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Investigation of Vitamin D, Bone Turnover Markers, Mineral Levels, and their Association with Hba1c and RBC Count in Type 2 Diabetes

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Annotation: This case-control study enrolled 219 individuals aged 40–80 years, including 149 diabetic patients and 70 healthy controls, categorized into three groups: diabetic patients without osteoporosis (G1), diabetic patients with osteoporosis (G2), and healthy individuals (G3). Participants were recruited from hospitals and clinics in Kirkuk, Iraq, between November 2024 and May 2025, and individuals with major systemic diseases were excluded. Blood samples were collected after overnight fasting and analyzed for fasting blood sugar (FBS), HbA1c, Vitamin D3, Ca^{2+}, Mg^{2+}, ALP, and Zn using standard biochemical methods. The results showed significantly higher RBs and HbA1c levels ($P < 0.05$) in diabetic patients (G1+G2) compared to healthy controls (G3), indicating poor glycemic control. While calcium levels did not differ significantly between groups, magnesium, zinc, and vitamin D3 levels were significantly lower in diabetic patients ($P \leq 0.05$). No significant differences were observed in ALP levels ($P > 0.05$). Comparisons between diabetic subgroups revealed that patients with osteoporosis exhibited significantly higher RBs and HbA1c levels ($P \leq 0.05$), and lower serum zinc and vitamin D3 levels ($P < 0.05$), whereas other mineral differences, including ALP, were not statistically significant.

Keywords: Type 2 Diabetes Mellitus

(T2DM), Osteoporosis, Bone Metabolism, Bone Metabolism, Vitamin D3.

Introduction

Diabetes is a metabolic disease with a high prevalence rate and may be associated with various skeletal disorders, such as osteoporosis, osteopenia, Charcot arthropathy, and diabetic foot disease [1]. Among these skeletal disorders, osteoporosis is the most significant metabolic bone disease affecting diabetes patients, who are at a higher risk of developing osteoporosis and fractures [2]. In particular, type 2 diabetes (T2D) and osteoporosis may co-occur in elderly postmenopausal women, significantly increasing their risk of fractures [3]. Type 2 diabetes mellitus (T2DM) can directly impact bone metabolism and strength. Additionally, certain oral hypoglycemic agents may influence bone metabolism in patients with T2DM and osteoporosis, particularly in elderly postmenopausal women, thereby increasing their risk of fractures[4]. Moreover, unlike type 1 diabetes, where osteoporosis or fractures result from decreased bone density, type 2 diabetes is associated with increased bone density but an elevated risk of fractures. Consequently, the traditional criteria for osteoporosis do not apply to patients with type 2 diabetes[5]. The mechanisms by which type 2 diabetes mellitus (T2DM) induces bone alterations remain a topic of debate and are not yet fully elucidated. However, it is well established that hyperglycemia affects bone health in multiple ways, leading to fragility, reduced mechanical strength, impaired bone matrix microstructure, and altered bone cell function, ultimately resulting in osteoporosis and an increased risk of fractures [6]. In fact, hyperglycemia leads to hypocalcemia by increasing urinary calcium excretion, impairing vitamin D status, and disrupting the balance between parathyroid hormone (PTH) and vitamin D. This imbalance negatively impacts bone health [7]. Moreover, it induces a chronic inflammatory state. Elevated blood glucose levels increase the formation of advanced glycation end-products (AGEs), which serve as a source of reactive oxygen species (ROS). These ROS cause direct damage to the extracellular bone matrix by forming irreversible cross-links between type I collagen fibers [6].

This study evaluates HbA1c as a marker of glucose control; Vitamin D3, Calcium, Magnesium, and Zinc for their roles in bone health; and ALP as an indicator of bone activity.

Materials and methods

Study Design and Participants

A total of 219 individuals, aged 40 to 80 years, were enrolled in this study, including 149 patients and 70 apparently healthy controls. The participants were categorized into three groups: Group 1 (G1) consisted of diabetic patients without osteoporosis, Group 2 (G2) included diabetic patients diagnosed with osteoporosis, and Group 3 (G3) comprised healthy individuals without diabetes or osteoporosis. Recruitment was conducted between November 2024 and May 2025 from Kirkuk Teaching Hospital, Azadi Teaching Hospital, and private medical clinics in Kirkuk, Iraq. Clinical diagnoses were verified by qualified specialists. To ensure accuracy and avoid confounding factors, individuals with a history of hepatic, renal, or pancreatic diseases, as well as those with Alzheimer's disease or previous stroke, were excluded from the study.

Sample Collection

Following an overnight fast, venous blood samples (6 mL) were collected aseptically from all participants via venipuncture. The samples were divided into two portions: 4 mL were transferred into plain tubes without anticoagulant and left at room temperature for 30 minutes to allow clotting. The samples were then centrifuged at 3000×g for 10 minutes, and the resulting clear serum was carefully separated and stored in sterile, dry Eppendorf tubes at −20 °C for subsequent biochemical analysis. These analyses included measurements of fasting blood sugar (FBS), Vitamin D3, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Alkaline Phosphatase (ALP), and Zinc

(Zn). The remaining 1 mL of whole blood was placed in an EDTA-containing tube and used specifically for the determination of Glycated Hemoglobin (HbA1c).

Biochemical Analyses

Fasting serum glucose (FSG) was determined using the glucose oxidase-peroxidase method with a commercial kit (Spinreact, Spain). HbA1c levels were measured using the AFIAS HbA1c Neo system (Boditech Med Inc., Korea), based on fluorescence immunoassay technology. Serum levels of alkaline phosphatase (ALP), calcium (Ca), magnesium (Mg), and zinc (Zn) were measured using colorimetric methods provided by BIOLAB (France) and Spectrum Diagnostics (Egypt), following the manufacturer's protocols. Vitamin D3 [25(OH)D] was quantified by electrochemiluminescence immunoassay using the Elecsys system (Roche Diagnostics, Germany). All biochemical parameters were measured using automated analyzers, and values were calculated based on absorbance readings relative to standard solutions. Assays were performed in duplicate to ensure accuracy.

Results

Determination demographic and clinical characteristics of diabetes mellitus patients and healthy controls

The findings presented in Table (1) demonstrated clear differences between patients with type 2 diabetes mellitus and healthy individuals. Random blood sugar (RBs) and glycated hemoglobin (HbA1c) levels revealed highly significant ($P < 0.05$) differences between the two groups(G1+G2) compared with G3.

Table (1) Demographic and and clinical characteristics of diabetes mellitus patients and healthy controls

Group	Diabetes mellitus cases No. (149)	healthy controls No. (70)	P-value
Age (years) Mean ± SD	50.78 ± 15.973	44.87 ± 15.752	0.566
Gender Females Males Total	75 74 149	32 38 70	
RBs (mg/dl) Mean ± SD	175.27 ±72.908	85.71 ±5.903	<.0001*
HbAic (%) Mean ± SD	7.582 ±5.351	4.952 ±0.345	<.0001*
Duration of disease Mean ± SD	4.65 ± 2.51		

* P<0.05 highly significant

Determination of Ca, Mg, VitD3, ALK, and Zn in G1+G2 compared with G3

The results presented in Table (2) demonstrate distinct differences in the concentrations of selected minerals between the patient group and the healthy controls. Although serum calcium (Ca) levels were slightly lower in patients, the difference was not statistically significant ($P > 0.05$), suggesting that calcium homeostasis may not be markedly altered in the studied patient population. In contrast, both magnesium (Mg) and zinc (Zn) levels were significantly lower in the patient group compared to controls ($P \leq 0.05$). Serum vitamin D levels were significantly lower ($P \leq 0.05$) in the patient groups compared to the control group. Meanwhile, no statistically significant difference was detected in alkaline phosphatase (ALK) levels between the two groups

(P > 0.05), suggesting that this enzyme may not be a sensitive indicator in this context.

Table (2): Determination Level of Ca, Mg and Zn of diabetes mellitus patients and healthy controls

Parameters \ Group	Patients mean ± SD (N = 149)	Control mean ± SD (N = 70)	probability
Ca (mg/dl)	8.676 ±0.951	8.804 ±0.289	0.1033
Mg (mg/dl)	1.675 ±0.345	2.072 ±0.197	0.0001*
Zn (µg/dl)	68.198 ±7.161	78.36 ±8.017	0.0001*
VitD3 (ng/dl)	16.561 ± 5.299	26.088 ± 9.359	0.0008*
ALK (U/L)	194.56 ± 77.386	189.48 ± 62.592	0.0682

* P≤ 0.05 highly significant

Comparison of clinical and demographic variables among diabetic patients with and without osteoporosis

The current study also compared clinical and biochemical characteristics between diabetic patients with and without osteoporosis. Although patients with osteoporosis were slightly older than those without, the difference in age was not statistically significant (P > 0.05). Gender distribution was relatively similar between the two groups. Notably, both random blood sugar (RBs) and HbA1c levels were significantly elevated (P ≤ 0.05) in diabetic patients with osteoporosis compared to those without, indicating poorer glycemic control in this subgroup.

Table (3): Clinical and Demographic Characteristics of Diabetic Patients Stratified by Osteoporosis Status

Group	**Diabetic patients without osteoporosis (72)**	**Diabetic patients with osteoporosis (77)**	**P-value**
	mean ± SD	**mean ± SD**	
Age (years)	48.49 a ± 15.664	52.92 b ± 16.062	0.090
Gender Females Males Total	 32 40 72	 34 43 77	
RBs (mg/dl)	189.14 ±12.908	288.26 ±11.873	<.0001*
HbAic (%)	6. 628± 1.775	8.743 ± 1.875	<.0001*
duration of disease	4.65 ± 2.51		

* P<0.05 highly significant

Determination of Ca, Mg, Zn, VitD and ALK in diabetic patients with and without osteoporosis

The analysis of serum mineral levels between diabetic patients with and without osteoporosis revealed statistically insignificant differences (P > 0.05), while Zn levels were significantly lower (P < 0.05) in those with osteoporosis. Serum vitamin D levels appeared a significant decreased (P < 0.05) in osteoporotic patients. Alkaline phosphatase (ALK) levels were slightly higher in patients without osteoporosis, but this difference was not statistically significant (P > 0.05).

Table (4) determination Level of Ca, Mg, Zn, VitD and ALK of diabetes patients with and without osteoporosis

Group	Diabetic patients without osteoporosis (72)	Diabetic patients with osteoporosis (77)	P-value
	mean ± SD	mean ± SD	
Ca (mg/dl)	8.224 ± 1.1256	8.327 ± 1.3815	0.0601
Mg (mg/dl)	1.106 ± 1.263	1.184 ± 2.1722	0.0811
Zn (µg/dl)	68.228 ± 8.6578	25.170 ± 5.5242	0.0001*
VitD (ng/dl)	17.281 ±15.2593	11.453 ± 4.5423	0.0008*
ALK (U/L)	206.972 ±80.4395	198.961 ± 73.5782	0.1020

* P<0.05 highly significant

Discussion

Determination demographic and clinical characteristics of diabetes mellitus patients and healthy controls

In the current study, significantly higher levels of random blood sugar (RBs) and glycated hemoglobin (HbA1c) were observed in patients with type 2 diabetes mellitus compared to healthy controls. The mean RBs level in diabetic patients was 175.27 ± 72.91 mg/dl, while in the control group it was 85.71 ± 5.90 mg/dl ($P < 0.0001$). Similarly, HbA1c levels were markedly elevated in the diabetic group (7.582 ± 5.351%) compared to controls (4.952 ± 0.345%) ($P < 0.0001$). These findings are in agreement with the results of a previous study [8] where fasting serum glucose (FSG) and HbA1c levels were also significantly higher in diabetic patients (183.25 ± 4.96 mg/dl and 8.35 ± 2.46%, respectively) than in the control group (99.12 ± 13.71 mg/dl and 4.6 ± 0.7%), with P-values of 0.001 and 0.02, respectively. Despite slight variations in the measurement method (random vs. fasting glucose), both studies demonstrated that poor glycemic control was a distinguishing feature of the diabetic group and may contribute to diabetes-related complications. Several studies have reported findings consistent with the results of the current study. For instance, the [9]**,** highlights that individuals with type 2 diabetes typically exhibit significantly higher levels of both random blood glucose and HbA1c compared to healthy individuals. Several studies have reported findings consistent with the results of the current study. For instance, the [9]**,** highlights that individuals with type 2 diabetes typically exhibit significantly higher levels of both random blood glucose and HbA1c compared to healthy individuals, Similarly, [10] reported a statistically significant elevation in HbA1c levels among diabetic patients, with no significant differences in age or gender distribution between diabetic and control groups—closely aligning with the findings presented in Table (1). Conversely, some studies have reported differing results. [11] identified a statistically significant age difference between diabetic patients and non-diabetic controls, suggesting age as a potential contributing factor to disease onset, which contradicts the non-significant age difference found in our study. Moreover, [12]observed a slight male predominance among diabetic patients, suggesting gender-related trends in diabetes prevalence that were not reflected in our data.

The gold standard for evaluating glycemic control in T2DM is represented by glycated hemoglobin (HbA1c) in line with the UK Prospective Diabetes Study [13] Strong correlations relate HbA1c levels to the development and progression of diabetes problems, making it a promising prognostic marker. The Diabetes Management and Complications Trial (DCCT) found that reducing HbA1c levels with stringent glycemic management substantially reduced microvascular complications in Type 1 diabetes [14]. The findings of the present study are consistent with those of a study conducted on 202 patients, half of whom had T2DM. The results of both the studies showed elevated levels of HbA1c and blood glucose in the diabetic group as compared with the normal control. The difference between the two groups for these

measurements was also highly significant ($p < 0.001$) in the previous study and supports the notion that diabetes produces a long-term blood sugar regulation problem as well as a short-term problem in that both short-term (FBS) and long-term (HbA1c) regulation of blood sugar are affected by the presence of diabetes [15]. This comparison demonstrates concordance of results between studies and supports the HA1c as a valid indicator of sugar control among diabetic patients. It also provides evidence for the clinical application of HbA1c as a diagnostic or progress monitoring marker [16].

Determination of Ca, Mg, Zn, VitD and ALK in G1+G2 compared with G3

In the present study, though the decline in serum calcium was statistically not significant, reductions in serum Mg and Zn were highly significant and might be associated with disease-mediated metabolic and oxidative stress perturbation. The findings of the present report demonstrate a significant decline in serum magnesium (Mg) and zinc (Zn) in patients compared with healthy subjects, and this finding is also consistent with those of a previous study. A study evaluating the status of trace elements in patients with T2DM with diabetic nephropathy (T2DN) observed marked reductions in serum Zn and Mg levels as compared to healthy subjects. Second, the low levels of Zn and Mg indicate a possible trace element imbalance that is related to oxidative stress and disturbances in absorption or renal loss, commonly observed in chronic metabolic disorders. Serum zinc acted as the independent protective factor of nephropathy in the T2DN study and suggested that we should pay attention to the trace element status in patients with chronic diseases. The observed similarities suggest further that the estimation of Zn and Mg levels could serve as diagnostic and perhaps prognostic measures for the course of disease [17]. Although humans contain trace elements, the body contains only small amounts of these elements, but they are essential to good health. A previous study of the connection between diabetes mellitus and trace elements showed that the appropriate homeostasis of trace elements contributes to the regulation of blood glucose and reduces tissue damage [18]. Trace elements such as zinc (Zn) and magnesium (Mg) are recognized for their role in the development of diabetes and its associated complications. Zinc plays a critical role in the production, storage, and secretion of insulin by islet β-cells, while also safeguarding vascular endothelial integrity through its antioxidative, anti-apoptotic, and membrane-stabilizing properties [19]. Moreover, magnesium is crucial for glucose homeostasis and the preservation of insulin bioactivity [20]

These findings suggest that vitamin D deficiency may be strongly associated with both diabetes and osteoporosis. Similarly, that study also reported significant alterations in serum ferritin levels between diabetic and non-diabetic groups, supporting the role of altered mineral and inflammatory markers in the progression of bone disorders among diabetic patients [21], and findings align with those from comprehensive observational research involving Chinese T2DM patients, which revealed that vitamin D insufficiency and deficiency were much more common in the diabetic foot (DF) group (77.51%) than in the non-DF group (59.2%). Additionally, the average blood levels of 25-hydroxyvitamin D [25(OH)D] were much lower in people with diabetic foot (DF) [35.80 nmol/L] than in those without DF [45.48 nmol/L, $p < 0.001$]. A similar drop in vitamin D levels was observed as the Wagner grades increased, although this was not statistically significant ($p = 0.114$), suggesting that more severe diabetes complications might be linked to lower vitamin D levels [22]. Tiwari et al. conducted an initial assessment of vitamin D status in patients with diabetic foot infection in India, concluding that vitamin D deficiency was more prevalent and severe in infected patients compared to those without infection. Their subsequent research confirmed this conclusion [23]. A similar drop in vitamin D levels was observed as the Wagner grades increased, although this was not statistically significant ($p = 0.114$), suggesting that more severe diabetes complications might be linked to lower vitamin D levels [22].

The results in the current study indicate that ALP alone may possess limited diagnostic efficacy for distinguishing diabetes patients from healthy individuals. Recent research involving people with high blood pressure found that higher initial ALP levels are linked to the development of

new diabetes, regardless of other liver enzymes and other influencing factors This underscores a possible predictive function of ALP in diabetes development, especially in populations with supplementary risk factors like hypertension. The association between ALP and diabetes remains contentious in the literature [24].

Comparison of clinical and demographic variables among diabetic patients with and without osteoporosis

The findings of the current study, which showed no statistically significant differences in age or gender between diabetic patients with and without osteoporosis, are in line with several previous reports. For example, [25] found that while osteoporosis prevalence increased slightly with age among type 2 diabetic patients, age was not a statistically significant independent predictor, supporting our observation of non-significant age differences (P = 0.090). Additionally, A study [26] found no significant correlation between gender and osteoporosis in individuals with diabetes. This suggests that the decline in bone health observed in diabetic patients may be primarily attributable to metabolic factors rather than sex-specific differences. These findings align with our own observations regarding gender, which showed a non-significant association (P=0.163).

The similar distribution of RBs and HbA1c levels we found in both T1D and T2D is corroborated by [27], who reported that glycemic management as a single factor might not explain the differences observed in BMD or the risk of developing osteoporosis in diabetic patients. This further supports our result that both subgroups were prevalent with poor glycemic control, suggesting other pathophysiological mechanisms may play a role.

However, conflicting findings have been published in some studies [28] found that longer duration of diabetes and increased HbA1c levels were significantly associated with lower BMD and increased risk of osteoporosis. This conclusion is in contrast to our findings, where HbA1c levels did not differ between groups and osteoporosis risk was not adjusted for disease duration. Furthermore, speculated on direct implication of poor/good glycemic control, especially prolonged hyperglycemia, on bone fragility, which indicates a more direct association between glucose parameters and osteoporosis compared with our results [29].

These discrepancies could be due to differences in the study population, sample size, comorbidities, drug treatment, or the ethnicity of the sample. Hence, more case-control studies on larger and more diverse samples are needed to clarify the multi-factorial aspects of the relationship between diabetes and osteoporosis.

The present study revealed no statistically significant differences in calcium and magnesium levels between diabetic patients with and without osteoporosis (P = 0.0601 and 0.0811, respectively). These results partially support the findings of Sales and Pedrosa (2006), who reported that diabetic individuals are prone to hypomagnesemia due to increased urinary magnesium loss associated with hyperglycemia [30]. Similarly, Barbagallo et al. (2015) emphasized the link between magnesium deficiency and poor glycemic control [31]. However, in our study, magnesium levels, although slightly lower in the non-osteoporotic group, did not differ significantly. This may indicate that osteoporotic status alone does not exacerbate magnesium depletion, or that individual compensatory mechanisms maintain magnesium homeostasis despite ongoing diabetic dysregulation. Further studies with more sensitive subgroup analyses may clarify whether these trends carry clinical importance.

In line with previous literature, serum calcium levels were not significantly altered between groups (P = 0.0601). This supports the hypothesis that calcium levels remain stable in early or uncomplicated diabetes, as they are tightly regulated by parathyroid hormone, calcitonin, and vitamin D, as discussed by [32]. This stability may persist unless secondary complications such as nephropathy disturb calcium homeostasis. Thus, our findings suggest that osteoporotic status in diabetes does not significantly influence calcium levels unless other mineral-imbalancing

factors coexist.

A key finding of our study was the significantly lower serum zinc levels in diabetic patients with osteoporosis compared to those without (25.17 ± 5.52 µg/dl vs. 68.23 ± 8.65 µg/dl, $P = 0.0001$). This sharp difference is consistent with [33] who reported reduced zinc in T2DM due to renal loss and its critical role in insulin metabolism. Moreover, as a powerful antioxidant, zinc deficiency may worsen oxidative stress and bone demineralization, thereby contributing to osteoporosis in diabetic patients. The significant reduction observed in our osteoporosis subgroup underlines the potential value of zinc status as both a metabolic and skeletal marker in diabetes management [34]. Regarding vitamin D, our results showed significantly lower levels in the osteoporosis group (11.45 ± 4.54 ng/dl) compared to those without (17.28 ± 15.26 ng/dl), with a P-value of 0.0008. Furthermore, Rianon et al. (2016) reported that vitamin D levels were lower in diabetic patients with osteoporosis compared to those without [35], in contrast to our findings where both groups had similarly low vitamin D levels and yet a statistically significant P-value. This discrepancy might be due to variability in assay methods or population-specific differences in sun exposure and vitamin D metabolism.

Additionally, the stady of [36] concluded that alkaline phosphatase (ALK) levels were significantly associated with osteoporosis in type 2 diabetic women, which contradicts our finding of a non-significant difference in ALK levels between the groups. The variation could be attributed to gender-specific hormonal influences or differences in medication use affecting bone turnover enzymes.

In summary, while our study's results are consistent with the majority of literature concerning elevated bone turnover and resorption markers in diabetic osteoporosis, some discrepancies exist—especially regarding vitamin D and ALK—which may be influenced by population demographics, disease duration, comorbidities, or assay techniques.

References

1. M. H. Tan, *Diabetes Mellitus: Impact on Bone, Dental and Musculoskeletal Health*. Academic Press, 2020.
2. H.-H. Lin, H.-Y. Hsu, M.-C. Tsai, L.-Y. Hsu, K.-L. Chien, and T.-L. Yeh, "Association between type 2 diabetes and osteoporosis risk: A representative cohort study in Taiwan," *PLoS One*, vol. 16, no. 7, p. e0254451, 2021.
3. L. J. Melton III, C. L. Leibson, S. J. Achenbach, T. M. Therneau, and S. Khosla, "Fracture risk in type 2 diabetes: update of a population-based study," *J. Bone Miner. Res.*, vol. 23, no. 8, pp. 1334–1342, 2008.
4. A. D. Dede, S. Tournis, I. Dontas, and G. Trovas, "Type 2 diabetes mellitus and fracture risk," *Metabolism*, vol. 63, no. 12, pp. 1480–1490, 2014.
5. J. N. Farr, M. T. Drake, S. Amin, L. J. Melton III, L. K. McCready, and S. Khosla, "In vivo assessment of bone quality in postmenopausal women with type 2 diabetes," *J. Bone Miner. Res.*, vol. 29, no. 4, pp. 787–795, 2014.
6. K. G. Kheniser, C. M. P. Santos, and S. R. Kashyap, "The effects of diabetes therapy on bone: a clinical perspective," *J. Diabetes Complications*, vol. 32, no. 7, pp. 713–719, 2018.
7. M. Carnovali, L. Luzi, I. Terruzzi, G. Banfi, and M. Mariotti, "Liquiritigenin reduces blood glucose level and bone adverse effects in hyperglycemic adult zebrafish," *Nutrients*, vol. 11, no. 5, p. 1042, 2019.
8. N. E. W. York, "Eorgian edical ews," vol. 1, no. 7, 2024.
9. N. A. ElSayed *et al.*, "Introduction and Methodology: Standards of Care in Diabetes—2023," *Diabetes Care*, vol. 46, no. Supplement_1, pp. S1–S4, Dec. 2022, doi: 10.2337/dc23-Sint.

10. Noori, N. N., & Murtadha, N. A. (2024). *Uncontrolled type 2 diabetes mellitus modulated plasma levels of lipid catabolic proteins*. Georgian Medical News, *7–8 Hasan, Y. (2024). *Study of heart type fatty acid binding protein in diabetic patients (Article review)*. Biochemistry Branch, Kirkuk Medical College, University of Kirkuk, Iraq, *2*(9), 12–21. ISSN(E): 2938-3773.
11. M. Abdul *et al.*, "Epidemiology of Type 2 Diabetes – Global Burden of Disease and Forecasted Trends," vol. 10, pp. 107–111, 2020.
12. S. Assari, M. Moghani Lankarani, J. D. Piette, and J. E. Aikens, "Socioeconomic status and glycemic control in type 2 diabetes; race by gender differences," in *Healthcare*, MDPI, 2017, p. 83.
13. C. Argano, L. Mirarchi, S. Amodeo, V. Orlando, A. Torres, and S. Corrao, "The role of vitamin D and its molecular bases in insulin resistance, diabetes, metabolic syndrome, and cardiovascular disease: state of the art," *Int. J. Mol. Sci.*, vol. 24, no. 20, p. 15485, 2023.
14. A. A. A. Algamdi *et al.*, "Efficiency of glycosylated hemoglobin (HbA1c) as a predictive marker for diabetic complications," *J. Int. Cris. Risk Commun. Res.*, vol. 7, no. S8, p. 2955, 2024.
15. H. Bin Maan, S. A. Meo, F. Al Rouq, I. M. U. Meo, M. E. Gacuan, and J. M. Alkhalifah, "Effect of glycated hemoglobin (HbA1c) and duration of disease on lung functions in type 2 diabetic patients," *Int. J. Environ. Res. Public Health*, vol. 18, no. 13, p. 6970, 2021.
16. P. Gillery, "HbA1c and biomarkers of diabetes mellitus in Clinical Chemistry and Laboratory Medicine: ten years after," *Clin. Chem. Lab. Med.*, vol. 61, no. 5, pp. 861–872, 2023.
17. J. Feng *et al.*, "Relationships of the trace elements zinc and magnesium with diabetic nephropathy-associated renal functional damage in patients with type 2 diabetes mellitus," *Front. Med.*, vol. 8, p. 626909, 2021.
18. K. Siddiqui, N. Bawazeer, and S. Scaria Joy, "Variation in macro and trace elements in progression of type 2 diabetes," *Sci. world J.*, vol. 2014, no. 1, p. 461591, 2014.
19. A. Nazarizadeh and S. Asri-Rezaie, "Comparative study of antidiabetic activity and oxidative stress induced by zinc oxide nanoparticles and zinc sulfate in diabetic rats," *AAPS PharmSciTech*, vol. 17, pp. 834–843, 2016.
20. U. Gröber, J. Schmidt, and K. Kisters, "Magnesium in prevention and therapy," *Nutrients*, vol. 7, no. 9, pp. 8199–8226, 2015.
21. A. Mater, S. Wasme, Y. H. Tahseen, and A. K. Abdulla, "CENTRAL ASIAN JOURNAL OF Association of some Biochemical Markers , Hepatitis B , and C Viruses with Type 2 Diabetes Mellitus in Kirkuk City / Iraq," vol. 6, no. April, pp. 578–585, 2025.
22. Wasme, A. M. S., Tahseen, Y. H., & Abdulla, A. K. (2025). *Association of some biochemical markers, hepatitis B, and C viruses with type 2 diabetes mellitus in Kirkuk City, Iraq*. Biochemistry Branch, Kirkuk Medical College, & College of Pharmacy, University of Kirkuk. ," vol. 6, no. April, pp. 578–585, 2025.
23. S. Tiwari, D. D. Pratyush, S. K. Gupta, and S. K. Singh, "Vitamin D deficiency is associated with inflammatory cytokine concentrations in patients with diabetic foot infection," *Br. J. Nutr.*, vol. 112, no. 12, pp. 1938–1943, 2014.
24. Y. Zhang *et al.*, "Serum alkaline phosphatase levels and the risk of new-onset diabetes in hypertensive adults," *Cardiovasc. Diabetol.*, vol. 19, pp. 1–13, 2020.
25. M. A. Bayani *et al.*, "The relationship between type 2 diabetes mellitus and osteoporosis in elderly people: a cross-sectional study," *Int. Biol. Biomed. J.*, vol. 2, no. 1, pp. 39–46, 2016.

26. V. Pedrazzi, M. F. Leite, R. C. Tavares, S. Sato, G. C. do Nascimento, and J. P. M. Issa, “Herbal mouthwash containing extracts of Baccharis dracunculifolia as agent for the control of biofilm: clinical evaluation in humans.,” *ScientificWorldJournal.*, vol. 2015, p. 712683, 2015, doi: 10.1155/2015/712683.

27. R. Stroescu, T. Bizerea, G. Doroş, M. Marazan, M. Lesovici, and O. Mărginean, “Correlation between adipokines and carotid intima media thickness in a group of obese Romanian children: is small for gestational age status an independent factor for cardiovascular risk?,” *Arch. Endocrinol. Metab.*, vol. 61, pp. 14–20, 2016.

28. V. D. Sherk and C. J. Rosen, “Senescent and apoptotic osteocytes and aging: Exercise to the rescue?,” *Bone*, vol. 121, pp. 255–258, 2019, doi: https://doi.org/10.1016/j.bone.2019.02.006.

29. J. Starup-Linde, S. A. Eriksen, S. Lykkeboe, A. Handberg, and P. Vestergaard, “Biochemical markers of bone turnover in diabetes patients—a meta-analysis, and a methodological study on the effects of glucose on bone markers,” *Osteoporos. Int.*, vol. 25, pp. 1697–1708, 2014.

30. C. H. Sales and L. de F. C. Pedrosa, “Magnesium and diabetes mellitus: their relation,” *Clin. Nutr.*, vol. 25, no. 4, pp. 554–562, 2006.

31. M. Barbagallo and L. J. Dominguez, “Magnesium and type 2 diabetes,” *World J. Diabetes*, vol. 6, no. 10, p. 1152, 2015.

32. A. J. Felsenfeld, B. S. Levine, and M. Rodriguez, “Pathophysiology of calcium, phosphorus, and magnesium dysregulation in chronic kidney disease,” in *Seminars in dialysis*, Wiley Online Library, 2015, pp. 564–577.

33. P. Gunasekara, M. Hettiarachchi, C. Liyanage, and S. Lekamwasam, “Effects of zinc and multimineral vitamin supplementation on glycemic and lipid control in adult diabetes,” *Diabetes, Metab. Syndr. Obes. targets Ther.*, pp. 53–60, 2011.

34. D. M. Farooq, A. F. Alamri, B. K. Alwhahabi, A. M. Metwally, and K. A. Kareem, “The status of zinc in type 2 diabetic patients and its association with glycemic control,” *J. Fam. Community Med.*, vol. 27, no. 1, pp. 29–36, 2020.

35. N. J. Rianon *et al.*, “Glycemic control and bone turnover in older Mexican Americans with type 2 diabetes,” *J. Osteoporos.*, vol. 2018, no. 1, p. 7153021, 2018.

36. C. Meier *et al.*, “Biochemical Markers of Bone Fragility in Patients with Diabetes. A Narrative Review by the IOF and the ECTS.,” *J. Clin. Endocrinol. Metab.*, vol. 108, no. 10, pp. e923-36, May 2023, doi: 10.1210/clinem/dgad255.