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Association Between Serum Vitamin D Levels and Peri-implant Diseases

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Abstract

Purpose

Dental implants are a reliable treatment for edentulism, but peri-implant diseases remain a challenge. Vitamin D's role in bone remodeling and immune function suggests it may influence peri-implant health.

Material and methods

In this cross-sectional study, 47 patients with functional dental implants were classified into peri-implant health, mucositis, and peri-implantitis groups using established clinical criteria. Clinical and radiographic assessments, including probing depth, plaque index, bleeding on probing, and bone loss, were performed. Serum vitamin D levels were measured from blood samples. Data analysis was conducted with SPSS, applying appropriate statistical tests and considering $p < 0.05$ as significant.

Results

Of the 47 participants, serum vitamin D levels were significantly lower in the peri-implantitis group compared to peri-implant health ($p = 0.003$). Vitamin D insufficiency was observed exclusively in peri-implant mucositis and peri-implantitis cases, with the highest prevalence in peri-implantitis. Lower vitamin D levels were significantly associated with increased bleeding on probing and greater bone resorption, particularly at 3 mm, 4 mm, and 5 mm ($p < 0.05$). No significant associations were found between vitamin D levels and probing depth or local plaque index ($p > 0.05$).

Conclusion

Within the limitations of this study, it can be concluded that lower serum vitamin D levels are significantly associated with peri-implantitis and increased alveolar bone resorption, suggesting its essential role in peri-implant health.

Trial Registration

Not applicable.

Introduction

Dental implants have become a reliable and successful treatment option for edentulous patients, representing high long-term survival rates. However, the increasing incidence of implant-related diseases remains a clinical challenge. (1) Peri-implant diseases are generally classified as peri-implant mucositis (PM) and peri-implantitis (PI). PM involves inflammation of the peri-implant soft tissue, while PI is characterized by inflammation accompanied by peri-implant bone loss and is a chronic inflammatory disease similar to periodontitis. (1–3) Currently, there is no definitive treatment that can reliably prevent PI; therefore, early identification of risk factors and prevention remain the most effective strategies. (1)

At the same time, peri-implant health (PH) is maintained when the surrounding tissues exhibit no clinical signs of inflammation, including redness, swelling, or bleeding on probing. (4, 5)

Successful implant therapy relies on proper osseointegration, which is defined as the direct structural and functional connection between the bone and the implant surface. (6) Various factors influence osseointegration and implant survival, which can be broadly categorized as implant-related (design and material), prosthetic protocol-related, and patient-related. (7, 8) Advances in implant designs and surgical protocols have reduced complications, yet early implant failures still occur, even in cases with optimal bone quality and adherence to standard protocols. This suggests that patient-related factors play a critical role in peri-implant tissue health and overall implant longevity. (9, 10) Effective prevention begins with the identification of risk factors associated with peri-implant diseases and the study of periodontal diseases (11, 12), such as smoking, previous periodontitis, inadequate oral hygiene, diabetes, alcohol use, and genetic susceptibility. (1, 13, 14)

Beyond these well-established risk factors, vitamin D status has emerged as a potential contributor to peri-implant tissue health, given its effects on bone remodeling and immune function. (15, 16) Vitamin D, a steroid hormone, can be obtained through diet or synthesized in the skin via sunlight exposure. (17) It is essential for calcium and phosphate metabolism, skeletal growth, and the maintenance of bone and dental health. (18–21) Vitamin D regulates bone remodeling by influencing osteoblast and osteoclast differentiation and activity, partially through its interaction with the nuclear Vitamin D Receptor (VDR). Activation of VDR upregulates the expression of bone-related proteins, such as type I collagen, osteocalcin, and osteopontin, thereby promoting bone formation and turnover. (2, 22–24) Additionally, vitamin D plays an immunomodulatory (23) and antimicrobial role in the oral cavity, which may protect periodontal and peri-implant tissues from inflammatory and infectious diseases. Previous studies have also demonstrated associations between vitamin D deficiency or VDR polymorphisms and chronic periodontitis. (22)

Vitamin D deficiency is a prevalent global health concern, typically defined as a serum 25[OH]D concentration below 20 ng/mL, with levels under 12 ng/mL indicating severe deficiency. (17, 25) Deficiency can impair bone healing and osseointegration, potentially increasing the risk of early implant failure and compromising long-term stability. (2, 23, 26)

Although several studies have examined the influence of vitamin D on osseointegration and short-term implant survival, the evidence remains inconclusive. Moreover, only a limited number of studies have explored the relationship between vitamin D deficiency and peri-implant mucosal inflammation. Considering the critical role of vitamin D in periodontal health, (27) and its high prevalence of deficiency in Iran, (17) this study aims to compare serum vitamin D levels in patients with peri-implant mucosal inflammation and those with healthy peri-implant mucosa.

Materials and methods

Sample preparation

This cross-sectional study was conducted on patients with a history of dental implant treatment at the Faculty of Dentistry, Alborz University of Medical Sciences. Initially, 81 patients were screened based on the inclusion criteria, and 63 were considered eligible. Ultimately, 16 patients were excluded due to poor cooperation. After obtaining written informed consent, data from 47 participants (24 females and 23 males) were analyzed.

Participants were divided into two main groups: 32 patients with peri-implant mucosal inflammation (PIMI, case group) and 15 patients with peri-implant health (PH, control group). The PIMI group was further classified into two subgroups based on clinical criteria: 15 patients with peri-implant mucositis (PM) and 17 with peri-implantitis (PI), resulting in three study groups, including the control group.

Inclusion criteria

Participants were included in the study if they met the following criteria:

- Age ≥ 18 years
- Good oral hygiene (daily toothbrushing with fluoride toothpaste and flossing)
- No history of periodontitis
- No prior regenerative bone treatment before implant placement
- No use of medications affecting peri-implant tissues (e.g., bisphosphonates, antibiotics)
- No vitamin D supplementation within the past 3 months
- Nonsmoker and nonalcoholic consumer
- No history of radiation therapy or chemotherapy
- Not pregnant
- Functional implants for at least 36 months
- Absence of systemic diseases (e.g., diabetes, immunodeficiency, bleeding disorders)

Diagnostic criteria

Diagnostic criteria were based on the “2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions” (4):

- **PH**: Absence of clinical inflammation, no bleeding on gentle probing, and no radiographic bone loss
- **PM**: Bleeding on gentle probing with no radiographic bone loss
- **PI**: Bleeding on gentle probing, increased pocket depth, and radiographic bone loss beyond the initial crestal bone level

Clinical and radiographic examinations

All clinical and radiographic assessments were performed at six sites per implant by a calibrated examiner, according to the definitions and protocols described by Newman et al. (28) and Kashefimehr et al. (29):

- **Keratinized mucosa (KM)**: Distance between the gingival margin and the mucogingival junction using a UNC-15 periodontal probe
- **Attached mucosa (AM)**: KM width minus probing depth
- **Probing depth (PD)**: Distance from the gingival margin to the base of the pocket with a UNC-15 probe
- **Plaque index (PI)**: Evaluated using O'Leary's index for implants and the whole- plaque index (WMPI)
- **Bleeding on probing (BOP)**: Recorded 15 seconds after probing as negative (−), mild (+), or profuse bleeding (++)
- **Bone loss (BL)**: Distance from the crestal bone to the crown margin compared with baseline radiographs after initial bone remodeling

Additionally, a blood sample was collected from each patient to measure serum vitamin D levels. All samples were analyzed in the same laboratory to ensure consistency.

Sample size calculation

The calculation was based on Agrawal et al., (30) targeting a type I error (α) of 0.05 and a statistical power (1 − β) of 0.90. A minimum of 7 participants per group was required, leading to three groups (PH, PM, PI) with 47 participants, with approximately equal distribution by sex.

Data analysis

Clinical parameters were evaluated visually and by tactile examination using a periodontal probe. Marginal bone loss was assessed through radiographic evaluation, and serum vitamin D levels were determined via laboratory analysis. Patient information, including age, peri-implant health status, and serum vitamin D level, was documented in variable-specific checklists. Finally, all collected data were analyzed, and the results were reported accordingly.

Data analysis was performed using SPSS software (version 23). Descriptive statistics included means and standard deviations, while inferential analyses employed the Chi-square, independent t-test, Mann-Whitney U, Kruskal-Wallis H, Spearman's rank correlation, and Pearson correlation coefficient tests. Data were presented as both numerical values and percentages in tabular format. A p-value of < 0.05 was considered statistically significant for all analyses.

Results

A total of 47 patients (23 males and 24 females) who had previously undergone dental implant treatment at the Faculty of Dentistry, Alborz University of Medical Sciences, were included in the study. Participants were classified into three groups: peri-implant health (PH; n = 15, 31.9%), peri-implant mucositis (PM; n = 15, 31.9%), and peri-implantitis (PI; n = 17, 36.2%). The baseline demographic characteristics of the participants are presented in Table 1. Statistical analysis revealed no significant differences in age or sex distribution among the three groups ($p > 0.05$), indicating that the groups were well matched for these demographic variables.

Table 1 Demographic Information of Patients

Variable	The health of peri-implant tissue (PH)	Peri-implant mucositis (PM)	Peri-implnatitis (PI)	Total N (%)	P Value
Number N (%)	15(31.9)	15(31.9)	17(36.2)	47(100)	0.872
Sex N (%) Male	7(46.7)	8(53.3)	8(47.1)	23(48.9)	0.798
Female	8(53.3)	7(46.7)	9(52.9)	24(51.1)	
Age N (%) <50	8(53.3)	6(40)	6(35.4)	20(42.6)	0.531
>50	7(46.7)	9(60)	11(64.3)	27(57.4)	
Type of Prostheses (Overdenture, Bridge, Single Crown)	0, 7(46.7), 8(53.3)	2(13.3), 7(46.7), 6(40)	1(6.7), 10(58.9), 6(35.4)	3(6.3), 24(51.1), 20(42.6)	0.339
Type of Edentulism (Complete, Partial)	0, 15(100)	2(13.3), 13(86.7)	1(6.7), 16(93.3)	3(6.3), 44(93.7)	0.570
Site of Implant (mandible posterior, mandible anterior, maxilla posterior, maxilla anterior area)	4(26.7), 2(13.3), 6(40), 3(20)	7(46.7), 3(20), 4(26.7), 1(6.7)	6(35.4), 3(17.6), 6(35.4), 2(11.7)	17(36.2), 8(17), 16(34), 6(12.8)	0.211
Type of Surgery (one-step, two-step)	4(26.7), 11(73.3)	7(47.7), 8(53.3)	5(29.4), 12(70.6)	16(34), 31(66)	0.288

The mean serum vitamin D levels in the PH, PM, and PI groups were 46.9 ng/mL, 44.6 ng/mL, and 34.2 ng/mL, respectively. These findings suggest a potential inverse relationship between peri-implant disease severity and serum vitamin D levels.

For qualitative assessment, serum vitamin D concentrations were categorized into two groups: insufficient (0–29 ng/mL) and **sufficient** (30–100 ng/mL). Among the 47 participants, 8 patients exhibited insufficient vitamin D levels. Of these, 1 patient was from the PM group, while 7 patients belonged to the PI group. Notably, none of the PH group patients exhibited vitamin D insufficiency. Within

the PM group, 6.7% of participants presented with insufficient levels, whereas 93.3% had sufficient levels. Conversely, in the PI group, 41.2% of patients showed insufficiency, while 58.8% maintained sufficient vitamin D levels. (Table 2)

Fisher's Exact Test revealed a statistically significant association between serum vitamin D status and peri-implant condition, with a notably higher prevalence of vitamin D insufficiency in the PI group (p = 0.003).

Table 2
Serum Vitamin D level in 3 groups of patients (PH, PM, PI)

Vitamin D (ng/ml)	**The health of peri-implant tissue (PH)**	**Peri-implant mucositis (PM)**	**Peri-implnatitis (PI)**	**Total N (%)**	**Statistical Significance**
Minimum	32.10	21.80	7.70		
Maximum	85.70	74.60	70.10		
Mean	46.94	44.65	34.27		
Insufficient	0(0)	1(6.7)	7(41.2)	8(17)	
Sufficient	15(100)	14(93.3)	10(58.8)	39(83)	

In the PM group, five patients demonstrated severe bleeding on probing (BOP), whereas 13 of 17 patients in the PI group exhibited severe BOP. The mean serum vitamin D level among patients is shown in Table 3, with those with severe BOP (++) having a lower mean level of 33.2 ng/mL. Statistical analysis using the independent t-test indicated a significant inverse relationship between serum vitamin D levels and BOP severity (p = 0.025).

Table 3
Relation between BOP and Vitamin D in PIMI patients

Variable (BOP)	**Number**	**Mean Vitamin D Level (ng/ml)**	**Statistical Significance**
+	14	46.71 ± 11.02	
++	18	33.25 ± 7.91	
BOP: bleeding on probing PIMI: Peri-implant mucosal inflammation			

The mean probing depths and the maximum probing depths in all groups are shown in Table 4. Pearson's correlation analysis indicated an inverse relationship between serum vitamin D levels and both mean and maximum probing depths; however, this correlation did not reach statistical significance (p > 0.05).

Table 4
Relation between mean and maximum probing depth and vitamin D in PIMI patients

Mean Probing Depth (mm)	**Peri-implant mucositis (PM) (n = 15)**	**Peri-implnatitis (PI) (n = 17)**
	4.78	**5.19**
	P = 0.703	**P = 0.591**
Maximum Probing Depth (mm)	5.26	5.94
	P = 0.868	P = 0.817
PIMI: Peri-implant mucosal inflammation Mm: millimeter		

The local plaque index (LPI) values for the PH, PM, and PI groups were 28.3%, 45.01%, and 52.93%, respectively. When participants were categorized by LPI levels of 25%, 50%, and 75%, their mean serum vitamin D concentrations were 37.34 ± 9.28 ng/mL, 35.12 ± 7.39 ng/mL, and 48.68 ± 11.15 ng/mL, respectively. Analysis of variance (ANOVA) demonstrated no statistically significant association between LPI and serum vitamin D levels ($p = 0.187$).

Among patients in the PI group, the mean bone resorption was 3.35 mm, ranging from 2 mm to 5 mm. Mean serum vitamin D levels for patients with 0 mm, 2 mm (n = 5), 3 mm (n = 4), 4 mm (n = 5), and 5 mm (n = 3) of bone resorption are shown in Table 5. As illustrated in Diagram 1, the lowest serum vitamin D levels were observed in patients with 3 mm, 4 mm, and 5 mm of bone resorption, which fall within the range of vitamin D insufficiency.

One-way ANOVA revealed a statistically significant difference in mean serum vitamin D levels (ng/mL) among patients with peri-implant mucosal inflammation (PIMI) based on the degree of bone resorption ($p = 0.001$). Post hoc Tukey multiple comparison analysis showed that patients with 3 mm, 4 mm, and 5 mm of bone loss had significantly lower mean serum vitamin D levels compared to those with 0 mm and 2 mm of bone loss ($p < 0.05$). No statistically significant differences were observed among the other groups ($p > 0.05$) (Diagram 1).

Table 5
Relation between Bone Loss and Vitamin D in PIMI Patients

Bone Loss (mm)	Number	Mean Vitamin D Level (ng/ml)	Standard Deviation
0.00	15	44.65[a]	13.37
2.00	5	48.76[a]	6.84
3.00	4	27.87[b]	15.39
4.00	5	19.22[b]	8.74
5.00	3	8.91[b]	8.91
Total	32	37.04	11.46

PIMI: Peri-implant mucosal inflammation

Groups with different English letters are statistically significantly different in mean ($P < 0.05$) according to Tukey's multiple comparisons test.

Diagram 1. The mean serum vitamin D level based on the degree of bone resorption in patients with PIMI

Discussion

Dental implants have revolutionized the management of edentulism; (31) however, the long-term success of implant therapy requires careful evaluation of local and systemic factors that may compromise peri-implant health. (7, 8, 32, 33) Peri-implant diseases, including peri-implant mucositis and peri-implantitis, are multifactorial infectious-inflammatory conditions that remain a clinical challenge, as no universally accepted gold-standard treatment currently exists. (34)

Current therapeutic strategies for peri-implant diseases include mechanical debridement, adjunctive laser therapy, and systemic or local antibiotics. In cases resistant to nonsurgical treatment, surgical interventions such as resective or regenerative procedures are considered. Despite these efforts, complete resolution of peri-implant diseases is rarely achieved (29), highlighting the importance of identifying risk factors that predispose individuals to these conditions. Among these, bone resorption—an almost irreversible outcome of osteoclastic activity in response to chronic inflammation—necessitates particular attention (35). This study specifically investigated the potential influence of serum vitamin D on peri-implant health.

The present study found that patients with peri-implant mucosal inflammation (PIMI) had markedly lower mean serum vitamin D levels (34.27 ng/mL) compared with healthy individuals (46.94 ng/mL). This difference was statistically significant in the peri-implantitis (PI) group ($p = 0.003$). Furthermore,

qualitative analysis revealed a strong association between vitamin D insufficiency and peri-implant disease, as all patients with insufficient vitamin D were classified within the PIMI group.

These findings align with previous studies. For instance, Ustaoğlu et al. investigated various serum biochemical markers in individuals with dental implants. They observed a negative correlation between vitamin D concentrations and the gingival index, with the lowest levels occurring in patients with PI. (1) Likewise, Acipinar et al., evaluating vitamin D levels in patients with different peri-implant diseases, reported significantly reduced vitamin D levels in patients with peri-implantitis compared with healthy controls, further supporting the potential importance of vitamin D in maintaining peri-implant health. (2)

A key finding of this study was the significant relationship between serum vitamin D levels and alveolar bone resorption around dental implants ($p = 0.001$). Notably, patients with 3 mm, 4 mm, and 5 mm of bone loss had significantly lower serum vitamin D concentrations compared to those with 0 mm or 2 mm of resorption. This is consistent with Alshouibi et al. (2013), who demonstrated that elderly men with higher vitamin D intake (> 800 IU/day) exhibited a reduced risk of severe chronic periodontitis and less alveolar bone loss, whereas those with low intake (< 400 IU/day) experienced greater resorption. (36) Similarly, Wagner et al. (2017) concluded that adequate vitamin D levels support marginal bone preservation and enhance bone formation around implants. (21) Consistent with these observations, Tabrizi et al. (2022) demonstrated that a low concentration of serum vitamin D is associated with increased marginal bone loss around dental implants. (37)

The biological plausibility of these findings is supported by the well-established role of vitamin D in bone metabolism and immune regulation. Vitamin D facilitates calcium absorption, reduces renal calcium excretion, and modulates osteoblast and osteoclast activity, which are essential for bone remodeling and osseointegration. (2, 23, 24) Experimental studies in animal models have consistently shown that vitamin D deficiency delays bone healing and mineralization, whereas supplementation promotes callus formation and bone repair. (38, 39) Moreover, vitamin D exerts anti-inflammatory effects (40), which may explain its association with reduced bleeding on probing (BOP). In the present study, higher vitamin D levels were inversely correlated with BOP severity ($p = 0.025$), consistent with the findings of Dietrich et al. (2005) and Ustaoglu et al., who reported that sufficient vitamin D levels are associated with reduced gingival inflammation. (1, 41)

Based on the current findings, there was no statistically significant difference in mean probing depth or local plaque index between the study groups ($p > 0.05$). In contrast, Acipinar et al. reported a significant negative correlation between serum vitamin D levels and both probing depth and modified plaque index. (2) It is important to note that the plaque indices used in our study and Acipinar et al.'s study differ, which may contribute to the variation in results observed between the two investigations.

Recent research has highlighted that vitamin D deficiency can hinder the bone healing process, given the vitamin’s essential role in regulating the activity of osteoclasts and osteoblasts, the cells responsible for bone resorption and formation. (42–44) Numerous studies examining the relationship between serum vitamin D levels and bone changes at implant sites during osseointegration suggest that maintaining

sufficient vitamin D levels is crucial not only for overall health but also for optimizing bone-to-implant contact (BIC). Consequently, vitamin D is increasingly recognized as a key factor that supports bone tissue growth and successful implant integration. (45–48)

Supporting these findings, a recent umbrella review by Tallon et al. systematically evaluated the existing literature on vitamin D's role in dental implant osseointegration. Their analysis of multiple systematic reviews confirmed that vitamin D positively influences the osseointegration process and is associated with a reduced risk of implant failure. However, the authors emphasize the need for future studies to address current methodological limitations to strengthen the quality and validity of evidence in this field. (16) Incorporating such comprehensive evidence underscores the growing recognition of vitamin D as a critical factor in optimizing implant outcomes and highlights the importance of considering vitamin D status in clinical implant dentistry.

Beyond skeletal health, vitamin D plays a key role in modulating innate and adaptive immunity by influencing the activity of T cells, B cells, and antigen-presenting cells. Its immunomodulatory properties may contribute to controlling peri-implant inflammation and reducing the risk of infection-related implant complications. (49) This dual role in both bone metabolism and immune regulation highlights vitamin D as a potential adjunctive factor in peri-implant disease prevention and management.

Given the emerging evidence linking vitamin D to peri-implant health, further studies with larger cohorts and longitudinal designs are recommended. Future research should explore the effects of vitamin D on primary implant stability, early implant failure, osseointegration, BIC, marginal bone loss, and clinical peri-implant parameters. Such investigations may ultimately clarify whether vitamin D optimization can serve as a preventive or therapeutic strategy in implant dentistry.

Conclusions

This study highlights a significant statistical association between vitamin D deficiency and peri-implantitis, with about 88% of deficient patients diagnosed with this condition. Lower serum vitamin D levels correlated with increased bone loss and greater bleeding on probing, underscoring vitamin D's potential role in maintaining peri-implant tissue health. These findings suggest that assessing vitamin D status before implant therapy may be essential to improve treatment outcomes and prevent implant-related complications.

Abbreviations

AM
Attached Mucosa
BIC
Bone-to-Implant Contact
BL
Bone Loss

BOP
Bleeding on Probing
KM
Keratinized Mucosa
LPI
Local Plaque Index
mm
millimeter
PD
Probing Depth
PI
Peri-implantitis
PIMI
Peri-implant Mucosal Inflammation
PM
Peri-implant Mucositis
VDR
Vitamin D Receptor

Declarations

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Competing Interests

The authors declare no conflicts of interest.

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Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of Alborz University of Medical Sciences (Approval Code: IR.ABZUMS.REC.1400.084). Written informed consent was obtained from all participants after explanation of the study objectives. Participation was voluntary, confidentiality was maintained, and no financial burden was imposed. The research complied with cultural and religious

values. All relevant studies influencing the findings have been appropriately cited in this article and will be cited in any related future publications.

Data availability

Data available upon reasonable request from the corresponding author.

Consent for Publication

All participants provided written informed consent for participation in this study and for the publication of anonymized data. In this study, no identifiable patient information, images, or personal details are included.

Use of AI and AI-Assisted Technologies

No artificial intelligence (AI) or AI-assisted technologies were used in the generation of data or analysis. The manuscript was written entirely by the authors. Grammarly (Grammarly Inc., USA) was used to assist with grammar and language editing.

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Figures

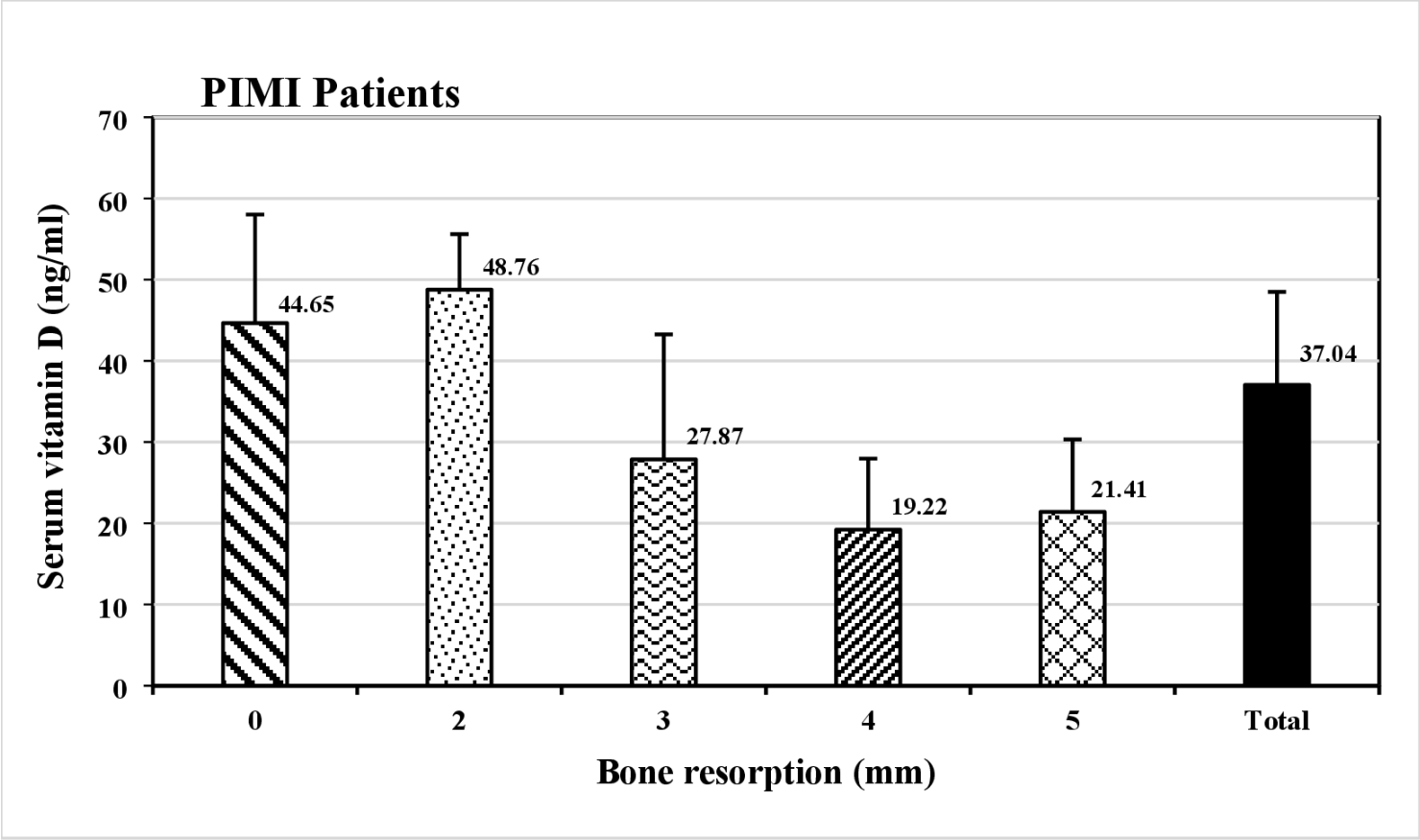


Figure 1

Legend not included with this version