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Research Article

Evaluation of Osteoporosis and Associated Factors in Patients with Type 1 Diabetes Mellitus

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Objective: This paper aims to assess the prevalence of osteoporosis in patients with T1DM by studying the influence of the main risk factors: BMI, calcium intake, vitamin D, lactose intolerance, and BMD, along with the risk of fractures.

Material and Methods: Cross-sectional study in 30 patients with T1DM and 30 normal controls. BMD was measured using DEXA, further calculating BMI, daily calcium intake, and vitamin D levels. Osteoporosis and fracture risk were evaluated by statistical analysis using the data obtained.

Results: Patients with T1DM had lower BMI ($p < 0.001$), lower daily calcium intake ($p < 0.001$), and lower L1-L4 Z scores ($p = 0.002$) compared to controls. High HbA1c was significantly associated with an increased risk of hip fracture (OR = 1.58, $p = 0.022$), and low BMI was also a crucial predictor of increased risk of fracture (OR = 1.49, $p = 0.012$) and osteoporosis (OR = 1.29, $p = 0.018$). It could be seen that lactose intolerance and calcium deficiency considerably increased the risk of osteoporosis and fractures.

Conclusion: Our study underlines the pivotal role of BMI, calcium intake, and lactose intolerance in determining osteoporosis and fracture risk in T1DM patients. Our findings emphasize once more how managing these risk factors by specific interventions may play a key role in preventing osteoporosis and fractures.

Keywords: Type 1 diabetes mellitus, Osteoporosis, Bone mineral density, Fracture risk, Calcium intake, Lactose intolerance, Vitamin D

1. INTRODUCTION

Osteoporosis is an important disease for public health, being characterized by a progressive reduction in bone mass, increasing the risk and incidence of fractures.[1] Both osteoporosis and diabetes mellitus are rising worldwide, contributing to high morbidity and mortality. [2] It is, therefore, crucial to follow up with such patients and their treatment. While T1DM accounts for only a small fraction of all diabetic patients, they are notably affected by diabetes-related complications at a higher prevalence rate.

T1DM is a form of the autoimmune disease characterized by the destruction of pancreatic beta cells.[3] Treatment of T1DM by insulin is needed for successful glycemic control to minimize or evade the complications related to diabetes.[4, 5] In inadequately controlled individuals with T1DM, neuropathy, retinopathy, nephropathy, and cardiovascular complications can occur.[6, 7] Although T1DM is a known secondary cause of osteoporosis, it is under-screened compared to other complications in clinical practice.[8] This will, unfortunately, lead to the patient being seen with osteoporosis only after the disease has progressed to a point beyond which prevention is possible. It mostly results in deterioration in the quality of life and permanent disability secondary to hip and vertebral fractures. This altogether harmed the social lives of people and the economies of countries.[8] Besides, because T1DM patients are younger and diagnosed early, more harm will be felt.

Salari et al. [9] extensively reviewed 86 studies that included about one hundred million participants. The mean prevalence of osteoporosis was 18.3%. In the breakdown of 70 reports, the prevalence of osteoporosis was 23.1% in women and 11.7% in men.

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T1DM in both genders promotes deterioration in the microarchitecture of bone, leading to osteoporosis, characterized by a reduction of bone mineral density.[10] Indeed, anabolic activity is reduced due to the absolute insulin deficiency in T1DM patients. Most patients with T1DM develop the disease when young and usually cannot attain optimal peak bone mass. In addition, hyperglycemia enhances glycosylation of tissues, adversely affecting bone tissue quality.[11] As such, there are higher bone loss and fracture risks in patients with diabetes complications.[11, 12] In fact, T1DM patients in the study by Valerio G. et al. [12] presented with bone mineral density lows, a feature associated with poor glycemic control. As such, this population of patients should be kept under good glycemic control.

Very few studies have been exclusively conducted on T1DM regarding bone mineral densities, though many are present regarding diabetes. Since osteoporosis is considered a disease of advanced age, it can be overlooked in young patients with Type 1 DM. However, many complications, such as osteoporosis, can begin in the early stages in patients with Type 1 DM. Fractures and permanent damage that may occur at an early age both disrupt the patient's comfort of life and cause high costs. This research aims to find the rate of osteoporosis in patients diagnosed with T1DM and assess the role of important factors such as overall calcium intake, vitamin D levels, lactose intolerance, and the risk of fracture.

2. METHODS

This hospital-based cross-sectional study was conducted following approval from the Local Non-Invasive Clinical Research Ethics Committee (Decision No: 2019/02, Date: 30.01.2019). Patients were consecutively selected from our internal medicine and endocrinology outpatient clinics between January 2019 and January 2020. Our study included patients between 18 and 50 with type 1 DM. When selecting patients for the study, patients who did not have other secondary osteoporosis-causing diseases were included. Secondary osteoporosis-causing causes were evaluated in the exclusion criteria. Exclusion criteria included patients with malignancy, chronic renal failure (GFR < 60 ml/min), systemic steroid use, Cushing's disease, hyperthyroidism, a diagnosis of celiac disease, and pregnancy. Patients with a history of bone surgery were not included in the study. Vitamin D levels, in accordance with the literature, were considered sufficient if they were above 20 ng/ml, insufficient if they were between 10 and 20 ng/ml, and deficient if they were below 10 ng/ml. Since vitamin D deficiency is among the causes of secondary osteoporosis, patients with vitamin D insufficiency were not included in our study. The control group consisted of 30 healthy individuals aged between 18 and 50.

The diagnosis of diabetes was made using the American Diabetes Association (ADA) criteria[13]. Antibody-positive patients were included in the study, with results confirmed by repeat testing[14]. Written informed consent was obtained from each participant. Patients were questioned regarding smoking and alcohol consumption, as well as their histories of fractures and lactose intolerance. Daily calcium intake was assessed using the IOF Bone Health Calcium Calculator. Bone mineral density (BMD) was measured at three anatomical sites—total lumbar spine, total hip, and femoral neck—using dual-energy X-ray absorptiometry (DEXA) with a Hologic-Discovery scanner (USA). In our study, the Z score was used for diagnosis in premenopausal women and men under 50 years of age in accordance with the World Health Organization Osteoporosis diagnostic criteria[15]. The FRAX score, which estimates the 10-year probability of fractures, was calculated for each patient. Vitamin D levels were measured using the Beckman Coulter DxI 800 immunoassay, and additional laboratory analyses were performed with a Beckman Coulter AU5800 analyzer.

2.1. Statistical analysis

The data from the study were analyzed using the SPSS 25.0 statistical software. Descriptive statistics were presented as frequencies, percentages, means, and standard deviations. The Pearson chi-square test was employed to compare categorical variables, while the Mann-Whitney U test was used for comparing groups with continuous variables that did not follow a normal distribution. Initially, a univariate analysis was

conducted, followed by a multivariate analysis to account for potential confounding factors. A p-value of less than 0.05 was considered statistically significant.

3. RESULTS

The study included 30 patients with T1DM and 30 healthy controls. Gender distribution was similar between the groups (53.3% male vs. 46.7% female in T1DM; 40.0% male vs. 60.0% female in controls, p = 0.438). The mean age was comparable (32.2 ± 9.5 years vs. 32.7 ± 8.1 years, p = 0.739). Height did not differ significantly between the groups (166.6 ± 10.9 cm vs. 164 ± 9 cm, p = 0.711). However, the T1DM group had a considerably lower mean weight (69.43 ± 11.5 kg vs. 79 ± 11 kg, p = 0.002) and BMI (25.09 ± 4.2 kg/m^2 vs. 28.9 ± 3.3 kg/m^2, p < 0.001). The mean duration of diabetes in the T1DM group was 15.3 ± 12.0 years. Smoking (30.0% vs. 23.3%, p = 0.770) and exercise habits (43.3% vs. 23.3%, p = 0.171) were similar between the groups (Table 1).

Table 1.

Sociodemographic characteristics of the study groups

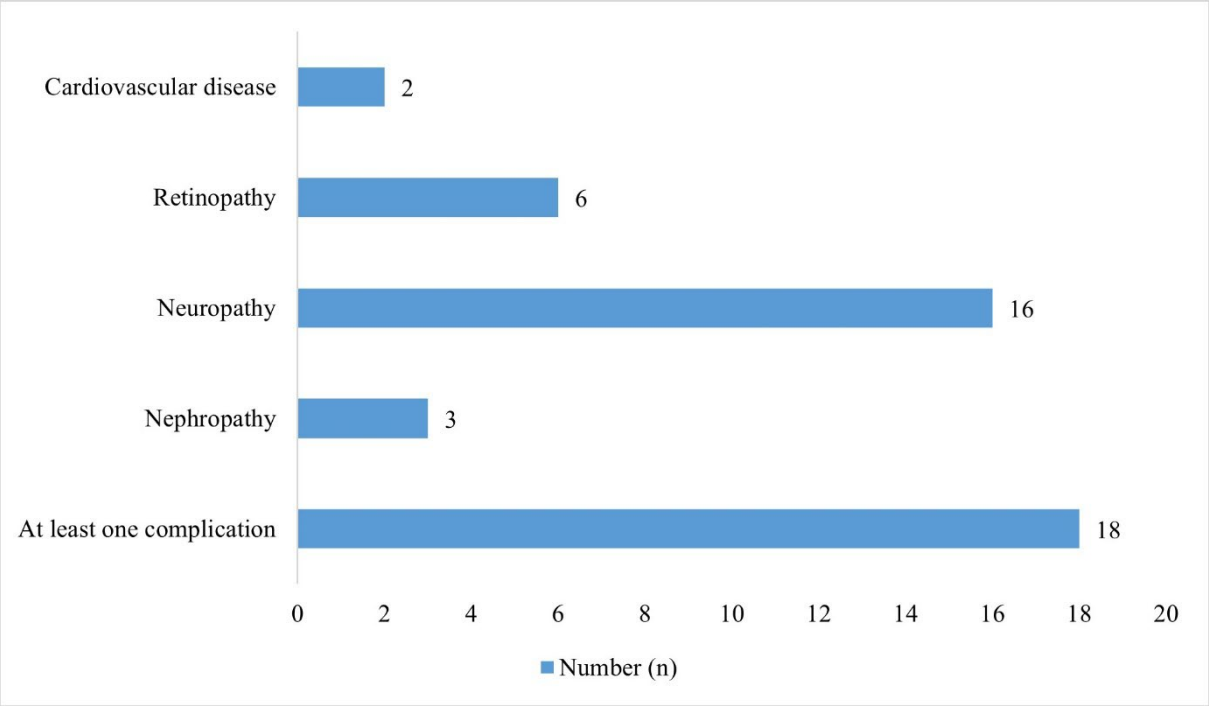
	Type 1 DM (n=30)	Control (n=30)	p
	Mean (±SD)	Mean (±SD)	
Gender, n (%)			
Male	16 (53.3)	12 (40.0)	0.438[a]
Female	14 (46.7)	18 (60.0)	
Age (years)	32.2 ±9.5	32.7±8.1	0.739[b]
Height (cm)	166.6 ±10.9	164 ±9	0.711[b]
Weight (kg)	69.43 ±11.5	79 ±11	0.002[b]
BMI (kg/m²)	25.09 ±4.2	28.9 ±3.3	<0.001[b]
DM duration (years)	15.3 ±12.0	-	-
Smoke, n(%)			
Yes	9 (30.0)	7 (23.3)	0.770[a]
No	21 (70.0)	23 (76.7)	
Exercise, n(%)			
Yes	13 (43.3)	7 (23.3)	0.171[a]
No	17 (56.7)	23 (76.7)	

BMI: body mass index, DM: diabetes mellitus
[a]Chi-square test, [b]Mann Whitney U test

Figure 1 illustrates the distribution of complications among patients with T1DM. The most common complication was neuropathy, affecting 16 patients, followed by retinopathy in 6 patients and nephropathy in 3 patients. Cardiovascular disease was observed in 2 patients. Overall, 18 patients experienced at least one complication (Figure 1).

Figure 1.

Distribution of complications in patients with type 1 DM



The T1DM patients had significantly higher creatinine levels (0.89 ± 0.15 mg/dL vs. 0.77 ± 0.09 mg/dL, p = 0.002) and fasting plasma glucose (FPG) levels (189.8 ± 79.7 mg/dL vs. 79.7 ± 7.0 mg/dL, p < 0.001) compared to the control group. HbA1c was also significantly higher in the T1DM group (8.6 ± 1.8% vs. 5.7 ± 0.2%, p < 0.001). The T1DM group had lower low-density lipoprotein (LDL) levels (108.9 ± 40.4 mg/dL vs. 119.9 ± 12.8 mg/dL, p = 0.005) and triglycerides (TG) (103.3 ± 73.1 mg/dL vs. 127.1 ± 28.5 mg/dL, p < 0.001) compared to controls. No significant differences were found in glomerular filtration rate (GFR) (115.8 ± 25.3 mL/min vs. 110.8 ± 13.8 mL/min, p = 0.156) or hemoglobin (Hgb) levels (14.3 ± 1.7 g/dL vs. 14.0 ± 1.2 g/dL, p = 0.391) (Table 2).

Vitamin D levels were similar between groups (38.5 ± 8.7 mg/dL vs. 34.9 ± 4.6 mg/dL, p = 0.131), but daily calcium intake was significantly lower in the T1DM group (903.23 ± 288.4 mg/dL vs. 1162.7 ± 253.9 mg/dL, p < 0.001). Calcium intake was insufficient in a more significant proportion of T1DM patients (73.3% vs. 30.0%, p = 0.002), and lactose intolerance was more prevalent in the T1DM group (36.7% vs. 10.0%, p = 0.033). Bone mineral density, as assessed by DEXA, showed significantly lower L1-L4 Z scores in the T1DM group (-0.83 ± 1.3 vs. 0.16 ± 0.79, p = 0.002), although femur neck Z scores did not differ significantly (-0.237 ± 1.34 vs. -0.013 ± 0.96, p = 0.283). The T1DM group also had higher FRAX major osteoporosis risk (5.1 ± 2.4% vs. 2.8 ± 1.0%, p < 0.001) and femur fracture risk (1.05 ± 1.4% vs. 0.17 ± 0.2%, p = 0.003) (Table 2).

Table 2.

DEXA results, FRAX risk, and biochemical properties of the study groups

	Type 1 DM (n=30)	Control (n=30)	p*
	Mean (±SD)	Mean (±SD)	
Creatinine (mg/dL)	0.89 ±0.15	0.77 ±0.09	0.002
GFR (ml/dk)	115.8 ±25.3	110.8 ±13.8	0.156
LDL (mg/dL)	108.9 ±40.4	119.9 ±12.8	0.005
TG (mg/dL)	103.3 ±73.1	127.1 ±28.5	<0.001
Hgb (g/dL)	14.3 ±1.7	14.0 ±1.2	0.391
FPG (mg/dL)	189.8 ±79.7	79.7 ±7.0	<0.001
HbA1c (%)	8.6 ±1.8	5.7 ±0.2	<0.001
D vitamin (mg/dL)	38.5±8.7	34.9±4.6	0.131
Daily Ca intake(mg/dL)	903.23±288.4	1162.7±253.9	<0.001
FRAX major osteoporosis risk (%)	5.1±2.4	2.8±1.0	<0.001
FRAX femur fracture risk (%)	1.05±1.4	0.17±0.2	0.003
L1-L4 Z score	-0.83±1.3	0.16±0.79	0.002
Femur neck Z score	-0.237±1.34	-0.013±0.96	0.283
Calcium Intake, n(%)			
Sufficient	8(26.7)	21(70.0)	0.002[a]
Insufficient	22(73.3)	9(30.0)	
Lactose intolerance, n(%)			
Yes	11(36.7)	3(10.0)	0.033[a]
No	19(63.3)	27(90.0)	

LDL: Low-density lipoprotein, Ca: Calcium Hgb: hemoglobin FPG: fasting plasma glucose FRAX: Fracture Risk Assessment Tool, D vitamin: 25-hydroxyvitamin D GFR: Glomerular filtration rate DEXA: Dual-energy X-ray absorptiometry, DM: Diabetes mellitus FRAX: Fracture Risk Assessment Tool
*Mann Whitney U test, [a]Chi-square test

3.1. L1-L4 Z score and related factors in patients with T1DM

In patients with T1DM, L1-L4 Z scores greater than -2 were compared to those with Z scores less than or equal to -2 to identify related factors. The mean BMI was significantly higher in patients with Z scores > -2 (27.5 ± 4.0 kg/m^2 vs. 23.4 ± 3.8 kg/m^2, p = 0.009). The duration of diabetes was shorter in patients with Z scores > -2 (7.2 ± 11.8 years vs. 10.2 ± 7.8 years, p = 0.032). Fasting plasma glucose (FPG) levels were lower in patients with Z scores > -2 (134.8 ± 68.4 mg/dL vs. 190.5 ± 93.5 mg/dL, p = 0.044), as were HbA1c levels (6.9 ± 1.9% vs. 8.4 ± 1.9%, p = 0.019). Patients with Z scores > -2 also had higher LDL levels (118.3 ± 29.4 mg/dL vs. 89.0 ± 24.0 mg/dL, p = 0.004) and higher triglyceride levels (121.0 ± 58.0 mg/dL vs. 77.3 ± 18.2 mg/dL, p = 0.004).

Although age, height, weight, hemoglobin, and GFR were not significantly different between the groups, patients with Z scores > -2 had higher vitamin D levels (37.4 ± 7.4 mg/dL vs. 32.0 ± 0.93 mg/dL, p = 0.050) and greater daily calcium intake (1066.7 ± 293.2 mg vs. 813.3 ± 256.7 mg, p = 0.018) (Table 3).

Table 3.

L1-L4 Z Score and related factors in patients with type 1 DM

	L1-L4 Z score > -2 (n=22)	L1-L4 Z score ≤ -2 (n=8)	p*
	Mean (±SD)	Mean (±SD)	
Age (years)	32.5±8.7	32.6±9.6	0.948
Height (cm)	165.4±9.7	170.6±11.5	0.210
Weight (kg)	75.2±11.5	68.8±16.1	0.322
BMI (kg/m²)	27.5±4	23.4±3.8	0.009
DM time (years)	7.2±11.8	10.2±7.8	0.032
FPG (mg/dL)	134.8±68.4	190.5±93.5	0.044
HbA1c (%)	6.9±1.9	8.4±1.9	0.019
Hemoglobin (g/dL)	14.2±1.5	13.9±1.44	0.550
LDL (mg/dL)	118.3±29.4	89.0±24.0	0.004
Triglycerides (mg(dL)	121.0±58.0	77.3±18.2	0.004
GFR (ml/dk)	113.2±20.4	113.7±24.6	0.965
D vitamin (mg/dL)	37.4±7.4	32.0±0.93	0.050
Ca intake (mg)	1066.7±293.2	813.3±256.7	0.018

Ca: Calcium, DM: Diabetes Mellitus FPG: fasting plasma glucose, D vitamin: 25-hydroxyvitamin D, GFR: glomerular filtration rate

*Mann Whitney U test

3.2. Factors associated with the FRAX femoral neck fracture risk

Factors associated with the FRAX femoral neck fracture risk were analyzed in patients with T1DM. Gender, smoking status, and exercise habits did not show significant differences in fracture risk scores (male: 0.90 ± 1.53 vs. female: 0.36 ± 0.57, p = 0.769; non-smokers: 0.45 ± 0.85 vs. smokers: 1.06 ± 1.67, p = 0.114; no exercise: 0.61 ± 1.11 vs. exercise: 0.61 ± 1.24, p = 0.714). However, the presence of diabetes-related complications was associated with a significantly higher fracture risk (1.40 ± 1.73 vs. 0.27 ± 0.51, p = 0.001). Similarly, patients with insufficient calcium intake had a higher fracture risk (1.03 ± 1.46 vs. 0.16 ± 0.27, p < 0.001), as did those with lactose intolerance (1.89 ± 1.84 vs. 0.22 ± 0.29, p = 0.001). The duration of diabetes did not significantly affect the fracture risk (1-10 years: 1.2 ± 1.74 vs. 11-60 years: 0.95 ± 1.34, p = 0.851) (Table 4).

Table 4.

Factors associated with the risk of FRAX femoral neck fracture risk in patients with type 1 DM

		FRAX femoral neck fracture risk score	p*
		Mean (±SD)	
Gender	**Male**	0.90±1.53	0.769
	Female	0.36±0.57	
Smoke	**No**	0.45±0.85	0.114
	Yes	1.06±1.67	
Exercise	**No**	0.61±1.11	0.714
	Yes	0.61±1.24	
DM Duration (years)	**1-10**	1.2±1.74	0.851
	11-60	0.95±1.34	
Complication	**No**	0.27±0.51	0.001
	Yes	1.40±1.73	

Table 4. (Continued)

Calcium Sufficiency	**No**	1.03±1.46	<0.001
	Yes	0.16±0.27	
Lactose Intolerance	**No**	0.22±0.29	0.001
	Yes	1.89±1.84	

DM: Diabetes Mellitus
*Mann Whitney U test

3.3. The logistic regression analysis for an increased risk of femoral neck fracture

In Model 1, higher body weight was associated with an increased fracture risk (OR = 1.09, 95% CI: 1.00–1.18, p = 0.048). A higher BMI was also a significant predictor of increased fracture risk (OR = 1.49, 95% CI: 1.09–2.04, p = 0.012). Elevated HbA1c levels were significantly associated with a higher fracture risk (OR = 1.58, 95% CI: 1.06–2.33, p = 0.022), as was insufficient calcium intake (OR = 1.007, 95% CI: 1.009–1.014, p = 0.015). The presence of diabetes-related complications dramatically increased the risk of femoral neck fractures (OR = 15.76, 95% CI: 1.68–147.50, p = 0.016). In Model 2, BMI remained a significant predictor of fracture risk (OR = 1.49, 95% CI: 1.09–2.04, p = 0.012), as did calcium intake (OR = 1.01, 95% CI: 1.00–1.02, p = 0.03). Age, height, smoking, exercise, vitamin D levels, and GFR did not significantly correlate with fracture risk in either model (Table 5).

Table 5.

Logistic regression analysis for femoral neck fracture risk and affecting factors

	Model 1				Model 2			
	OR	**95% GA**		**p**	**OR**	**95% GA**		**p**
Age	1.03	0.93	1.13	0.52				
Height	1.05	0.97	1.15	0.19				
Weight	1.09	1.00	1.18	**0.048***				
BMI	1.49	1.09	2.04	**0.012***	1.49	1.09	2.04	**0.012***
Smoke	3.15	0.56	17.57	0.19				
Exercise	1.00	0.16	5.98	1.00				
HbA1c	1.58	1.06	2.33	**0.022***				
D vitamin	1.21	0.92	1.59	0.16				
Ca intake	1.007	1.009	1.014	**0.015***	1.01	1.00	1.02	**0.03***
Complication	15.76	1.68	147.50	**0.016***				
GFR	1.02	0.98	1.06	0.308				

BMI: Body mass index, Ca: Calcium, GFR: Glomerular filtration rate

3.4. The logistic regression analysis for the risk of osteoporosis

In Model 1, higher BMI was significantly associated with an increased risk of osteoporosis (OR = 1.29, 95% CI: 1.04–1.59, p = 0.018). Additionally, insufficient calcium intake was found to be a significant risk factor (OR = 1.004, 95% CI: 1.00–1.007, p = 0.037), and lactose intolerance was strongly associated with an increased risk of osteoporosis (OR = 7.96, 95% CI: 1.60–39.50, p = 0.011).

In Model 2, BMI remained a significant predictor of osteoporosis (OR = 1.24, 95% CI: 1.00–1.54, p = 0.048), as did lactose intolerance (OR = 7.96, 95% CI: 1.60–39.50, p = 0.011). Age, height, weight, smoking, exercise, HbA1c, vitamin D levels, and diabetes-related complications did not significantly correlate with osteoporosis risk in either model (Table 6).

Table 6.

Logistic regression analysis for osteoporosis and affecting factors

	Model 1				Model 2			
	OR	**95% GA**		**P**	**OR**	**95% GA**		**p**
Age	1.00	0.92	1.09	0.97				
Height	1.05	0.97	1.13	0.18				
Weight	0.95	0.89	1.02	0.17				
BMI	1.29	1.04	1.59	**0.018***	- 1.24	1.00	1.54	**0.048***
Smoke	0.30	0.06	1.38	0.12				
Exercise	0.81	0.17	3.7	0.78				
HbA1c	1.38	0.98	1.94	0.06				
D vitamin	0.75	0.56	1.02	0.07				
Ca intake	1.004	1.00	1.007	**0.037***				
Lactose intolerance	7.96	1.60	39.50	**0.011***	- 7.96	1.60	39.50	**0.011***
Complication	2.7	0.59	12.35	0.19				
GFR	1.00	0.96	1.03	0.95				

BMI: Body mass index, Ca: Calcium, GFR: Glomerular filtration rate

4. DISCUSSION

The present study explained several important factors related to the development of femoral neck fractures and osteoporosis in T1DM patients: increased BMI was a strong predictor of heightened risk concerning femoral neck fracture and osteoporosis throughout, underlining the multifaceted effect of adiposity on bone health in this population. In addition, dietary calcium intake and lactose intolerance were strongly associated with an increased risk of osteoporosis. Indeed, poor glycemic control, as manifested by high levels of HbA1c, further complicated by the presence of diabetes-related complications, was associated with an increased risk of fractures of the femoral neck. These findings emphasize the need for targeted interventions on BMI management, adequate intake of calcium, and lactose intolerance to reduce the risk of osteoporosis and subsequent fractures in patients with T1DM. Further discussion will be conducted on the wider clinical implications of such associations, which may inform potential preventative strategies. T1DM is a rapidly rising incidence condition where insulin deficiency is at the core and is associated with many complications, including osteoporosis.

Since impaired bone formation and failure to achieve optimal peak bone mass are major factors, reduced bone strength and increased risk for osteoporosis later in life are typical for T1DM patients.[16] It exerts a negative effect on bone development through several mechanisms: suppression of the expression of genes critical for osteoblast maturation [17], a direct inhibiting effect on bone formation, increasing the expression of proinflammatory cytokines that impede osteoblast differentiation, and increased osteoblastic apoptosis.[18] Moreover, hyperglycemia increases osteoclast activity through the production of free oxygen radicals.[19] The consequence of chronic hyperglycemia is the development of microvascular complications: neuropathy, retinopathy, and nephropathy.[20] Additionally, it can aggravate the condition of osteoporosis by encouraging increased protein loss.[21]

T1DM is related to poor bone quality and an increased risk of fractures. While most studies report lower BMD in patients with T1DM, some studies did not find any significant effect on the measurements of BMD. According to the results of DEXA in 30 patients with T1DM, our study showed that the L1-L4 Z score was below -1 in 15 patients (50%) and below -2 in 8 patients (26.7%). Our results also demonstrate that, compared with controls, L1-L4 Z scores were significantly lower in our T1DM patients. Similar to this study, Gunczler et al. [22] found reduced BMD in T1DM

patients, with 45% of L2-L4 Z scores below -1. Similarly, Valerio et al. [12] showed that 37% of L1-L4 Z scores were below -1, and 11% were below -2 in T1DM patients. Our results of DEXA are in concordance with the literature, corroborating that BMD is decreased in patients with T1DM.

Both cross-sectional and longitudinal studies have shown that poor glycemic control in T1DM patients is significantly associated with an increased risk of the development of osteoporosis and fractures.[23, 24] For example, Heilman et al. [25] reported that poor glycemic control, linked with higher levels of HbA1c, was significantly associated with increased risk for osteoporosis in patients with T1DM. Our regression analysis surprisingly did show that those subjects presenting with higher levels of HbA1c had a significantly higher risk for hip fractures. In the study conducted by Brandao et al., they found that bone mineral density was worse in type 1 Diabetes patients with poor metabolic control, and BMD was inversely correlated with HbA1c[26].

Another critical factor affecting BMD is BMI. It has been found that a lower BMI is associated with an increased risk of osteoporosis because adipose tissue exerts its action by providing mechanical loading and adipocytokines, which increase BMD. As patients with T1DM usually have a lower BMI, their likelihood of developing osteoporosis and fractures is thereby increased[27]. This is supported by the study of Bridges MJ et al. [28], which found a significant relationship with increased BMI and increased BMD. In the study conducted by Tuominenin et al. [29], lower BMD was found in patients with type 1 DM. When the factors associated with lower BMD were evaluated, BMI was lower in patients with type 1 DM, and it has been associated with low BMI and low BMD in the literature. In our study, BMI was indeed lower in patients with T1DM, and this was associated with an increased risk of hip fractures and lower BMD.

Prolonged hyperglycemia can cause microvascular complications that may contribute to bone density loss through many mechanisms. Conditions like retinopathy and neuropathy could also predispose the patients to a great chance of falling and, consequently, increase the risk of fractures.[30, 31] Eller-Vainicher et al. [32] demonstrated a lower BMD in patients with chronic complications, consistent with our findings.

Lower BMD was also associated with lower vitamin D levels in our study. However, in terms of the risk for hip fracture, our regression analysis did not find any significant relationship with the level of vitamin D. This finding is in partial agreement with that of Wierzbicka et al. [33], who reported a positive association of vitamin D level with muscle mass. While the need for vitamin D supplementation to prevent complications of diseases has been emphasized, how T1DM affects vitamin D metabolism has been underexamined in the literature, and more investigation is needed.

Although a few studies have been conducted linking low daily calcium intake with osteoporosis, there are not enough studies performed on patients with T1DM.[34] Maggio et al. [35] demonstrated that the daily calcium intake was insufficient in patients with T1DM and underlined the importance of adequate calcium intake. In the current study, the daily calcium intake was also significantly lower in T1DM patients compared to the control group. Moreover, the subjects with low calcium intake had lower BMD and increased risk of femoral hip fractures, which places our study among the first studies in this field.

Another determinant of osteoporosis in patients with T1DM is lactose intolerance. While the association between lactose intolerance and osteoporosis is well-established in the general population, there is a lack of studies in patients with T1DM. Honkanen et al. [36] observed a lower BMD in lactose-intolerant subjects, which was explained by their lower calcium intake. This is further supported by our results, in that we have found increased osteoporosis and hip fracture risk among the T1DM patients with lactose intolerance, with great importance given to ensuring that enough calcium intake protects against such risks.

5. CONCLUSION

In summary, our study shows the multifactorial nature of bone health in patients with T1DM. It

underscores the critical role of glycemic control, BMI, calcium intake, and lactose intolerance in determining bone mineral density and fracture risk. While much of the previous work has centered primarily on the general diabetic population, our results strongly emphasize the peculiar susceptibilities of patients with T1DM concerning osteoporosis development and femoral neck fractures. Identifying low BMI, insufficient calcium intake, and lactose intolerance as major risk factors underline the requirement for focused interventions to prevent bone loss in this population. It is finally noted that vitamin D metabolism has not been well studied in T1DM patients and its role in bone health points toward areas for future investigation. Our study contributes to the growing body of evidence that calls for comprehensive management strategies in T1DM to mitigate the long-term complications associated with compromised bone health.

Limitations

Our sample size is relatively small due to the lower prevalence of T1DM in the general population, which inherently limits the availability of eligible participants for the study.

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by authors.

Copyright Statement

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