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Original Research Article

COMPARATIVE EVALUATION OF BONE MINERAL DENSITY IN PATIENTS WITH TYPE 2 DIABETES MELLITUS AND NON-DIABETIC INDIVIDUALS USING QUANTITATIVE ULTRASOUND

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ABSTRACT

Background: Type 2 Diabetes Mellitus (T2DM) is associated with several metabolic complications, including alterations in bone metabolism and skeletal strength. Bone mineral density (BMD) may be affected by chronic hyperglycaemia, increasing age, disease duration and other metabolic factors. Quantitative ultrasound (QUS) provides a simple, non-invasive and radiation-free method for assessing bone health.

Aim: To comparatively evaluate bone mineral density in patients with Type 2 Diabetes Mellitus and non-diabetic individuals using quantitative ultrasound and to assess its association with clinical and biochemical parameters.

Materials and Methods: This cross-sectional comparative case-control study was conducted in the Department of General Medicine, Khaja Banda Nawaz Teaching and General Hospital, Kalaburagi, over 18 months. A total of 124 participants were included, comprising 62 patients with T2DM of at least five years' duration and 62 non-diabetic controls, aged 30–65 years. BMD was assessed using QUS and classified as normal, osteopenia or osteoporosis based on T-score. Glycaemic, haematological and selected biochemical parameters were recorded. Data were analysed using independent-samples t-test, chi-square test and correlation analysis, with $p<0.05$ considered statistically significant.

Results: Osteopenia was observed in 83.9% of participants with T2DM compared with 69.4% of non-diabetic participants, while osteoporosis was present in 8.1% and 3.2%, respectively. Diabetic status was significantly associated with QUS bone status category ($p=0.011$). The mean QUS T-score was significantly lower in the T2DM group than in the non-diabetic group (-1.78 ± 0.48 vs. -1.53 ± 0.54; $p=0.009$). FBS, PPBS, and HbA1c were significantly higher among participants with T2DM (all $p<0.001$), whereas hemoglobin did not differ significantly between the groups ($p=0.124$). Age was significantly associated with bone status ($p=0.002$), while sex was not significantly associated ($p=0.362$). QUS T-score showed significant negative correlations with FBS ($r=-0.238$, $p=0.008$), PPBS ($r=-0.293$, $p<0.001$), HbA1c ($r=-0.275$, $p=0.002$), and duration of diabetes ($r=-0.284$, $p=0.008$).

Conclusion: Patients with T2DM demonstrated poorer bone mineral density compared with non-diabetic individuals. Increasing age, longer disease duration and poor glycaemic control were associated with reduced QUS T-scores. QUS may serve as a useful screening tool for early identification of skeletal deterioration in diabetic patients.

Key words: Type 2 Diabetes Mellitus; Bone Mineral Density; Quantitative Ultrasound; Osteopenia; Osteoporosis.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycaemia resulting from insulin resistance, progressive impairment of pancreatic β-cell function, or a combination of both. It is associated with a wide spectrum of microvascular and macrovascular complications and has become an important cause of long-term morbidity worldwide. In addition to the commonly recognized complications involving the cardiovascular system, kidneys, retina and peripheral nerves, increasing attention has been directed toward the adverse effects of diabetes on the musculoskeletal system. Alterations in bone metabolism, bone mineral density (BMD), bone microarchitecture and skeletal strength are increasingly recognized as clinically relevant manifestations of T2DM. Osteopenia, osteoporosis and fragility fractures can adversely affect mobility, independence and quality of life, particularly in individuals with prolonged diabetes and advancing age.[1] Bone is a metabolically active tissue that undergoes continuous remodelling through the coordinated actions of osteoblasts, osteoclasts and osteocytes. Normal bone strength depends not only on the amount of mineral present but also on cortical and trabecular architecture, collagen quality, mineralization and the balance between bone formation and resorption. Diabetes may disturb these processes through several metabolic pathways. Chronic hyperglycaemia promotes oxidative stress, inflammation and accumulation of advanced glycation end products within the bone matrix. These alterations may impair collagen properties, osteoblast differentiation and bone formation. Insulin resistance, changes in adipokines and disturbances in bone-regulating factors may further contribute to impaired skeletal homeostasis. Consequently, assessment of skeletal health has become increasingly important as part of the comprehensive evaluation of patients with T2DM.[2] The relationship between T2DM and BMD is complex. Unlike several forms of secondary osteoporosis in which reduced BMD clearly explains increased skeletal fragility, patients with T2DM may have normal, reduced or even relatively preserved BMD while still remaining susceptible to fractures. This apparent paradox emphasizes that BMD alone may not completely represent bone strength in diabetes. Diabetes-related deterioration of bone material properties and microarchitecture, together with complications such as neuropathy, visual impairment, muscle weakness and impaired balance, may contribute to skeletal vulnerability. Therefore, techniques capable of evaluating bone characteristics beyond conventional density measurements may provide additional information about bone health in diabetic individuals.[3] Diabetic bone fragility is considered multifactorial and may develop through interacting cellular, metabolic and vascular mechanisms. Persistent hyperglycaemia can modify proteins within the extracellular bone matrix and interfere with normal collagen cross-linking. Reduced bone turnover, altered osteocyte function, microvascular disease and impaired skeletal repair may further compromise bone quality. Ageing, duration of diabetes, glycaemic control, body composition, nutritional status, physical inactivity and the presence of diabetic complications can modify these effects. Certain glucose-lowering therapies may also influence skeletal metabolism. These considerations highlight the need to evaluate bone health in T2DM using approaches that take into account both bone quantity and characteristics related to bone quality.[4] Dual-energy X-ray absorptiometry (DXA) is widely accepted for clinical measurement of BMD and for classification of osteoporosis; however, its interpretation in patients with T2DM may present challenges because fracture susceptibility can be underestimated when BMD appears relatively preserved. Assessment strategies for diabetic skeletal disease therefore require consideration of additional clinical risk factors and complementary techniques. Quantitative ultrasound (QUS) offers a non-invasive method for evaluating skeletal characteristics without ionizing radiation. It is portable, relatively inexpensive and suitable for repeated assessment. Ultrasound parameters reflect the transmission of sound through bone and may provide information influenced by mineral content, elasticity and structural organization. These features make QUS particularly attractive as a screening and comparative assessment tool in clinical populations where access to conventional densitometry may be limited.[5] The growing recognition of osteoporosis and skeletal fragility in people with diabetes has created a need for practical approaches that can identify individuals at risk before the occurrence of fractures. Diabetes-related bone disease may remain clinically silent for a prolonged period, and routine evaluation of bone health is not always incorporated into diabetes care. Early identification of reduced bone density may facilitate timely lifestyle modification, nutritional optimization, correction of reversible risk factors and appropriate therapeutic intervention. Comparative assessment of diabetic and non-diabetic individuals may also help clarify the extent to which disturbances in glucose metabolism are associated with alterations in skeletal status.[6]

MATERIALS AND METHODS

This cross-sectional comparative case-control study was conducted in the Department of General Medicine, Khaja Banda Nawaz Teaching and General Hospital, Kalaburagi. The study was carried out over a period of 18 months, from 1 March 2024 to 30 September 2025. Patients attending the Department of General Medicine as outpatients or inpatients during the study period were considered for inclusion. The study population was divided into two groups comprising patients with Type 2 Diabetes Mellitus and non-diabetic individuals. A convenience sampling method was used to recruit eligible

participants. The total sample size was 124 participants, comprising 62 cases and 62 controls.

Eligibility Criteria

Patients of either sex aged more than 30 years and up to 65 years were included in the study. The case group consisted of patients diagnosed with Type 2 Diabetes Mellitus for at least five years, whereas the control group consisted of non-diabetic individuals. Patients with chronic kidney disease, ischemic heart disease, primary hyperparathyroidism, hyperthyroidism, malabsorption syndromes, malignant diseases, inflammatory joint diseases, or a history of immunosuppressant drug therapy were excluded. Women with a history of hysterectomy or those receiving steroid therapy or hormone replacement therapy were also excluded. Participants taking calcium or vitamin D supplements were not included in the study.

Methodology

After obtaining informed consent, eligible participants were enrolled following the application of the inclusion and exclusion criteria. Information was collected using a semi-structured proforma. A detailed history regarding age, sex, clinical condition, associated comorbidities such as diabetes mellitus and hypertension, and drug use was recorded. A general physical examination was performed, followed by a systemic examination. Bone mineral density was assessed using quantitative ultrasound. The QUS-based T-score was classified as osteoporosis when the score was ≤ -2.5, osteopenia when the score ranged from -1.0 to -2.4, and normal bone mineral density when the score was ≥ -1.0. The investigations included complete blood count, quantitative ultrasound, glycated haemoglobin, fasting blood sugar, postprandial blood sugar, serum calcium, and X-ray of the long bones. Liver function tests, renal function tests, and lipid profiles were performed whenever required.

Statistical Analysis

The collected data were analysed using appropriate statistical methods. Frequencies and proportions were used to describe demographic characteristics, clinical features, and categories of bone mineral density. Continuous variables, including BMD and laboratory parameters, were expressed as mean and standard deviation. The independent-samples t-test was used to compare mean BMD and blood parameters between diabetic and non-diabetic participants. The chi-square test was applied to determine the association of BMD categories with clinical and demographic factors. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 124 participants were included in the study. The age distribution showed that the highest proportion of participants belonged to the age groups of 36–40 years and 46–50 years, with 23 participants each, accounting for 18.5% of the total study population in each group. This was followed by the 56–60-year age group, which included 19 participants (15.3%). The age groups of 51–55 years and 61–65 years each comprised 17 participants (13.7%), while 16 participants (12.9%) were aged between 41 and 45 years. The smallest proportion was observed in the 30–35-year age group, with 9 participants (7.3%). Regarding sex distribution, males constituted a slightly higher proportion of the study population, with 68 participants (54.8%), whereas females accounted for 56 participants (45.2%). (Table 1)

Among the 124 participants, 62 were patients with Type 2 Diabetes Mellitus and 62 were non-diabetic individuals. Osteopenia was the most common bone mineral density abnormality in both groups. It was observed in 52 diabetic participants (83.9%) compared with 43 non-diabetic participants (69.4%). Osteoporosis was also more frequent among participants with Type 2 Diabetes Mellitus, affecting 5 individuals (8.1%), whereas only 2 non-diabetic individuals (3.2%) had osteoporosis. Normal bone mineral density was found in 3 participants (4.8%) in each group. The bone density result could not be classified in 14 non-diabetic participants (22.6%) and 2 diabetic participants (3.2%). Overall, osteopenia was present in 95 participants (76.6%), osteoporosis in 7 participants (5.6%), normal bone mineral density in 6 participants (4.8%), and unclassified results in 16 participants (12.9%). The association between diabetic status and bone mineral density category was statistically significant, with a chi-square value of 11.138, 3 degrees of freedom, and a p-value of 0.011. (Table 2)

Table 3 compares the QUS T-score and selected biochemical parameters between participants with type 2 diabetes mellitus (T2DM) and non-diabetic participants. The mean QUS T-score in the T2DM group was -1.78 ± 0.48, whereas it was -1.53 ± 0.54 in the non-diabetic group. The difference between the two groups was statistically significant, with a t-value of -2.661 and p-value of 0.009. The mean hemoglobin level was 13.38 ± 1.54 in participants with T2DM compared with 12.83 ± 2.35 in non-diabetic participants. Although the mean hemoglobin level was numerically higher in the T2DM group, the difference was not statistically significant ($t = 1.549$, $p = 0.124$). A marked difference was observed in fasting blood sugar (FBS) levels. The mean FBS level was 177.06 ± 39.25 in the T2DM group and 91.85 ± 5.18 in the non-diabetic group. The difference was highly statistically significant, with a t-value of 16.949 and p-value <0.001. Similarly, the mean postprandial blood sugar (PPBS) level was substantially higher among participants with T2DM. The mean PPBS was 237.18 ± 64.53 in the T2DM group compared with 112.37 ± 19.77 in the non-diabetic group. This difference was highly statistically significant ($t = 14.561$, $p < 0.001$), indicating a significantly higher postprandial blood glucose level in the T2DM group. The mean HbA1c level also showed a highly significant difference between the two groups. Participants with T2DM had

a mean HbA1c of 8.91 ± 1.30, while non-diabetic participants had a mean value of 5.42 ± 0.37. The difference was highly statistically significant, with a t-value of 20.364 and p-value <0.001. (Table 3)

A statistically significant association was observed between age group and bone mineral density status ($\chi^2 = 40.651$, df = 18, p = 0.002). Among participants aged 30–35 years, osteopenia was present in 4 individuals (44.4%), while 2 (22.2%) had normal bone mineral density and 3 (33.3%) had unclassified results. No case of osteoporosis was observed in this age group. Among those aged 36–40 years, 12 participants (52.2%) had osteopenia, 3 (13.0%) had normal bone mineral density, and 8 (34.8%) had unclassified results. Osteoporosis was not observed in this age group.

In the 41–45-year age group, osteopenia was present in 15 participants (93.8%), while 1 participant (6.3%) had an unclassified result. No participant in this age group had normal bone mineral density or osteoporosis. Among participants aged 46–50 years, 20 (87.0%) had osteopenia and 1 (4.3%) had osteoporosis, while 2 (8.7%) had unclassified findings. In the 51–55-year age group, 14 participants (82.4%) had osteopenia, 1 (5.9%) had osteoporosis, 1 (5.9%) had normal bone mineral density, and 1 (5.9%) had an unclassified result.

Among participants aged 56–60 years, osteopenia was observed in 16 individuals (84.2%) and osteoporosis in 2 individuals (10.5%), while 1 participant (5.3%) had an unclassified result. In the oldest age group of 61–65 years, 14 participants (82.4%) had osteopenia and 3 participants (17.6%) had osteoporosis. No participant in this age group had normal or unclassified bone mineral density. Overall, osteopenia was the predominant finding across nearly all age groups. The proportion of osteoporosis increased progressively in the older age groups, reaching its highest level among participants aged 61–65 years. (Table 4)

Among the 56 female participants, 42 (75.0%) had osteopenia, 4 (7.1%) had osteoporosis, 1 (1.8%) had normal bone mineral density, and 9 (16.1%) had unclassified findings. Among the 68 male participants, 53 (77.9%) had osteopenia, 3 (4.4%) had osteoporosis, 5 (7.4%) had normal bone mineral density, and 7 (10.3%) had unclassified findings. Osteopenia was therefore highly prevalent in both sexes and was slightly more frequent among males. However, osteoporosis was comparatively more common among females than males. Normal bone mineral density was more frequently observed among males than females. Despite these differences, the association between sex and bone mineral density status was not statistically significant ($\chi^2 = 3.202$, df = 3, p = 0.362). (Table 5)

Table 6 presents the correlation analysis between QUS T-score and glycemic parameters, including fasting blood sugar (FBS), postprandial blood sugar (PPBS), and HbA1c. All three parameters showed a statistically significant negative correlation with the QUS T-score, indicating that higher glycemic values were associated with lower QUS T-scores. FBS showed a negative correlation with QUS T-score, with a correlation coefficient of r = −0.238. This correlation was statistically significant, with a p-value of 0.008. The negative value of the correlation coefficient indicates an inverse relationship between FBS and QUS T-score, where an increase in FBS was associated with a decrease in the QUS T-score. PPBS demonstrated the strongest negative correlation with QUS T-score among the three parameters assessed. The correlation coefficient was r = −0.293, with a p-value <0.001, indicating a highly statistically significant inverse relationship. Thus, higher PPBS values were associated with lower QUS T-scores. HbA1c also showed a statistically significant negative correlation with QUS T-score. The correlation coefficient was r = −0.275, with a p-value of 0.002. Overall, FBS, PPBS, and HbA1c were all significantly and negatively correlated with QUS T-score. Among these variables, PPBS showed the strongest negative correlation (r = −0.293), followed by HbA1c (r = −0.275) and FBS (r = −0.238). All three associations were statistically significant, with p-values below 0.05. (Table 6)

Table 1: Distribution of Participants According to Demographic Characteristics

Characteristic	Category	Frequency (n)	Percentage (%)
Age group (years)	30–35	9	7.3
	36–40	23	18.5
	41–45	16	12.9
	46–50	23	18.5
	51–55	17	13.7
	56–60	19	15.3
	61–65	17	13.7
Sex	Female	56	45.2
	Male	68	54.8
Total		124	100.0

Table 2: Association Between Bone Mineral Density Status and Diabetic Status

Bone Density Result	Non-Diabetic, n (%)	T2DM, n (%)	Total, n (%)	χ^2	df	p-value
Not classified	14 (22.6)	2 (3.2)	16 (12.9)	11.138	3	0.011
Normal	3 (4.8)	3 (4.8)	6 (4.8)			
Osteopenia	43 (69.4)	52 (83.9)	95 (76.6)			
Osteoporosis	2 (3.2)	5 (8.1)	7 (5.6)			
Total	62 (100.0)	62 (100.0)	124 (100.0)			

Table 3: Comparison of QUS and Biochemical Parameters Between T2DM and Non-Diabetic Participants

Variable	T2DM, Mean ± SD	Non-Diabetic, Mean ± SD	t-value	p-value
QUS T-score	−1.78 ± 0.48	−1.53 ± 0.54	−2.661	0.009
Hemoglobin (Hb)	13.38 ± 1.54	12.83 ± 2.35	1.549	0.124
FBS	177.06 ± 39.25	91.85 ± 5.18	16.949	<0.001
PPBS	237.18 ± 64.53	112.37 ± 19.77	14.561	<0.001
HbA1c	8.91 ± 1.30	5.42 ± 0.37	20.364	<0.001

Table 4: Association Between Age Group and Bone Mineral Density Status

Age Group (years)	Not Classified, n (%)	Normal, n (%)	Osteopenia, n (%)	Osteoporosis, n (%)	Total, n (%)	χ^2	df	p-value
30–35	3 (33.3)	2 (22.2)	4 (44.4)	0 (0.0)	9 (7.3)	40.651	18	0.002
36–40	8 (34.8)	3 (13.0)	12 (52.2)	0 (0.0)	23 (18.5)			
41–45	1 (6.3)	0 (0.0)	15 (93.8)	0 (0.0)	16 (12.9)			
46–50	2 (8.7)	0 (0.0)	20 (87.0)	1 (4.3)	23 (18.5)			
51–55	1 (5.9)	1 (5.9)	14 (82.4)	1 (5.9)	17 (13.7)			
56–60	1 (5.3)	0 (0.0)	16 (84.2)	2 (10.5)	19 (15.3)			
61–65	0 (0.0)	0 (0.0)	14 (82.4)	3 (17.6)	17 (13.7)			
Total	16 (12.9)	6 (4.8)	95 (76.6)	7 (5.6)	124 (100.0)			

Table 5: Association Between Sex and Bone Mineral Density Status

Sex	Not Classified, n (%)	Normal, n (%)	Osteopenia, n (%)	Osteoporosis, n (%)	Total, n (%)	χ^2	df	p-value
Female	9 (16.1)	1 (1.8)	42 (75.0)	4 (7.1)	56 (45.2)	3.202	3	0.362
Male	7 (10.3)	5 (7.4)	53 (77.9)	3 (4.4)	68 (54.8)			
Total	16 (12.9)	6 (4.8)	95 (76.6)	7 (5.6)	124 (100.0)			

Table 6: Correlation Analysis of Factors Associated with QUS T-Score

Variable	Correlation Coefficient (r)	p-value
FBS	−0.238	0.008
PPBS	−0.293	<0.001
HbA1c	−0.275	0.002

DISCUSSION

The present study included 124 participants, with equal numbers of T2DM patients and non-diabetic controls. The largest proportions were observed in the 36–40-year and 46–50-year age groups (18.5% each), while males constituted 54.8% and females 45.2% of the study population. These demographic characteristics were broadly comparable with the Indian study by Khandelwal et al. (2023), who evaluated 850 individuals comprising 425 patients with T2DM and 425 non-diabetic controls. Their diabetic and control groups had mean ages of 42.21 ± 10.5 and 42.18 ± 10.4 years, respectively, with no significant age difference (p=0.786). They also reported male-to-female ratios of 316:109 among diabetics and 279:146 among controls. Thus, similar to the present investigation, their population consisted predominantly of middle-aged adults with a male predominance. The comparable age distribution is particularly relevant because age is an important determinant of bone mass and could otherwise confound comparisons between diabetic and non-diabetic individuals.[7] In the present study, osteopenia represented the predominant bone abnormality, being detected in 83.9% of T2DM patients compared with 69.4% of non-diabetic participants. Osteoporosis was also more frequent among diabetics than controls (8.1% vs. 3.2%), and the overall association between diabetic status and QUS category was statistically significant (χ^2=11.138, p=0.011). Abdulameer et al. (2018) similarly evaluated bone status by heel quantitative ultrasound in 450 Malaysian patients with T2DM and reported that approximately 82% were at high risk of abnormal BMD. Their mean QUS T-scores were −0.41 ± 0.44 among participants with normal bone status, −1.65 ± 0.39 among those with osteopenia, and −2.76 ± 0.27 among those with osteoporosis. They further demonstrated significant associations of QUS measures with demographic and diabetes-related characteristics. The high proportion of abnormal bone status in their study is therefore consistent with the 92.0% combined prevalence of osteopenia and osteoporosis among the classified diabetic participants in the present study, supporting a substantial burden of impaired skeletal health in T2DM.[8] A major finding of the present study was the significantly lower mean QUS T-score in T2DM patients compared with non-diabetic individuals (−1.78 ± 0.48 vs. −1.53 ± 0.54; t=−2.661, p=0.009), suggesting comparatively poorer bone status in diabetes. However, published findings regarding BMD in T2DM are not uniform. Kamalanathan et al. (2014) evaluated 194 Asian Indian patients with T2DM, including 97 men and 97 women, and compared them with 571 non-diabetic controls. They reported normal BMD in 156 diabetic participants (80.5%) and low BMD in 38 (19.5%). Interestingly, DXA-measured BMD at the hip and spine was

initially significantly higher in diabetic subjects than controls, although this difference disappeared when participants were matched for BMI. Therefore, their findings differ from the lower QUS T-scores observed in the present study. This discrepancy may be related to differences in the skeletal site examined, measurement technique (DXA versus QUS), BMI distribution, age, disease duration and other metabolic characteristics.[9] The biochemical comparison in the present study demonstrated markedly poorer glycaemic control among T2DM participants. Mean FBS was 177.06 ± 39.25 mg/dL compared with 91.85 ± 5.18 mg/dL in non-diabetic controls, while mean PPBS was 237.18 ± 64.53 mg/dL compared with 112.37 ± 19.77 mg/dL, and mean HbA1c was 8.91 ± 1.30% compared with 5.42 ± 0.37%**.** All three glycaemic parameters differed highly significantly between the groups ($p<0.001$). The mean hemoglobin level was 13.38 ± 1.54 in T2DM participants and 12.83 ± 2.35 in non-diabetic participants; however, this difference was not statistically significant ($p=0.124$). Together with the significantly lower QUS T-score in the T2DM group, these findings indicate that participants with diabetes had substantially higher glycaemic indices along with poorer quantitative ultrasound bone measurements. Arikan et al. (2012) similarly demonstrated a relationship between adverse metabolic status and skeletal health in T2DM. Among diabetic subjects, fasting glucose was 160.1 ± 77.0 mg/dL in those with lower insulin resistance and 195.1 ± 58.9 mg/dL in those with greater insulin resistance; corresponding HbA1c values were 10.5 ± 3.3% and 11.3 ± 2.5%. Importantly, the more insulin-resistant group had significantly lower lumbar T-scores ($p=0.020$) and BMD ($p=0.033$), supporting an adverse relationship between metabolic dysfunction and bone status.[10] Age demonstrated a strong relationship with bone status in the present investigation ($\chi^2=40.651$, $p=0.002$). Osteoporosis was absent in participants aged 30–40 years but progressively appeared in the older groups, occurring in 4.3% of those aged 46–50 years, 5.9% at 51–55 years, 10.5% at 56–60 years and 17.6% at 61–65 years. Osteopenia was also highly prevalent in the older age categories. Tang et al. (2020) evaluated 1,474 patients with T2DM aged 45–85 years, comprising 817 males and 657 females, and similarly identified age-related deterioration in bone health. Femoral-neck BMD decreased with increasing age among males, while BMD at all evaluated skeletal sites decreased with age among females. Their findings therefore reinforce the significant age-related pattern identified in the present study. The progressive increase in osteoporosis observed in the current population is biologically plausible because ageing is associated with reduced osteoblast activity, hormonal alterations, reduced muscle mass and cumulative exposure to diabetes-related metabolic disturbances.[11] With regard to sex, the present study found osteopenia in 75.0% of females and 77.9% of males, whereas osteoporosis occurred in 7.1% of females and 4.4% of males. Although osteoporosis was numerically more frequent among women, the overall association between sex and QUS bone status was not statistically significant ($\chi^2=3.202$, $p=0.362$). Xu et al. (2020), in contrast, demonstrated a clearer sex difference among 1,222 patients with T2DM aged ≥50 years. The overall prevalence of osteoporosis and osteopenia in their study was 9.2% and 41.3%, respectively; osteoporosis was substantially more frequent in females than males (14.7% vs. 2.8%), as was osteopenia (48.5% vs. 33.0%).[12] The present study further demonstrated a significant negative correlation between duration of diabetes and QUS T-score ($r=-0.284$, $p=0.008$), indicating deterioration in bone status with longer exposure to T2DM. This finding is supported by Jang et al. (2018), who analysed 3,383 Korean men aged ≥50 years and specifically examined the effect of diabetes duration on BMD. Among 505 diabetic men included in the duration analysis, femoral-neck BMD was 0.786 ± 0.009 g/cm² in those with diabetes for ≤5 years compared with 0.746 ± 0.008 g/cm² in those with diabetes for >5 years ($p=0.001$), while total-hip BMD was 0.968 ± 0.009 versus 0.940 ± 0.008 g/cm² ($p=0.026$). After multivariable adjustment, femoral-neck BMD remained significantly lower in those with diabetes for >5 years (0.738 ± 0.004 vs. 0.773 ± 0.004 g/cm², $p=0.018$).[13] Correlation analysis in the present study showed statistically significant inverse relationships between QUS T-score and all three evaluated glycaemic parameters. FBS demonstrated a negative correlation with QUS T-score ($r=-0.238$, $p=0.008$), while PPBS showed the strongest inverse correlation ($r=-0.293$, $p<0.001$). HbA1c was also negatively correlated with QUS T-score ($r=-0.275$, $p=0.002$). These findings indicate that increasing fasting glucose, postprandial glucose and long-term glycaemic levels were associated with progressively lower QUS T-scores. Conti et al. (2017) evaluated calcaneal QUS in 400 diabetic patients and likewise demonstrated relationships between QUS parameters and metabolic characteristics. In their T2DM subgroup, QUS measurements correlated significantly with age, HbA1c, triglycerides, HDL cholesterol, serum creatinine and other clinical variables. In multivariable analysis of the whole cohort, age was independently negatively associated with estimated BMD ($\beta=-0.236$, $p=0.001$), while HbA1c remained independently associated with estimated BMD ($\beta=0.148$, $p=0.043$).[14]

CONCLUSION

The study demonstrated that patients with Type 2 Diabetes Mellitus had significantly lower QUS T-scores and a higher prevalence of osteopenia and osteoporosis compared with non-diabetic individuals. Increasing age, longer duration of diabetes, and poor glycaemic control were significantly associated with worsening bone mineral density. Quantitative ultrasound proved to be a useful, non-invasive and accessible method for

assessing bone health in diabetic patients. Early screening and appropriate preventive measures may help reduce the risk of future skeletal complications in this population.

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