Measurement of Forearm Bone Density by Dual Energy X-Ray Absorptiometry Increases the Prevalence of Osteoporosis in Men With Celiac Disease

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BACKGROUND & AIMS: **Guidelines advise measurement of bone mineral density (BMD) in patients with a diagnosis of celiac disease. The lumbar spine (LS) and hip sites are usually measured. Although skeletal sites rich in trabecular bone are believed to be vulnerable to osteoporosis in patients with celiac disease, most studies have not measured the cortical distal 1/3-radius.**

METHODS: **We collected data from 721 patients (mean age, 43.6 years; 68.4% female) with celiac disease who underwent 3-site dual energy x-ray absorptiometry (DXA, at a median 1.22 years after diagnosis). We assessed skeletal site- and sex-specific osteoporosis prevalence and the incremental utility of 1/3-radius measurement by DXA.**

RESULTS: **Mean T- and Z-scores were normal in patients, but 43.3% had osteopenia and 19.6% had osteoporosis. Osteoporosis was found in 12.1% of patients at the LS, 5.3% of patients at the total hip, 7.6% of patients at the femoral neck, and 11.5% of patients at the 1/3-radius. A greater degree of villous atrophy at diagnosis was associated with male sex and lower T-scores at the 1/3-radius ($P = .03$), but not other skeletal sites. Isolated forearm osteoporosis was detected in 4.9% of patients. A higher proportion of patients with isolated forearm osteoporosis were male and had a greater weight and body mass index (all $P < .01$, compared to patients with osteoporosis only at other sites). Z-scores were lower at the LS and 1/3-radius and osteoporosis was more common in men than women. In men, the 1/3-radius was the most frequent site for osteoporosis. Among patients 50 years or older, isolated forearm osteoporosis was present in 10.7%.**

CONCLUSIONS: **Based on DXA analysis of patients with celiac disease, the prevalence of osteoporosis appears to be underestimated—particularly in men and when BMD at the 1/3-radius is not measured. Degree of villous atrophy is associated with BMD at the 1/3-radius and nearly 5% of patients have osteoporosis limited to that site. Recommendations for osteoporosis screening in patients with celiac disease should include measurement of the distal 1/3-radius in addition to the hip and LS.**

Keywords: Diagnostic Factor; Complication; Cortical; Parathyroid Hormone; BMI.

Celiac disease (CD) is an autoimmune condition characterized by intestinal inflammation due to gluten exposure in genetically at risk individuals. CD can be complicated by metabolic bone disease including osteoporosis and osteopenia, vitamin D deficiency, secondary hyperparathyroidism, and less frequently osteomalacia. Data regarding fracture risk in patients with CD are conflicting but a recent meta-analysis of prospective studies indicated that CD is associated with a 30% increase in the risk of any fracture and a 69% increase in the risk of hip fracture.[1–5] Some data indicate an increased risk of fractures at peripheral skeletal sites.[2,6] Multiple reports suggest that osteopenia and osteoporosis are frequent complications of CD and osteoporosis screening is recommended at diagnosis.[7] There is, however, a wide range of prevalence estimates described, varying from ∼6 to ≥70%.[8–11] A recent meta-analysis challenged the notion that the rate of CD

Abbreviations used in this paper: **BMD, bone mineral density; BMI, body mass index; CD, celiac disease; CUMC, Columbia University Medical Center; DXA, dual-energy x-ray absorptiometry; FN, femoral neck; LS, lumbar spine; PHPT, primary hyperparathyroidism; PTH, parathyroid hormone; TH, total hip.**

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among those with osteoporosis is increased. This study found that CD was present in 1 in 62 or about 1.6%, which is comparable to the rate in the general population.[12] However, most of the studies that have assessed the prevalence of osteoporosis in CD or prevalence of CD in patients with osteoporosis have not measured BMD at the distal one-third radius and some only measured the lumbar spine region.[9,13–26]

The distal one-third radius is a skeletal site composed predominantly of cortical bone and particularly sensitive to the effects of elevated parathyroid hormone (PTH).[27] While bone loss in CD is likely multifactorial, a major mechanism is thought to be villous atrophy in the small bowel, the main site of calcium and vitamin D absorption. Malabsorption of calcium and vitamin D may have a direct impact on BMD or lead to compensatory secondary hyperparathyroidism and bone resorption to maintain normal serum calcium levels.[7,28,29] Limited data indicate that secondary hyperparathyroidism is present in 25% or more of CD patients and that PTH level is negatively associated with BMD at the forearm.[30,31]

The purpose of this analysis was to assess skeletal site and sex-specific prevalence rates of osteoporosis in a large cohort of patients with CD who underwent dual-energy x-ray absorptiometry (DXA) and to determine the incremental value of measurement of BMD at the one-third radius site.

What You Need to Know

Background

Most studies assessing bone mineral density in patients with celiac disease have not included measurement of the distal one-third radius, a cortical skeletal site affected by increased levels of parathyroid hormone.

Findings

In a study of 721 patients with celiac disease, we found that 43.3% had osteopenia and 19.6% had osteoporosis. Osteoporosis was most frequent at the spine (12.1%) and one-third radius (11.5%). Degree of villous atrophy was associated with lower *t* scores at the one-third radius. Isolated forearm osteoporosis was present in 4.9%. Patients with isolated forearm osteoporosis were more likely to be male and had a greater weight and body mass index. *Z* scores were lower at the LS and one-third radius and osteoporosis was more common in men than women. In men, the one-third radius was the most frequent site for osteoporosis.

Implications for patient care

Recommendations for osteoporosis screening in patients with celiac disease should include measurement at the distal one-third radius, in addition to hip and spine.

Materials and Methods

Design

This is a cross sectional analysis of BMD data obtained in adult patients with CD (17 years of age and older) as part of their care at the Celiac Disease Center at Columbia University Medical Center (CUMC) in New York, New York. This study was approved by the Institutional Review Board of CUMC.

Participants

We identified CD patients (n = 721) from our CD registry of 2396 who had DXA testing at CUMC as part of their clinical care. All patients had CD confirmed by duodenal biopsy. Each participant's BMD and sex, as well as age, height, and weight at time of DXA, was obtained from densitometer data. Data regarding date of CD diagnosis and disease presentation were available in our registry. We considered the date of diagnosis the date of biopsy because not all CD patients have symptoms or the recognition or recollection of the onset of such symptoms is variable. Information about degree of villous atrophy (partial or total) was available in 256 participants in our registry from the biopsy at CD diagnosis. Disease duration was calculated as the time interval between the date of diagnosis and DXA. Menopause status was not available in women. We assessed whether CD patients who had DXA at our center differed from those who did not have DXA: those who had DXA at CUMC did not differ by sex (68.6% vs 71.7% female; $P = .13$) or age of diagnosis (39.0 ± 16.4 years vs 38.2 ± 17.2 years; $P = .32$) compared with those who did not have DXA.

Dual X-Ray Absorptiometry

Areal BMD was measured at the lumbar spine (LS) L1–L4, total hip (TH), femoral neck (FN), and the distal one-third radius using a QDR 4500 instrument (Hologic Inc, Waltham, MA). All *t* and *Z* scores were obtained using the manufacturer's reference norms. In vivo precision, determined according to the standard method at this facility is 1.28% at the LS, 1.36% at the hip, and 0.70% for the distal radius (one-third site). DXA measurements were made between 1993 and 2018. For each participant, we utilized BMD values from the DXA closest in time to the date of their CD diagnosis. The dates of the first DXA in relation to the date of CD diagnosis were variable and dependent on individual practitioner patterns. Of all scans, 5.4% were obtained before the diagnosis of CD was made, 0.3% were acquired on the day of diagnosis, and 94.3% were obtained after the diagnosis.

Table 1. Cohort Demographics

	Whole Cohort	>50 Years of Age	Within 5 y of Diagnosis	Within 1 y of Diagnosis
	n = 721	n = 244	n = 543	n = 407
Age at time of DXA, y	43.6 ± 16.2	62.7 ± 8.8	42.1 ± 15.9	41.7 ± 15.8
Age at CD diagnosis, y	38.8 ± 16.4	55.9 ± 12.7	40.3 ± 16.0	40.6 ± 15.9
Median time to DXA, y	1.22	1.97	0.59	0.37
Female, %	68.4	55.6	68.3	68.2
Height, inches	66.1± 3.7	66.3 ± 4.0	66.2 ± 3.7	66.2 ± 3.7
Weight, lbs	147.7 ± 34.2	153.6 ± 37.1	147.5 ± 33.4	147.5 ± 33.5
BMI, kg/m^2	23.6 ± 4.3	24.4 ± 4.7	23.5 ± 4.2	23.4 ± 4.2
Pathology				
Partial villous atrophy, %	58.2	56.6	59.7	60.1
Total villous atrophy, %	41.8	43.4	40.3	39.9
Diarrhea at presentation, %	40.8	46.2	39.2	37.9
Osteoporosis, %	19.6	44.3	18.0	18.1
Osteopenia, %	43.3	40.1	43.8	46.2
t score				
Lumbar spine	−0.9 ± 1.4	−1.6 ± 1.5	−0.9 ± 1.4	−0.9 ± 1.3
Total hip	−0.6 ± 1.1	−1.3 ± 1.1	−0.6 ± 1.1	−0.6 ± 1.0
Femoral neck	−0.9 ± 1.1	−1.7 ± 1.0	−0.8 ± 1.1	−0.9 ± 1.1
One-third radius	−0.7 ± 1.5	−1.7 ± 1.7	−0.7 ± 1.4	−0.7 ± 1.4
Z score				
Lumbar spine	−0.4 ± 1.3	−0.4 ± 1.4	−0.4 ± 1.3	−0.5 ± 1.3
Total hip	−0.2 ± 1.0	−0.4 ± 1.0	−0.2 ± 1.0	−0.2 ± 1.0
Femoral neck	−0.3 ± 1.0	−0.4 ± 1.0	−0.3 ± 1.1	−0.3 ± 1.1
One-third radius	−0.1 ± 1.3	−0.4 ± 1.5	0.0 ± 1.3	−0.1 ± 1.3

Values are mean ± SD unless otherwise indicated.
BMI, body mass index; DXA, dual-energy x-ray absorptiometry.

Statistical Analysis

Descriptive statistics were used to calculate means and percentages. Between-group differences were evaluated with Student's *t* test or chi-square as appropriate. A 2-tailed *P* value <.05 was considered statistically significant.

Results

Seven hundred twenty-one patients within the celiac registry had DXA measured at CUMC. As shown in Table 1, the cohort was predominantly female, 97.2% were Caucasian (2.1% were Hispanic and 0.7% African American) and age ranged from 17 to 83 years. Mean age at CD diagnosis was 38.8 ± 16.4 years and mean age at DXA was 43.6 ± 16.2 years. DXA was performed at a median of 1.22 years after the diagnosis of CD. Mean BMI was normal (23.6 ± 4.3 kg/m^2) and 40.8% had classical CD presentation (diarrhea predominant). In those in whom data on degree of villous atrophy was available, 58.2% and 41.8% had partial or total villous atrophy, respectively. As shown in Table 1, on average *t* and *Z* scores were normal at the LS (*t*-score range, −5.2 to 3.5; *Z*-score range, −4.7 to 4.2), TH (*t*-score range, −4.3 to 2.5; *Z*-score range, −2.9 to 4.1), FN (*t*-score range, −4.4 to 2.5; *Z*-score range, −3.2 to 3.5), and one-third radius (*t*-score range, −7.1 to 3.0; *Z* score range, −5.8 to 4.1), but 43.3% had osteopenia (based on *t* score −1.1 to −2.4 at any site) and 19.6% osteoporosis (based on *t* score ≤−2.5) in the whole cohort.

As shown in Table 1, *t* scores were lower at the LS and FN compared with the TH (both $P < .001$) and one-third radius sites (both $P < .01$). As shown in Figure 1, osteoporosis was present in 12.2% at the LS, 5.3% at the TH, 7.7% at the FN, and 11.6% at the one-third radius and rates were higher at the LS and one-third radius compared with the total hip and femoral neck (all $P < .05$). Given that some participants were younger than 50 (and/or premenopausal), we also assessed the prevalence of low BMD based on *Z* score ≤2.0. Prevalence rates were similar: 15.0% at any site, 9.2% at the lumbar spine, 2.8% at the total hip, 2.6% at the femoral neck, and 7.5% at the one-third radius. 4.2% had a *Z* score of −2.0 or lower only at the one-third-forearm.

As shown in Table 2, greater degree of villous atrophy was associated with lower *t* score and *Z* score at the one-third radius but no other skeletal sites. Patients with total vs partial atrophy were more likely to have osteoporosis at any site (26.1% vs 19.5%; $P < .001$) and were more likely to be male (43.9% vs 28.2%; $P = .01$), but not more likely to have diarrhea ($P = .64$). Diarrhea was associated with *t* score (−0.8 ± 1.2 vs −0.6 ± 1.0; $P = .03$) and *Z* score (−0.3 ± 1.0 vs −0.2 ± 1.0; $P = .04$) at the hip, but not BMD at other sites (data not shown).

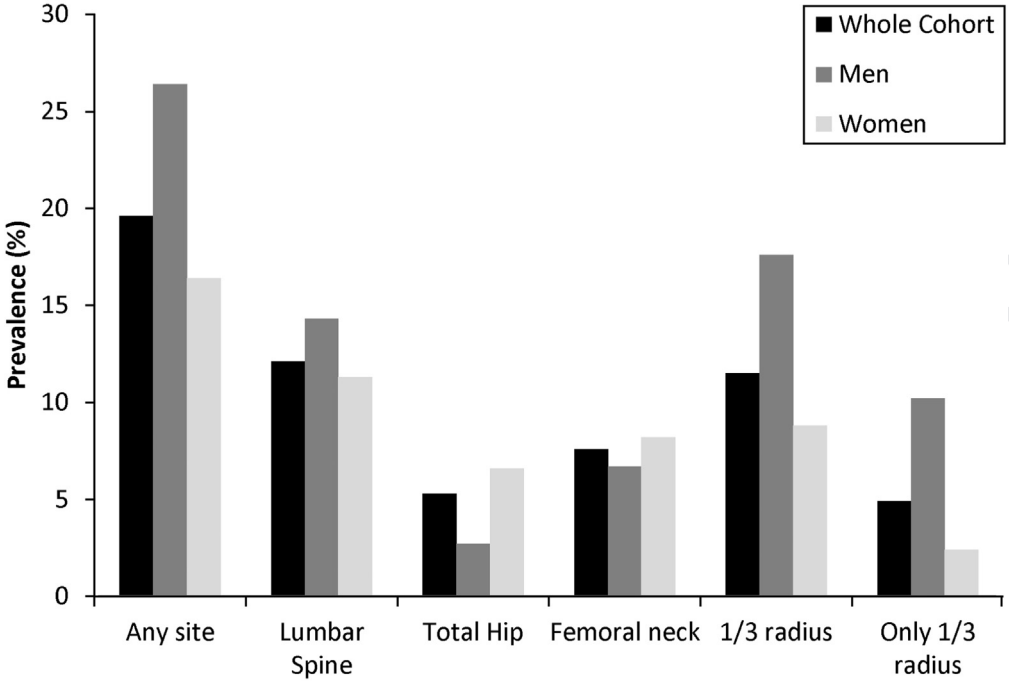

Figure 1. Prevalence of osteoporosis by skeletal site and sex. Men are shown in dark gray and women in light gray.

Among those with osteoporosis, 35 (4.9%) had osteoporosis only at the one-third radius. Those with isolated forearm osteoporosis were more likely to be male (64.7% vs 35.0%; $P = .004$), and had greater weight (153.3 ± 32.3 pounds vs 130.0 ± 26.6 pounds; $P < .001$) and BMI (24.5 ± 4.48 kg/m^2 vs 21.5 ± 3.2 kg/m^2; $P < .001$) compared with those with osteoporosis only at nonforearm sites, but there was no difference in age at DXA (56.4 ± 17.4 years vs 58.5 ± 16.3 years; $P = .52$), age at CD diagnosis (49.3 ± 18.2 years vs 52.5 ± 16.1 years; $P = .32$), time from diagnosis to DXA (6.6 ± 11.5 years vs 5.5 ± 9.0 years; $P = .56$), or diarrhea at CD presentation (41.2% vs 44.7%; $P = .88$). Measurement of forearm BMD led to recategorization from normal to osteopenic or osteoporotic, or osteopenic to osteoporotic in 61 patients (8.5%) and an increase in the prevalence of osteoporosis ($P < .001$).

Table 2. Association Between Biopsy and BMD

	Partial Villous Atrophy (n = 149)	Total Villous Atrophy (n = 107)	*P* Value
Age at time of DXA, y	44.6 ± 15.6	46.6 ± 17.3	.33
Age at CD diagnosis, y	42.3 ± 15.7	43.4 ± 17.6	.59
Female	71.8	56.1	.01
Height, in	65.1 ± 4.9	66.5 ± 4.0	.01
Weight, lbs	144.4 ± 31.8	149.0 ± 33.5	.27
BMI, kg/m^2	24.7 ± 19.3	23.1 ± 3.7	.32
Osteoporosis	19.5	26.1	<.001
Diarrhea	47.7	43.9	.64
Osteopenia	48.3	50.4	.07
t score			
Lumbar spine	−1.0 ± 1.5	−1.0 ± 1.3	.83
Total hip	−0.7 ± 1.1	−0.9 ± 1.1	.21
Femoral neck	−1.0 ± 1.2	−1.1 ± 1.3	.48
One-third radius	−0.7 ± 1.4	−1.1 ± 1.7	.03
Z score			
Lumbar spine	−0.5 ± 1.3	−0.5 ± 1.4	.98
Total hip	−0.3 ± 1.0	−0.4 ± 1.0	.35
Femoral neck	−0.4 ± 1.0	−0.4 ± 1.1	.85
One-third radius	0.0 ± 1.3	−0.4 ± 1.5	.05

Values are mean ± SD or %.
BMD, bone mineral density; BMI, body mass index; CD, celiac disease; DXA, dual-energy x-ray absorptiometry.

Comparing men vs women, men were older at CD diagnosis (43.6 ± 16.6 years vs 36.8 ± 15.9 years; $P < .001$) but time from diagnosis to DXA (3.9 ± 7.7 years vs 3.9 ± 7.4; $P = .97$) and rates of diarrhea at CD presentation (41.9% vs 40.7%; $P = .79$) did not differ. Men had higher BMI than women (25.1 ± 4.1 kg/m^2 vs 23.0 ± 4.3 kg/m^2; $P < .001$). As shown in Figure 2, men (n = 227) had lower *Z* scores at the LS ($P = .048$) and one-third radius ($P < .01$), but not the TH ($P = .82$) or FN ($P = .73$). Osteoporosis at any site was more common in men (26.4% vs 16.4%; $P = .002$). Men had high rates of osteoporosis at the one-third radius (17.6% vs 8.8%; $P < .001$) compared with women and the one-third radius was the most common site of osteoporosis in men: LS 14.3%, FN 6.7%, TH 2.7%, and one-third radius 17.6% ($P < .001$). Isolated forearm osteoporosis was present in 10.2% of men and measurement of forearm BMD led to an increase in the prevalence of osteoporosis in men ($P < .001$).

When the analysis was limited to adults ≥50 years of age (n = 244), mean *t* scores were in the osteopenic range, while *Z* scores were still normal (Table 1) but the prevalence of osteoporosis was higher: 44.3% had

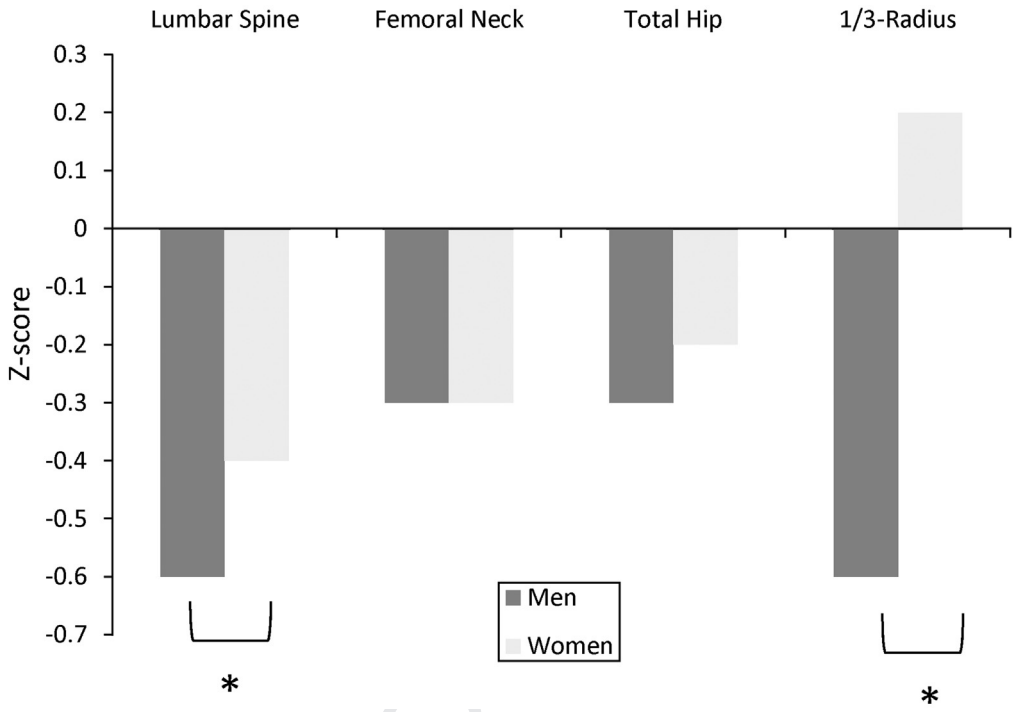

Figure 2. *Z* scores in men (dark gray) and women (light gray) by skeletal site. *$P < .05$.

osteoporosis (based on *t* score ≤–2.5) at any site and 26 (10.7%) had osteoporosis only at the forearm. When the analysis was limited to those who had DXA within 5 years of diagnosis (n = 527) or 1 year of diagnosis (n = 331), results were similar to the whole cohort: 18.0% and 18.1% had osteoporosis at any site, respectively, and 4.2% had osteoporosis only at the forearm in both subgroups.

Among those who had DXA before CD diagnosis (5.4% of the cohort), DXA was performed at a median of 77.5 days before diagnosis and 34.2% had diarrhea. Based on the indication listed for DXA, CD was suspected in 12.8%. The prevalence of osteoporosis in this subset was (23.1%).

Discussion

To our knowledge, this is the largest CD cohort in whom the prevalence of osteoporosis has been evaluated with DXA and one of only a few studies to measure BMD at the one-third radius.[9,13–26] Osteoporosis was present in nearly one-half of our participants 50 years of age or older. Further osteoporosis was as common at the forearm as the spine. Moreover, 10% 50 years of age and older had isolated forearm osteoporosis. Men were more likely than women to have osteoporosis and isolated forearm osteoporosis as well as lower *Z* scores at the spine and forearm. Greater villous atrophy was more common in men and associated with *t* score at the radius. Thus, our results suggest the measurement of BMD by DXA at the forearm may provide additional information regarding skeletal health in CD patients, particularly men. These results imply that the diagnosis of osteoporosis may be missed and prevalence of osteoporosis in CD underestimated if forearm BMD is not measured.

Osteoporosis and osteopenia are reportedly common in CD, but prevalence rates (6%–70%) vary widely between studies. Disparities may be due to differences in several factors including the skeletal sites measured as well as the size, age and gender distribution of the cohort. Most studies have not assessed the distal one-third radius and some included the spine only. The spine is subject to artifactually high BMD in older adults due to arthritis and vascular calcification,[9,13–26] leading to potential underestimates of osteoporosis prevalence. Most prior studies have been small and may not accurately reflect prevalence.[9,13–26] The largest study (n = 1408) reported a combined rate of osteopenia and osteoporosis of 19.6% but BMD was available only in 244 and only at the spine and femoral neck.[19] In this cohort, age-specific rates of osteoporosis were 67% and 70% in older (≥65 years of age) men and women but only 14% and 9% in young (18–65 years of age) men and women, respectively. Thus, cohorts enrolling mostly children and younger adults, who are less likely to be affected by osteoporosis, may underestimate prevalence.

While we had no internal non-CD control, the high prevalence (43.9%) of osteoporosis among those ≥50 years of age in our study suggests CD may increase risk for bone loss. In comparison, the prevalence of osteoporosis among Caucasian women >50 years of age in the general population is 30%.[32] Several mechanisms are hypothesized to predispose to bone loss in CD, though few studies have investigated pathophysiology. Weight loss, general malnutrition, and hypogonadism may contribute. Chronic inflammation and increased proinflammatory cytokines increase the ratio of receptor

activator of nuclear factor kappa B ligand to osteoprotegerin,[7,33,34] stimulating osteoclastogenesis and bone resorption. A key mechanism in CD, however, is postulated to be small bowel villous atrophy leading to calcium and vitamin D malabsorption. Rarely, osteomalacia may be present.[35] Our results indicating that degree of villous atrophy and diarrhea are associated with BMD supports the hypothesis that malabsorption is a significant factor.

In about 25%, CD's malabsorption leads to secondary hyperparathyroidism.[7,28–31] Studies in primary hyperparathyroidism (PHPT) indicate the one-third radius, a site composed predominantly of cortical bone, is particularly sensitive to the effects of elevated PTH. Some studies have shown PTH levels are negatively correlated with forearm BMD in CD.[30,31] Unfortunately PTH levels are not available in our cohort. Osteoporosis at the forearm, however, is not necessarily specific to CD but seen in conditions of PTH excess (PHPT and secondary hyperparathyroidism) and hyperthyroidism.[27,36] Forearm BMD has infrequently been measured in other gastrointestinal disorders but might be expected in any condition causing malabsorption of calcium and vitamin D (eg, Crohn's disease) or impaired hydroxylation of vitamin D (eg, cirrhosis) and secondary hyperparathyroidism.[37,38]

We suspect the reasons men with CD are more at risk for bone loss and more likely to have isolated forearm osteoporosis is their later diagnosis and greater degree of villous atrophy observed compared with women in our study, leading to greater calcium and vitamin D malabsorption (and perhaps a higher likelihood of secondary hyperparathyroidism). Measurement of PTH would be important to include in future studies. Consistent with our results, prior studies also suggest BMD is lower in men than women with CD relative to age-matched norms (9). The slightly older age of men vs women in our cohort is unlikely to account for the sex-differences given *Z* scores were also lower in men. It is also possible that higher weight or BMI in men is protective at the central skeleton or hip or alternatively that arthritis is more common in men, making the central skeleton less accurate.

While fracture data were not collected in our study, we anticipate lower BMD at the forearm in men with CD would lead to greater fracture risk. An Argentinean study suggests men with CD have a higher risk of peripheral (forearm) fractures than both age- and sex-matched control subjects without CD as well as women with CD.[6] In this study, men had a decrease in fractures after CD diagnosis, but continued to have excess risk, whereas fracture risk in women declined to rates of control subjects after diagnosis.[6] The majority of data suggest those with CD are at increased risk for not only forearm fractures but also hip and other fractures.[1,5,39]

There is conflicting information regarding screening for osteoporosis in CD and guidelines vary by society.[40,42] The American College of Gastroenterology recommends screening with DXA and vitamin D at diagnosis.[41] More conservative guidelines suggest testing only in adults, those who are symptomatic, those likely to be at high risk for fracture, or after 1 year GFD.[40,43,44] For Q3 example, the British Society of Gastroenterology suggests measurement after 1 year GFD in patients with additional osteoporosis risk factors or if over 55 years of age.[44] Based on the high prevalence of osteoporosis in adults ≥50 years of age in our study, we suggest screening CD patients ≥50 years of age with DXA at the time of diagnosis. DXA may be repeated at 1–3 years after GFD depending on initial results.[20,40,45–53] In those with osteoporosis at diagnosis, repeating DXA at 1 year can be considered. The majority of BMD recovery takes place within the first year after GFD[20,45–53] at which time pharmacological therapy could be considered in post/perimenopausal women and men ≥50 years of age with osteoporosis or who are at high risk of fracture, though data specifically in CD are lacking. Consideration for testing younger patients should take into account traditional fracture risk factors (eg, low BMI or weight loss, prior fracture, hypogonadism, and steroid use as well as sex) and degree of villous atrophy as well as compliance or responsiveness to GFD.

Our data suggest that forearm BMD should be included in the overall assessment of skeletal health in CD. The International Society for Clinical Densitometry recommends measurement of BMD at both the spine and hip and forearm when the hip and/or spine cannot be measured or interpreted, in hyperparathyroidism, or very obese patients. Data in the general population and those with PHPT suggest that measurement of the forearm increases the prevalence of osteoporosis.[54–56] Further forearm BMD predicts fracture, particularly forearm fracture, and there is an association between number of osteoporotic sites by DXA and increasing fracture risk.[57–61] Because fractures are associated with subsequent fractures, loss of productivity, and increased morbidity and mortality, attempts at defining those at risk and instituting appropriate therapies should be a goal for those with CD.[62–66]

Our study has several limitations. Not all participants in our CD registry had DXA available and it is possible that our results are influenced by selection bias, though the demographics of those who did and did not have DXA were similar. Our study was conducted at a referral center and it is possible that patients referred may have more severe or complicated disease. We do not have information on baseline transglutaminase antibody levels or changes in them or villous healing with GFD or GFD compliance. Future studies aimed at understanding the relationships among GFD compliance, changes in antibodies, and duodenal pathology and BMD would be helpful to fully elucidate the pathophysiology of skeletal disease in CD. Our study also has several strengths. To our knowledge, this is the largest CD cohort in whom BMD has been measured and we assessed males and females as well as younger and older adults separately.

Additionally, 3-site DXA was obtained and all patients had biopsy confirmed CD. We also assessed the association of biopsy data with BMD.

In conclusion, osteoporosis is common in CD and degree of villous atrophy is associated with lower BMD at the radius. The prevalence of osteoporosis in CD increases with measurement of forearm BMD. Measurement of forearm BMD is particularly useful in men who were more likely to have isolated osteoporosis at the forearm. Recommendations for osteoporosis screening in patients with CD should consider including measurement at the distal one-third radius in addition to the hip and spine.

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Conflicts of interest
The authors disclose no conflicts.