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ORIGINAL RESEARCH

Association of Mean Platelet Volume Expression with Bone Mineral Density in Patients with T2DM and CKD

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Objective: To investigate the clinical significance of mean platelet volume (MPV) in patients with type 2 diabetes mellitus (T2DM) complicated with chronic kidney disease (CKD), and its association with bone mineral density (BMD).

Methods: A retrospective analysis was conducted on 296 T2DM patients with CKD. Based on MPV values, patients were divided into Group A (n=177, MPV 7.50–11.00 fL) and Group B (n=119, MPV >11.00 fL). Clinical and biochemical parameters including BMD were compared between groups. Pearson correlation and multiple linear regression were used to evaluate the relationship between MPV and BMD.

Results: Group A showed significantly higher levels of PLT, SUA, and L1-L4 BMD than Group B ($P<0.05$); no statistically significant differences were found in other indicators between the groups ($P>0.05$). Pearson correlation analysis showed that MPV was negatively correlated with PLT ($r=-0.253$, $P=0.012$), SUA ($r=-0.246$, $P=0.015$), L1-L4 BMD ($r=-0.351$, $P<0.01$), femoral BMD ($r=-0.271$, $P=0.007$), and Ward BMD ($r=-0.238$, $P=0.019$). Multiple linear regression analysis revealed that high MPV was independently associated with lower L1-L4 BMD ($\beta=-0.066$, $P=0.003$).

Conclusion: High MPV is closely related to BMD in T2DM patients with CKD, especially L1-L4 BMD, and may serve as a potential indicator for the occurrence of osteoporosis.

Keywords: T2DM, CKD, mean platelet volume, bone mineral density, association

Introduction

Type 2 diabetes mellitus (T2DM) is currently one of the most common chronic metabolic diseases worldwide, with its pathogenesis involving insulin resistance, β-cell dysfunction, and multiple metabolic disorders.[1] In recent years, with the continuous rise in the prevalence of diabetes, increasing attention has been paid to its complications. Chronic kidney disease (CKD) is one of the most common chronic microvascular complications of T2DM, with an incidence as high as 30%–40%, significantly affecting patients' quality of life and greatly increasing the risk of cardiovascular events and mortality.[2,3] Meanwhile, bone metabolism abnormalities and decreased bone mineral density (BMD) are also common in patients with both T2DM and CKD, and both are considered important risk factors for secondary osteoporosis.[4,5] The pathogenesis of CKD-related bone disease (CKD-MBD) is complex, involving disorders of mineral metabolism as well as the combined influence of inflammatory states, oxidative stress, and hormonal imbalances.[6] T2DM may affect bone formation and resorption through mechanisms such as insulin resistance, accumulation of advanced glycation end-products (AGEs), and low-grade chronic inflammation.[7] Previous studies[8] have shown that patients with T2DM and CKD are at a significantly higher risk of decreased BMD and fractures compared with patients with T2DM or CKD alone.

Mean platelet volume (MPV) is a routine hematological indicator reflecting platelet size and activation status, and has recently been found to be associated with various chronic diseases, such as diabetes, atherosclerosis, cardiovascular

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disease, and kidney disease.[9,10] An elevated MPV usually indicates a state of heightened platelet activation, suggesting the presence of inflammation or oxidative stress in the body.[11] Chronic inflammation is not only a shared pathological basis of DM and CKD, but also a key factor in the development of osteoporosis.[12] Studies[13] have indicated that MPV is positively correlated with various inflammatory markers (such as CRP and IL-6), and may indirectly affect bone metabolism processes. However, current research on the association between MPV levels and BMD in T2DM patients with CKD remains limited. In particular, whether MPV can reflect bone status and thus aid in assessing high-risk individuals lacks systematic investigation.Therefore, this study selected 296 patients with T2DM and CKD treated in our hospital as research subjects, aiming to explore the clinical significance of MPV levels and further analyze their association with BMD at sites such as the lumbar spine and femur. The goal is to provide new insights and references for the assessment and intervention of osteoporosis in clinical practice.

Data and Methods

Study Subjects

This study is a retrospective analysis that included 296 hospitalized patients with T2DM and CKD who were diagnosed and treated in the Departments of Endocrinology and Nephrology of our hospital from March 2020 to September 2023. The study was approved by the Medical Ethics Committee of the People's Hospital of Chengyang District (Approval No.: NFMJY2407) and was conducted in strict accordance with the ethical principles of the Declaration of Helsinki. Informed consent was obtained from all participants or their legal guardians prior to data collection.

Inclusion and Exclusion Criteria

Inclusion criteria: Patients met the clinical diagnostic criteria for T2DM;[14] met the diagnostic criteria for CKD formulated by K/DOQI,[15] namely, glomerular filtration rate (GFR) <60 mL/min/1.73m² or presence of kidney damage (eg, proteinuria [UACR ≥30 mg/g], abnormal urinary microalbumin) lasting ≥3 months; patients aged ≥18 years, regardless of gender; complete clinical data, laboratory test results, and bone mineral density (BMD) reports were available; patients and their families were fully informed about the study and signed the relevant informed consent form.

Exclusion criteria: Patients with other types of diabetes (such as type 1 diabetes, gestational diabetes, etc); those with acute kidney injury (AKI) or who had undergone kidney transplantation; patients with conditions affecting bone metabolism such as hyperparathyroidism, bone tumors, rheumatoid arthritis, systemic lupus erythematosus, etc.; patients using medications affecting bone metabolism such as glucocorticoids, calcitonin, bisphosphonates, vitamin D supplements, etc.; those with severe liver dysfunction, malignancies, or infectious diseases; pregnant or lactating women.

According to MPV levels at admission, the 296 patients were divided into two groups. Group A (normal MPV group) included 177 patients with MPV values ranging from 7.5 to 11.0 fL, which corresponds to our laboratory's reference range based on the manufacturer's guidelines for the Sysmex XN-9000 analyzer. Group B (high MPV group) included 119 patients with MPV values >11.0 fL. MPV levels were measured using a Sysmex XN-9000 automated hematology analyzer. All measurements were performed on EDTA-anticoagulated blood samples processed within 2 hours of collection to minimize pre-analytical variability.

Data Collection and Detection Methods

Clinical data for all patients were extracted from the hospital's electronic medical record system and independently verified by two researchers to ensure accuracy and consistency. The following baseline information was collected: gender, age, height, weight, body mass index (BMI), duration of disease, and menopausal status.

Blood Sampling Protocol

All venous blood samples were collected in the morning between 7:00–9:00 AM after an overnight fast of at least 8 hours. For hematological analysis, 3 mL of blood was drawn into K_2EDTA anticoagulant tubes (Becton Dickinson, USA). For biochemical analysis, 5 mL of blood was collected in serum separator tubes (SST), allowed to clot at room temperature for 30 minutes, and centrifuged at 3000 rpm for 10 minutes to separate the serum.

Laboratory Indicators and Analytical Methods

Hematological Parameters

Hematological measurements were performed using a Sysmex XN-9000 automated hematology analyzer (Sysmex Corporation, Japan). Platelet count (PLT) was determined using the impedance method, while mean platelet volume (MPV) was measured by flow cytometry employing CD61 fluorescent antibodies. To minimize EDTA-induced platelet swelling, all MPV measurements were completed within 2 hours of blood collection. Daily internal quality control was conducted using CELLPACK DCL reagents provided by the manufacturer, maintaining a coefficient of variation (CV) of less than 3%.

Renal Function Tests

Renal function indicators were assessed using the Cobas c702 modular analyzer (Roche Diagnostics, Switzerland). Serum creatinine (Scr) was measured using the enzymatic creatininase method, and blood urea nitrogen (BUN) was quantified via the urease–glutamate dehydrogenase (GLDH) method. The estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation.

Urinary Parameters

Urinary markers were analyzed using the AU5800 system (Beckman Coulter, USA). The urinary albumin-to-creatinine ratio (UACR) was calculated using a turbidimetric immunoassay for urinary albumin and an enzymatic method for urinary creatinine.

Glucose Metabolism

Glycemic control was evaluated using the D-100™ system (Bio-Rad Laboratories, USA). Glycated hemoglobin (HbA1c) levels were determined via high-performance liquid chromatography (HPLC), providing accurate long-term indicators of blood glucose regulation.

Nutritional and Bone Metabolism

Markers related to nutritional status and bone metabolism were measured using the ADVIA 2400 clinical chemistry analyzer (Siemens Healthcare Diagnostics, Germany). Serum albumin (ALB) was quantified by the bromocresol green dye-binding method. Alkaline phosphatase (ALP) activity was determined using the p-nitrophenyl phosphate substrate method. Serum calcium (Ca^{2+}) and phosphorus (Pi) concentrations were measured using the o-cresolphthalein complexone method and phosphomolybdate UV method, respectively. Serum magnesium (Mg^{2+}) levels were evaluated using a xylidyl blue colorimetric assay.

Mineral Metabolism

Mineral metabolism indicators were analyzed using the Elecsys E601 immunoassay analyzer (Roche Diagnostics, Switzerland). Serum intact parathyroid hormone (PTH) was measured by electrochemiluminescence immunoassay (ECLIA), while serum 25-hydroxyvitamin D [25(OH)D] levels were determined using a competitive ECLIA method.

Lipid Profile and Uric Acid

Lipid profile and serum uric acid were measured using the Cobas c702 analyzer (Roche Diagnostics, Switzerland). Total cholesterol (TC) and triglycerides (TG) were measured via cholesterol oxidase and glycerol phosphate oxidase methods, respectively. High-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were determined using homogeneous enzymatic assays. Serum uric acid (SUA) was measured by the uricase–peroxidase anti-peroxidase (PAP) colorimetric method.

Quality Assurance

All instruments were subjected to daily calibration using manufacturer-provided internal quality controls. The intra-assay coefficient of variation (CV) for all laboratory parameters was maintained below 5%. Additionally, the laboratory

participated in external quality assurance programs accredited by the China National Accreditation Service for Conformity Assessment (CNAS) under ISO 15189 standards.

Statistical Analysis

All data were analyzed using SPSS 26.0. Measurement data were tested for normality and expressed as mean±SD; group comparisons used independent sample *t*-tests; categorical data used χ^2-tests. Pearson correlation analysis explored associations between MPV and other indicators. Multiple linear regression models for BMD included covariates: age, BMI, menopausal status, CKD stage, PLT, MPV, and SUA. P<0.05 was considered statistically significant.

Results

Comparison of General Information

There were no significant differences between Group A and Group B in terms of sex, age, BMI, duration of disease, menopausal status, and education level (P > 0.05), indicating comparability. See Table 1.

Comparison of Clinical Laboratory Indicators and BMD

Group A had significantly higher levels of PLT, SUA, and L1-L4 BMD than Group B (P < 0.05). No statistically significant differences were observed for the remaining indicators (P > 0.05). See Table 2.

Table 1 Comparison of General Information ($\bar{x} \pm s$, n [%])

	Group A (n=177)	Group B (n=119)	t/χ^2	*P*
Sex	–	–	1.457	0.227
Male	90 (50.85)	52 (43.70)	–	–
Female	87 (49.15)	67 (56.30)	–	–
Age (years)	61.64±8.25	62.59±8.12	0.977	0.329
BMI (kg/m²)	24.78±2.19	24.51±2.26	1.026	0.305
T2DM duration (years)	10.45±6.28	9.53±6.07	1.252	0.211
Menopausal status (females only)	–	–	2.221	0.136
Yes	58/87 (66.67)	52/67 (77.61)	–	–
No	29/87 (33.33)	15/67 (22.39)	–	–
Education level	–	–	0.025	0.874
Primary school or below	146 (82.49)	99 (83.19)	–	–
Secondary school or above	31 (17.51)	20 (16.81)	–	–
CKD Stage			1.921	0.584
G1 (≥90)	42 (23.73)	38 (31.93)		
G2 (60–89)	68 (38.42)	45 (37.82)		
G3a (45–59)	39 (22.03)	22 (18.49)		
G3b (30–44)	21 (11.86)	11 (9.24)		
G4 (15–29)	7 (3.95)	3 (2.52)		

Table 2 Comparison of Clinical Laboratory Indicators and BMD ($\bar{x} \pm s$)

	Group A (n=177)	Group B (n=119)	*t*	*P*
PLT ($\times 10^9$/L)	233.15±58.67	192.43±55.11	5.998	<0.001
MPV ($\times 10^9$/L)	10.09±0.53	11.97±0.62	27.928	<0.001
UACR (mg/g)	322.79±87.74	344.39±112.64	1.850	0.065
HbA1c (%)	8.53±1.84	8.68±1.61	0.722	0.470
ALB (g/L)	40.09±3.56	39.07±6.64	1.711	0.088
ALP (U/L)	68.74±18.62	73.45±24.69	1.868	0.062

(*Continued*)

Table 2 (Continued).

	Group A (n=177)	Group B (n=119)	t	P
Scr (μmol/L)	66.97±15.32	65.29±15.18	0.928	0.353
BUN (mmol/L)	6.08±1.84	5.97±1.73	0.516	0.605
GFR [mL·(min·1.73m²)$^{-1}$]	118.09±37.16	120.84±30.75	0.668	0.504
SUA (μmol/L)	341.36±82.97	301.35±92.59	3.881	<0.001
TC (mmol/L)	4.96±1.82	4.99±2.27	0.125	0.900
TG (mmol/L)	2.85±1.53	2.96±1.57	0.600	0.548
HDL-C (mmol/L)	1.14±0.36	1.21±0.92	0.914	0.361
LCL-C (mmol/L)	3.02±1.09	2.88±1.04	1.103	0.270
Ca^{2+} (mmol/L)	2.18±0.11	2.20±0.09	1.646	0.100
Mg^{2+} (mmol/L)	0.91±0.12	0.89±0.10	1.501	0.134
Pi (mmol/L)	1.24±0.15	1.22±0.18	1.036	0.300
TBMM (%)	67.37±7.94	66.25±6.68	1.266	0.206
TBFM (%)	32.76±8.01	33.73±6.59	1.095	0.274
L1-L4 BMD (g/cm²)	1.12±0.21	1.01±0.18	4.674	<0.001
Femoral BMD (g/cm²)	1.03±0.19	0.99±0.21	1.701	0.089
Ward BMD (g/cm²)	0.89±0.25	0.83±0.28	1.928	0.054

Pearson Correlation Analysis

Pearson correlation analysis showed that MPV was negatively correlated with PLT, SUA, L1-L4 BMD, femoral BMD, and Ward BMD. See Table 3 and Figure 1.

Table 3 Correlation Between Clinical Indicators and MPV

Variable	MPV	
	r	P
Age	0.178	0.085
BMI	−0.047	0.673
T2DM duration	−0.099	0.341
PLT	−0.253	0.012
UACR	0.158	0.124
HbAlc	0.095	0.352
ALB	−0.117	0.259
ALP	0.173	0.096
Scr	−0.127	0.221
BUN	−0.048	0.662
GFR	−0.002	0.993
SUA	−0.246	0.015
TC	0.042	0.687
TG	0.063	0.552
HDL-C	0.023	0.836
LCL-C	0.031	0.775
Ca^{2+}	0.174	0.093
Mg^{2+}	0.083	0.439
Pi	−0.035	0.742
TBMM	−0.135	0.245
TBFM	0.133	0.251
L1-L4 BMD	−0.351	<0.01
Femoral BMD	−0.271	0.007
Ward BMD	−0.238	0.019

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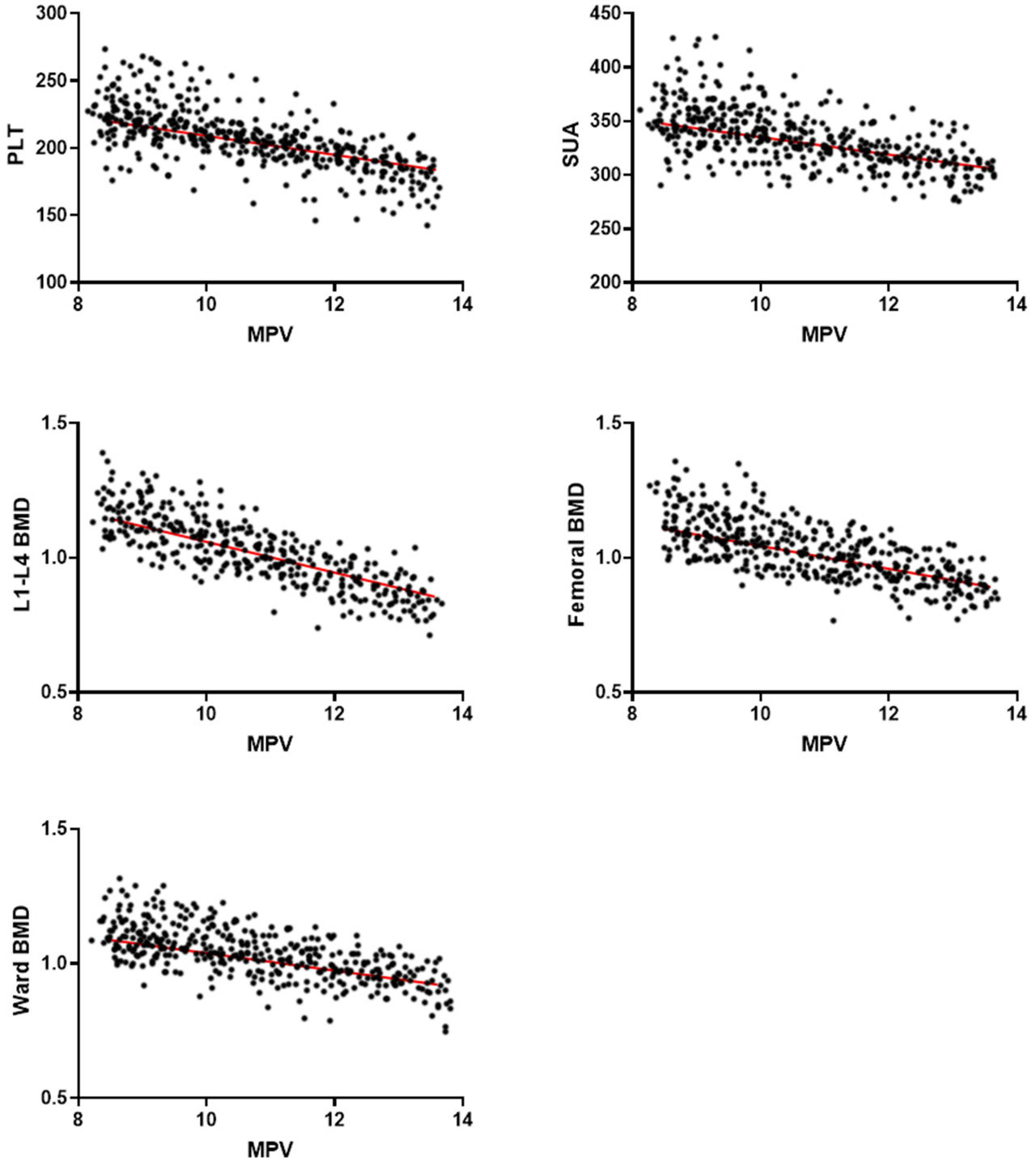

Figure 1 Scatter Plot of the association Between Clinical Indicators and MPV.

Multiple Linear Regression Analysis

Multiple linear regression analysis was performed to assess the independent association of mean platelet volume (MPV) with lumbar spine bone mineral density (L1-L4 BMD) after adjusting for clinically relevant covariates. The model included age, body mass index (BMI), menopausal status (with postmenopausal women coded as 1 and premenopausal women as 0), CKD stage group (stages G3-4 vs G1-2), platelet count (PLT), and serum uric acid (SUA). As presented in Table 4, higher MPV

Table 4 Multivariable Analysis of L1-L4 BMD

Variable	β	Std. Error	t	P
MPV	−0.061	0.019	−3.142	0.002
Age	−0.004	0.001	−3.571	<0.001
BMI	0.011	0.004	2.75	0.006
Menopause (Yes)	−0.042	0.017	−2.471	0.014
CKD Stage G3-4	−0.038	0.015	−2.533	0.012
PLT	0	0	−0.901	0.368
SUA	0	0	1.492	0.137

levels remained significantly associated with lower L1-L4 BMD (β = −0.061, P = 0.002). Notably, advanced age (β = −0.004, P<0.001), postmenopausal status (β = −0.042, P=0.014), and advanced CKD stages (G3-4; β = −0.038, P=0.012) were also independently associated with reduced BMD, while higher BMI showed a protective association (β = 0.011, P=0.006). Platelet count and serum uric acid did not reach statistical significance in the fully adjusted model (P>0.05). The model explained approximately 28.4% of the variance in L1-L4 BMD (adjusted R^2 = 0.284).

Discussion

This study analyzed the clinical data of patients with T2DM complicated with CKD to explore the association between MPV and BMD. The findings revealed that elevated MPV was not only significantly associated with reduced PLT and decreased SUA levels, but also negatively correlated with BMD at several key skeletal sites. Critically, after adjusting for age, BMI, menopausal status, and CKD stage, high MPV remained independently associated with lower lumbar BMD (β = −0.061, P = 0.002). These results provide empirical evidence supporting MPV as a potential biomarker reflecting bone metabolism disorders.

Clinical Characteristics and Physiological Significance of MPV in T2DM Patients with CKD

MPV is an important hematological parameter reflecting platelet size and activation status.[16] In recent years, increasing attention has been paid to MPV in various metabolic diseases and their complications, and it has been confirmed to be closely associated with cardiovascular events, inflammatory states, and thrombosis risk.[17,18] However, the mechanistic role and clinical indications of MPV in patients with T2DM complicated with CKD remain to be fully elucidated. T2DM itself is characterized by chronic low-grade inflammation and metabolic disturbances. Previous studies[19] have shown that oxidative stress, persistent activation of inflammatory cytokines such as IL-6 and TNF-α, and insulin resistance in diabetic patients can lead to sustained platelet activation, resulting in increased platelet volume and, consequently, elevated MPV.[20] However, we acknowledge that unmeasured mineral metabolism markers (PTH, vitamin D) may partially confound this relationship.

In this study, MPV levels were negatively correlated with PLT, indicating that as the average platelet volume increased, the platelet count decreased. This result aligns with previous research,[21,22] reflecting a compensatory mechanism of hematopoiesis under stress—where the body produces larger, younger platelets to compensate for a shortage of mature platelets, thereby maintaining total platelet mass. Additionally, it may indicate accelerated platelet consumption due to inflammation and coagulation activation, further disrupting hematologic homeostasis. Another important finding was the negative correlation between MPV and SUA levels. Uric acid, the final product of purine metabolism, possesses both antioxidant properties and the potential to induce oxidative stress and inflammatory responses at high levels.[23] Some studies[24,25] have suggested that elevated SUA levels can indirectly affect bone marrow hematopoietic function and platelet production by stimulating endothelial cell activation, inhibiting nitric oxide synthesis, and enhancing oxidative damage. Therefore, the negative association between MPV and SUA may reflect the dual role of uric acid in regulating platelet production and inflammation. In addition to these mechanisms, systemic inflammatory responses and disturbances in the renin-angiotensin-aldosterone system (RAAS) induced by renal dysfunction may also play key roles in platelet activation and

MPV elevation.[26] Studies[27] have found that RAAS activation not only promotes vasoconstriction and sodium-water retention but also induces endothelial dysfunction and vascular sclerosis by stimulating TGF-β and other inflammatory mediators, thereby exacerbating the systemic metabolic burden in patients with T2DM complicated with CKD.

Multidimensional Exploration of Potential Mechanisms Linking MPV and Bone Mineral Density Decline

Bone mineral density decline is a common and significant clinical issue among patients with T2DM and CKD, with complex underlying mechanisms involving interactions among metabolic, inflammatory, and endocrine factors.[28,29] In recent years, increasing studies[30,31] have focused on the role of hematological indicators in bone metabolic disorders, among which MPV has gradually been regarded as a potential biomarker of bone alterations due to its sensitivity to inflammatory status and platelet activation. In this study, we observed a negative correlation between MPV and multiple BMD indicators—including L1-L4 BMD, femoral BMD, and Ward's triangle BMD. This finding suggests that elevated MPV may not only represent chronic inflammation associated with diabetes and kidney disease but may also directly or indirectly participate in the regulation of bone remodeling processes.

From an inflammatory perspective, MPV serves as a marker of platelet activation, and its elevation typically indicates a chronic inflammatory state. Previous studies have shown that chronic low-grade inflammation can significantly promote the differentiation and maturation of osteoclast precursors and enhance bone resorption activity through the release of inflammatory cytokines such as IL-1β, IL-6, and TNF-α.[32] Activated platelets can also contribute to the maintenance of an inflammatory microenvironment by releasing cytokines such as platelet factor 4 (PF4) and transforming growth factor-β (TGF-β), thus fostering a pathological state conducive to bone loss.[33] Moreover, the bone marrow, as a dual-function organ responsible for both hematopoiesis and osteogenesis, requires a stable microenvironment to maintain bone metabolic balance. Elevated MPV may partially reflect increased responsiveness of megakaryocytes in the bone marrow to external inflammatory stimuli, potentially indicating a compensatory hematopoietic stress state. In this context, dysregulation of the coordination between hematopoietic and osteogenic units may disrupt signal transduction and intercellular communication between osteoblasts, osteocytes, and hematopoietic cells, thereby disturbing bone remodeling rhythms. Furthermore, previous research[34] has proposed that under chronic inflammatory conditions, mesenchymal stem cells in the bone marrow may exhibit a differentiation bias, shifting from osteogenesis to adipogenesis, which may further exacerbate bone density loss. Critically, even after adjusting for confounding variables such as PLT and SUA, as well as other key factors (age, BMI, menopausal status, CKD stage), a stable and significant independent negative association between MPV and BMD remained. Specifically, each 1 fL increase in MPV was associated with a 0.061 g/cm² decrease in lumbar spine BMD. This effect size, while statistically significant, translates to approximately a 0.122 g/cm² reduction when comparing patients with normal versus high MPV (mean difference of about 2 fL), which represents roughly 10% of the mean lumbar BMD in our cohort. Given that a 1 standard deviation decrease in BMD is associated with a 50–100% increase in fracture risk in CKD patients,[35] the observed MPV-related BMD difference may have clinical relevance. However, the direct impact on fracture risk remains to be established in longitudinal studies. This was further confirmed by multivariate linear regression analysis, suggesting that MPV may serve not only as a reflection of platelet physiology but also as an indicator associated with BMD decline. Li et al also reported in a study of postmenopausal women[36] that elevated MPV was associated with the occurrence of osteoporosis, suggesting its potential utility as an auxiliary tool for assessing bone loss. It is worth noting that CKD patients inherently present with mineral and bone disorders (CKD-MBD), characterized by disrupted calcium-phosphorus metabolism, secondary hyperparathyroidism, and vitamin D deficiency, which further undermine bone stability and reparative capacity.[37] Importantly, our study did not measure key regulators of bone metabolism such as parathyroid hormone (PTH) and vitamin D, which are integral to CKD-MBD and could confound the observed association between MPV and BMD. Therefore, the independent contribution of MPV should be interpreted with caution until these factors are accounted for in future studies.

Potential Value of MPV in Assessing Bone Metabolism Disorders

Currently, the diagnosis of osteoporosis primarily relies on imaging techniques such as DEXA to assess bone mineral density levels. However, although these methods have relatively high diagnostic accuracy, they present practical limitations including high costs, strong dependence on equipment, and complex operations. These limitations make widespread implementation particularly challenging in primary healthcare institutions or among populations undergoing general health screening. In contrast, MPV, as a routine indicator in complete blood count tests, offers advantages such as convenient sampling, cost-effectiveness, and good reproducibility. If a stable correlation between MPV and bone mineral density can be established, its clinical significance may far exceed conventional perceptions, potentially serving as a clinical marker for bone metabolism abnormalities. Nevertheless, our cross-sectional design precludes claims about MPV's ability to predict fractures or osteoporosis incidence. MPV not only reflects platelet volume and activation status but also partially indicates the body's systemic inflammatory level and bone marrow hematopoietic function. Considering the key role of chronic low-grade inflammation in bone metabolism disorders associated with T2DM and CKD, MPV, as an indirect marker of inflammatory activity, may participate in the pathological process even before significant bone density loss becomes apparent. Therefore, incorporating MPV into the clinical evaluation system for bone metabolism abnormalities may help address the blind spots of existing screening methods, especially for populations who cannot undergo DEXA examinations, and thus carries practical guiding value. Additionally, combining MPV with other metabolic parameters (such as serum uric acid, eGFR, calcium and phosphorus levels, total protein, and albumin) may facilitate the construction of multi-parameter assessment models for bone metabolism risk. Such models can provide individualized fracture risk assessments for T2DM patients with CKD, and also assist in determining whether to initiate anti-osteoporosis treatment, supplement vitamin D, or adjust nutritional support strategies. However, it is crucial to emphasize that our study did not evaluate longitudinal outcomes such as fracture incidence, and thus the utility of MPV for predicting fracture risk remains unproven. Future prospective studies are needed to determine whether MPV can contribute to fracture prediction models. Particularly in elderly patients or those with nutritional deficiencies, dynamic monitoring of MPV may serve as an auxiliary tool for evaluating bone metabolic stability.

Limitations

Although this study revealed inspiring findings regarding the association between MPV and bone mineral density, several limitations must be acknowledged. First, the study adopted a single-center, retrospective design, with data derived from a centralized source and a relatively limited sample structure, which may affect the generalizability and representativeness of the research conclusions. Moreover, baseline differences and potential confounding factors (such as nutritional status, medication history, and exercise level) among the enrolled patients were not fully controlled, which might interfere with the assessment of the association between MPV and bone metabolism. Secondly, the study did not systematically collect data on biomarkers closely related to bone metabolism, such as serum osteocalcin (OC), C-terminal telopeptide (CTX), bone-specific alkaline phosphatase (BALP), or the RANKL/OPG ratio, resulting in a lack of in-depth analysis of the specific mechanisms by which MPV may participate in bone remodeling. In addition, as a variable indicator, MPV is influenced by multiple factors such as the timing of the test, delays in sample processing, and blood anticoagulation methods, which may introduce deviations in data stability and consistency. Therefore, future studies should define the detection process and establish standardized operating protocols. Prospective longitudinal studies in multi-center, large-sample populations are warranted to further explore the temporal relationship between MPV changes over time and dynamic changes in bone mineral density. On this basis, with the help of artificial intelligence algorithms and clinical big data resources, it is possible to develop MPV-based risk scoring systems and promote the construction of early screening pathways for bone metabolism abnormalities in clinical settings. Furthermore, attempts can also be made to integrate MPV with inflammatory factor levels, bone metabolism markers, and bioinformatics data to conduct in-depth mechanistic studies, thereby clarifying its specific role in the pathogenesis and progression of diabetic osteopathy.

Conclusion

In conclusion, this study demonstrates that elevated MPV is independently associated with reduced bone mineral density in patients with T2DM and CKD, particularly at the lumbar spine. The effect size of this association, while statistically significant, requires further validation in prospective studies to determine its clinical relevance for fracture risk prediction. Given the limitations of unmeasured confounders (particularly PTH and vitamin D) and the cross-sectional design, MPV should currently be regarded as a potential indicator of bone health status rather than a proven predictor of fractures. Future research should focus on longitudinal assessments incorporating mineral metabolism markers and clinical endpoints to establish the utility of MPV in osteoporosis management for this high-risk population.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Zhu XR, Yang FY, Zhang L, et al. Prevalence and associated factors of diabetic retinopathy among type 2 diabetes in Dongcheng District and Tongzhou District, Beijing City: a cross-sectional study. *Zhonghua Yu Fang Yi Xue Za Zhi*. 2024;58(9):1324–1330. doi:10.3760/cma.j.cn112150-20240222-00136
2. Wu BT, An N, Yang YW, et al. Further understanding and paying attention to normoalbuminuric diabetic kidney disease. *Zhonghua Yu Fang Yi Xue Za Zhi*. 2023;57(10):1663–1673. doi:10.3760/cma.j.cn112150-20230404-00256
3. Ding HL, Luo HJ, Xu DP, et al. Emphasis on the diagnosis of chronic kidney disease in diabetes mellitus. *Zhonghua Yi Xue Za Zhi*. 2021;101(10):687–690. doi:10.3760/cma.j.cn112137-20201115-03094
4. Qiu Y, Zhao Q, Wang N, et al. Association of hyperuricemia with risk of incident chronic kidney disease in adult in Songjiang district, Shanghai: a follow-up study. *Zhonghua Liu Xing Bing Xue Za Zhi*. 2021;42(9):1607–1614. doi:10.3760/cma.j.cn112338-20200719-00957
5. Aleksova J, Ebeling P, Elder G. The effects of type 1 and type 2 diabetes mellitus on bone health in chronic kidney disease. *Nat Rev Endocrinol*. 2025;21(5):301–313. doi:10.1038/s41574-024-01083-8
6. Zhang TD, Cao S, Ren H-Y, et al. Cemented vertebra and adjacent vertebra refractured in a chronic kidney disease-mineral and bone disorder patient: a case report. *World J Clin Cases*. 2024;12(10):1804–1809. doi:10.12998/wjcc.v12.i10.1804
7. Ding L, Jiang X. The mediating role of BMI in the association between OSAHS and bone metabolism in male patients with T2DM. *Sleep Breath*. 2025;29(2):157. doi:10.1007/s11325-025-03302-6
8. Wang XF, Yu -J-J, Wang X-J, et al. The associations between hypovitaminosis D, higher PTH levels with bone mineral densities, and risk of the 10-year probability of major osteoporotic fractures in Chinese patients with T2DM. *Endocr Pract*. 2018;24(4):334–341. doi:10.4158/EP-2017-0164
9. Liu C, Wu SY, Zhang AB, et al. Expression level of Wilms' tumor 1 gene and its correlation with clinical features in patients with myeloproliferative neoplasms. *Zhonghua Yi Xue Za Zhi*. 2023;103(45):3658–3664. doi:10.3760/cma.j.cn112137-20231007-00663
10. Ding Q, Wang F, Guo X, et al. The association between mean platelet volume and metabolic syndrome in patients with type 2 diabetes mellitus: a retrospective study. *Medicine*. 2021;100(13):e25303. doi:10.1097/MD.0000000000025303
11. Gulia M, Gupta M, Singh Lehl S, et al. Mean platelet volume and glycaemic control in patients with new-onset Type 2 diabetes mellitus. *J R Coll Physicians Edinb*. 2022;52(2):105–109. doi:10.1177/14782715221107948
12. Kelly DM, Kelleher EM, Rothwell PM. The kidney-immune-brain axis: the role of inflammation in the pathogenesis and treatment of stroke in chronic kidney disease. *Stroke*. 2025;56(4):1069–1081. doi:10.1161/STROKEAHA.124.047070
13. Kamińska J, Koper OM, Siedlecka-Czykier E, et al. The utility of inflammation and platelet biomarkers in patients with acute coronary syndromes. *Saudi J Biol Sci*. 2018;25(7):1263–1271. doi:10.1016/j.sjbs.2016.10.015
14. Raveendran AV. Remission of type 2 diabetes mellitus: emerging concepts and proposed diagnostic criteria. *World J Methodol*. 2024;14(4):95210. doi:10.5662/wjm.v14.i4.95210
15. Huang S, Wu X. Clinical application of full age spectrum formula based on serum creatinine in patients with chronic kidney disease. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue*. 2018;30(9):877–881. doi:10.3760/cma.j.issn.2095-4352.2018.09.011
16. Shang GQ, Xiang S, Guo CC, et al. Diagnostic value of platelet associated biomarkers in chronic periprosthetic joint infection. *Zhonghua Wai Ke Za Zhi*. 2021;59(9):767–772. doi:10.3760/cma.j.cn112139-20210401-00152
17. Zhao S, Chen Y, Ren XW. Predictive value of platelet parameters for arterial complications in patients with myeloproliferative neoplasms. *Zhongguo Shi Yan Xue Ye Xue Za Zhi*. 2025;33(1):198–205. doi:10.19746/j.cnki.issn.1009-2137.2025.01.029
18. Jiang YJ, Song DY, Li JL. Predictive value of complete blood count and inflammation marker on risk of recurrence in children with Henoch-Schönlein Purpura. *Zhongguo Shi Yan Xue Ye Xue Za Zhi*. 2023;31(3):837–842. doi:10.19746/j.cnki.issn.1009-2137.2023.03.032
19. Haile K, Kedir R, Timerga A, et al. Role of platelet indices as diagnostic and predictive biomarkers for comorbidity of diabetes and metabolic syndrome in southern Ethiopia: a comparative cross-sectional study. *PLoS One*. 2022;17(11):e0277542. doi:10.1371/journal.pone.0277542
20. Tunca O, Kazan S, Kazan ED. Can mean platelet volume predicts renal outcome in acute on chronic kidney disease? *Ther Apher Dial*. 2023;27(2):232–239. doi:10.1111/1744-9987.13935
21. Zhen YN, Gong FY, Zhu HJ, et al. Changes in platelet related parameters in obese patients after sleeve gastrectomy. *Zhonghua Nei Ke Za Zhi*. 2021;60(11):993–996. doi:10.3760/cma.j.cn112138-20210224-00155
22. Uyanık BS, Cakiroglu B, Gozukucuk R. Predictive values and associations of serum PSA levels, delta neutrophil index, neutrophil-lymphocyte ratio and other hematological parameters in patients with acute prostatitis. *Urologia*. 2024;91(4):775–780. doi:10.1177/03915603241273883
23. Fang FS, Wang N, Sun J, et al. association between hemoglobin and serum uric acid in adults with various glucose metabolism status. *Zhonghua Yu Fang Yi Xue Za Zhi*. 2023;57(4):516–521. doi:10.3760/cma.j.cn112150-20221006-00960

24. Yin YH, Lin YQ, Wu J, et al. Investigation of prevalence rate of osteoporosis and analysis of its influencing factors in older adults in Jiuting Town, Songjiang District, Shanghai City. *Zhonghua Yu Fang Yi Xue Za Zhi*. 2024;58(7):1048–1054. doi:10.3760/cma.j.cn112150-20231210-00423
25. Bao F, Wang Y, Ju SQ, et al. Correlation between serum uric acid and creatinine ratio and metabolic syndrome based on physical examination population in Nantong area. *Zhonghua Yu Fang Yi Xue Za Zhi*. 2022;56(11):1630–1635. doi:10.3760/cma.j.cn112150-20220617-00620
26. Cao YH, Li X, Liu MH, et al. Association of RAAS gene polymorphisms with susceptibility to essential hypertension in military secret service personnel. *Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi*. 2022;40(7):504–508. doi:10.3760/cma.j.cn121094-20210202-00072
27. Papadopoulos KI, Papadopoulou A, Aw TC. MicroRNA-155 mediates endogenous angiotensin II type 1 receptor regulation: implications for innovative type 2 diabetes mellitus management. *World J Diabetes*. 2023;14(9):1334–1340. doi:10.4239/wjd.v14.i9.1334
28. Yan J, Zheng K, Lin C, et al. Correlation between sarcopenia and albuminuria in patients with type 2 diabetes. *Nan Fang Yi Ke Da Xue Xue Bao*. 2020;40(3):407–412. doi:10.12122/j.issn.1673-4254.2020.03.20
29. Mishima T, Motoyama K, Imanishi Y, et al. Decreased cortical thickness, as estimated by a newly developed ultrasound device, as a risk for vertebral fracture in type 2 diabetes mellitus patients with eGFR of less than 60 mL/min/1.73 m2. *Osteoporos Int*. 2015;26(1):229–236. doi:10.1007/s00198-014-2843-x
30. Sökmen FC, Ulucaköy C. Diagnostic and prognostic role of mean platelet volume and mean platelet volume/platelet ratio in patients with primary malignant bone tumor. *Jt Dis Relat Surg*. 2021;32(1):198–203. doi:10.5606/ehc.2021.76357
31. Lv X, Hu H, Shen C, et al. Risk factors associated with lower bone mineral density in primary aldosteronism patients. *Front Endocrinol*. 2022;13:884302. doi:10.3389/fendo.2022.884302
32. Zhang ZW, Zhao JY, Feng Y, et al. Study on the mechanism of cross-linked hyaluronic acid-dexamethasone hydrogelin post-traumatic osteoarthritis. *Zhonghua Yi Xue Za Zhi*. 2024;104(9):695–703. doi:10.3760/cma.j.cn112137-20231008-00672
33. Yang J, Guo A, Li Q, et al. Platelet-rich plasma attenuates interleukin-1β-induced apoptosis and inflammation in chondrocytes through targeting hypoxia-inducible factor-2α. *Tissue Cell*. 2021;73:101646. doi:10.1016/j.tice.2021.101646
34. Chen X, Wang C, Sun N, et al. Aurka loss in CD19 + B cells promotes megakaryocytopoiesis via IL-6/STAT3 signaling-mediated thrombopoietin production. *Theranostics*. 2021;11(10):4655–4671. doi:10.7150/thno.49007
35. Prasad B, Ferguson T, Tangri N, Ng CY, Nickolas TL. Association of bone mineral density with fractures across the spectrum of chronic kidney disease: the Regina CKD-MBD study. *Can J Kidney Health Dis*. 2019;6:2054358119870539. doi:10.1177/2054358119870539
36. Li XS, Zhang J-R, Meng S-Y, et al. Mean platelet volume is negatively associated with bone mineral density in postmenopausal women. *J Bone Miner Metab*. 2012;30(6):660–665. doi:10.1007/s00774-012-0362-4
37. Cejka D, Wakolbinger-Habel R, Zitt E, et al. Diagnosis and treatment of osteoporosis in patients with chronic kidney disease: joint guidelines of the Austrian Society for Bone and Mineral Research (ÖGKM), the Austrian Society of Physical and Rehabilitation Medicine (ÖGPMR) and the Austrian Society of Nephrology (ÖGN). *Wien Med Wochenschr*. 2023;173(13–14):299–318. doi:10.1007/s10354-022-00989-0