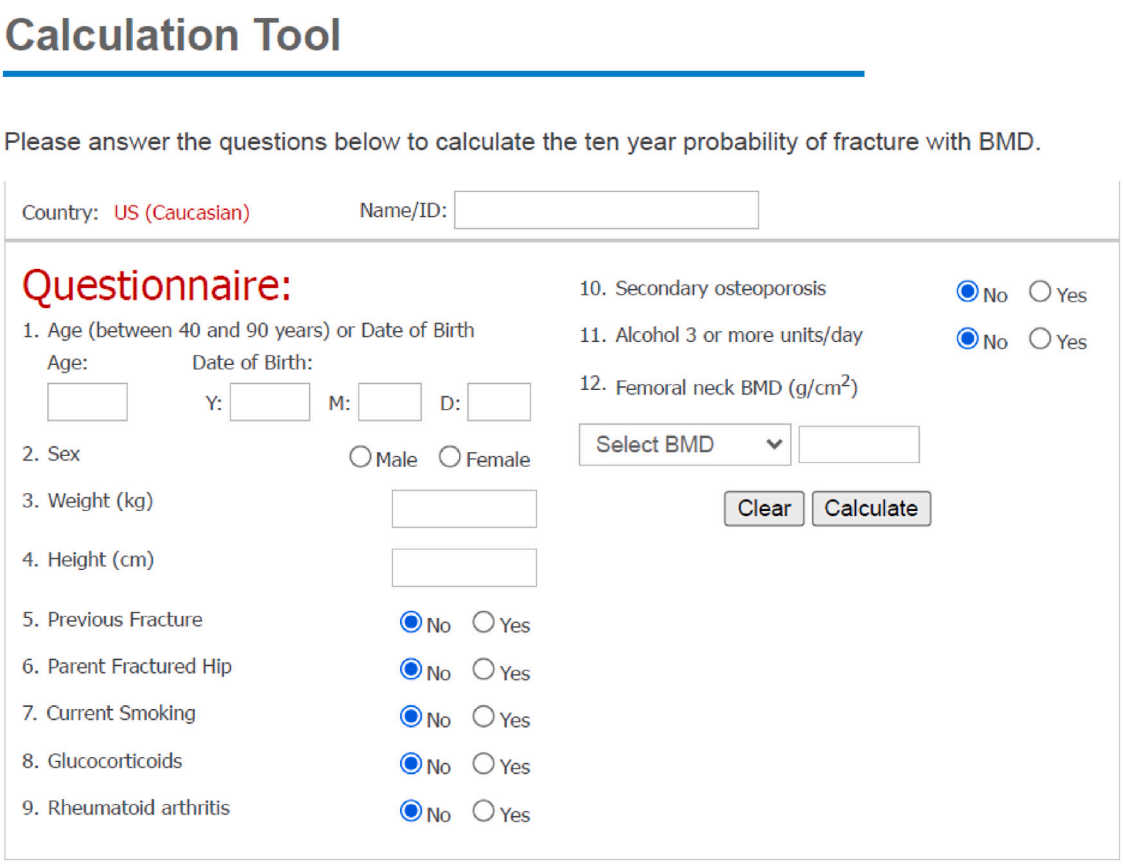
Appendix

FRAX tool. The free FRAX calculator can be found at https://www.sheffield.ac.uk/FRAX/.



Risk Factors

Age	The model accepts ages between 40 and 90 y. If ages below or above are entered, the program will compute probabilities at 40 and 90 y, respectively
Gender	Male or female. Enter as appropriate
Weight	This should be entered in kg
Height	This should be entered in cm
Previous fracture	A previous fracture denotes more accurately a previous fracture in adult life occurring spontaneously, or a fracture arising from trauma which, in a healthy individual, would not have resulted in a fracture. Enter yes or no (see also notes on risk factors)
Parent fractured hip	This enquires for a history of hip fracture in the patient's mother or father. Enter yes or no
Current smoking	Enter yes or no depending on whether the patient currently smokes tobacco (see also notes on risk factors)
Glucocorticoids	Enter yes if the patient is currently exposed to oral glucocorticoids or has been exposed to oral glucocorticoids for more than 3 mo at a dose of prednisolone of 5 mg daily or more (or equivalent doses of other glucocorticoids) (see also notes on risk factors)
Rheumatoid arthritis	Enter yes where the patient has a confirmed diagnosis of rheumatoid arthritis. Otherwise enter no (see also notes on risk factors)
Secondary osteoporosis	Enter yes if the patient has a disorder strongly associated with osteoporosis. These include type I (insulin dependent) diabetes, osteogenesis imperfecta in adults, untreated long-standing hyperthyroidism, hypogonadism or premature menopause (<45 y), chronic malnutrition, or malabsorption and chronic liver disease
Alcohol 3 or more units/d	Enter yes if the patient takes 3 or more units of alcohol daily. A unit of alcohol varies slightly in different countries from 8 to 10 g of alcohol. This is equivalent to a standard glass of beer (285 mL), a single measure of spirits (30 mL), a medium-sized glass of wine (120 mL), or 1 measure of an aperitif (60 mL) (see also notes on risk factors)
Bone mineral density (BMD)	(BMD) Please select the make of DXA scanning equipment used and then enter the actual femoral neck BMD (in g/cm^2). Alternatively, enter the *T*-score based on the NHANES III female reference data. In patients without a BMD test, the field should be left blank (see also notes on risk factors) (provided by Oregon Osteoporosis Center)