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Original Article

Serum 25 Hydroxycholecalciferol in Periodontitis Patients with Type 2 Diabetes Mellitus–A Socioeconomic and Clinicobiochemical Study in Chhattisgarh

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Abstract

Very few studies have examined the impact of the concurrent presence of periodontitis (PD) and type 2 diabetes mellitus (T2DM) on serum Vitamin D levels, particularly in developing nations like India, and needs further investigation. Aim: This study aims to assess the relationship between serum Vitamin D values and PD in T2DM patients and to study the correlation between socioeconomic and demographic variables that influence the serum Vitamin D levels and the extent of PD in patients with T2DM. Materials and Methods: This was a cross-sectional, hospital-based research. Medical, dental, and diet histories were obtained from the participants, and their socioeconomic status (SES) was determined. Clinical parameters – plaque index (PI), gingival index (GI), sites with gingival bleeding, probing pocket depth (PPD), and clinical attachment level (CAL) were compared among three groups -patients with generalized Stage III Grade B PD with T2DM (n=35), patients with generalized stage III Grade B PD (n=35) and healthy controls (n=35) and the clinical parameters - plaque index(PI), gingival index(GI), sites with gingival bleeding, probing pocket depth(PPD), and clinical attachment level(CAL) were measured. Biochemical tests included the evaluation of serum 25-hydroxyvitamin D (25[OH] D) and hemoglobin A1C (HbA1c) levels. Statistical Analysis: Periodontal and biochemical parameters were compared using a one-way analysis of variance across the three groups. The association between clinical parameters, SES, and 25(OH)D was examined using Pearson's correlation coefficient test and linear regression analysis. Results: The serum 25(OH)D levels were lowest in the subjects with generalized Stage III Grade B PD with T2DM (13.54 ± 3.31 ng/mL). Furthermore, there was a significant ($P < 0.01$) negative correlation between serum 25(OH)D and periodontal parameters, PI (−0.442), PPD (−0.474), CAL (−0.459), sites with gingival bleeding (−0.354), and GI (−0.346) among the groups. The regression analyses showed that an increase in periodontal parameters (PI, GI, PPD, and CAL) and a higher HbA1c was linked to a lower 25(OH)D. However, the periodontal parameters and 25(OH)D levels showed no correlation with socioeconomic and demographic parameters in the study. Conclusion: Serum Vitamin D values are negatively influenced by the synergistic effect of PD and T2DM or by the presence of PD alone. However, the association of SES on serum Vitamin D values in individuals with PD and T2DM or PD alone could not be demonstrated.

Key words: Diabetes mellitus, Periodontitis, Vitamin D, Chhattisgarh

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Introduction

Periodontitis (PD) is a microbially associated, host-mediated inflammatory disease destroying the tooth-supporting structures.[1] By and large, PD is highly prevalent among a sizeable adult population.[1] Robust evidence reveals a possible

link between PD and systemic conditions such as type 2 diabetes mellitus (T2DM), cardiovascular illnesses, respiratory diseases, and certain cancers.[2]

Diabetes mellitus (DM) is particularly linked to PD, with studies indicating a two to three-fold increased risk, particularly if diabetes is not well controlled.[3] About 9.3% of the world's population is affected by DM, a chronic metabolic disease.[4] It is well known that there is a two-way relationship between DM and PD; PD is not only seen as a complication of DM but also has a big impact on DM management, incidence, and complications.[3]

Vitamin D is the best recognized for the preservation of bone health.[5] It is now known that sufficient Vitamin D values are crucial for the effective functioning of several body systems.[5] 25-hydroxyvitamin D (25[OH]D) blood level is the key predictor of a person's Vitamin D level.[5] According to recent studies, Vitamin D values may be related to PD and DM.[6-8] The host responses to microbial antigens in PD include innate and adaptive immunity, which are said to be partly modulated by Vitamin D.[9] In addition, PD, being a chronic inflammatory disorder brought on by repeated microbial dysbiosis may result in low values of Vitamin D and Vitamin D-associated endocrine dysfunction.[9] In a similar vein, new data indicate that low Vitamin D values result in decreased insulin production.[10] There have been theories linking inherited gene polymorphisms and altered immunoregulatory function to the potential connection between Vitamin D deficiency and insulin resistance.[10] When present simultaneously, both diabetes and periodontal infection may compound each other's negative consequences. Hence, it is hypothesized that patients diagnosed with both PD and T2DM may have much lower Vitamin D values than those of individuals with PD alone or healthy individuals. The relationship between PD and Vitamin D has been the subject of several investigations. However, only a few studies, particularly in developing nations like India, have explicitly assessed the serum Vitamin D values in patients with PD and T2DM.

The state of Chhattisgarh today, inter alia, faces several challenges to enhance the dental health status of its population.[11] The cultural patterns and the socioeconomic status (SES) of the people vary a lot and so does their oral health.[12] People in Chhattisgarh have lower levels of education and economic achievement and have less access to public utilities and health care, which may negatively influence their Vitamin D levels.[12]

To the best of our knowledge, there is no existing research in the Chhattisgarh population to evaluate the serum Vitamin D values in individuals with co-existing PD and T2DM. Against this backdrop, the current study was conducted to assess the relation between serum Vitamin D levels and PD in T2DM patients and to study the correlation between socioeconomic and demographic variables that influence serum Vitamin D values and the extent of PD in individuals with T2DM.

Materials and Methods

This was a hospital-based, cross-sectional study. The study participants were chosen from among the outpatients of the Department of Periodontics after obtaining written informed consent from them. The investigation was executed in adherence with the Helsinki Declaration (2013) and was sanctioned by the Institutional Ethics Committee of Government Dental College and Hospital, Raipur. (IEC: ECR/6488/GDC/CG/2019).

Patients aged 35–55 years, residing in Chhattisgarh state, and having a minimum of 20 teeth were eligible for the study. Subjects were categorized into three groups: Patients with generalized Stage III Grade B PD (PD group), patients with generalized Stage III Grade B PD with T2DM (PD-DM group), and subjects without any evidence of periodontal and systemic disease (healthy control group). The clinical case definitions for Stage III Grade B PD were based on the diagnostic criterion laid down by the American Academy of Periodontology Criteria 2017.[13] Patients with T2DM were included depending on standards of medical care in diabetes 2018 criteria (hemoglobin A1C [HbA1c] ≥6.5% (48 mmol/mol).[14] Participants with conditions linked to Vitamin D deficiency such as bone disorders and cancers, or other systemic disorders such as renal diseases or cardiovascular disorders, history of smoking or any other form of tobacco use, pregnant women or lactating women, postmenopausal women, and history of any form of periodontal treatment and patients who used antibiotics or other drugs that affect periodontal status in the past 6 months were exempted from the present study.

The minimum projected sample size was 33 subjects per group, according to the sample size calculation, which was based on the findings of Joseph *et al*. to achieve 80% power at a 95% confidence interval. G*Power Version 3.1.9.2 (Heinrich-

Heine- Universität Düsseldorf, Düsseldorf, Germany). was used to obtain the sample size.[15] The overall sample size to be employed in the study was computed as 105 after rounding off the sample size to 35 in each group.

Before the oral examination, each participant had their full medical, dental, and diet histories obtained. During the interview with the respondents, demographic information such as age, gender, location, outdoor activity, amount of sun exposure (in hours per day), diet, level of exercise, frequency of dental visits, family type, and housing type were elicited. The body mass index (BMI) was determined by dividing the subject's height (in meters) by their squared weight (in kilograms). The 2019 version of the modified Kuppuswamy scale was used to determine SES.[16] The Kuppuswamy SES Scale consists of three parameters: the educational and occupational status of the family head, the overall aggregate income of the entire family pooled from all sources, and each of these factors is further divided into subgroups and given a score.[16] The Kuppuswamy SES total score spans from 3 to 29 and divides families into five categories: "upper class, upper middle class, lower middle class, upper lower, and lower socioeconomic class."[16]

Biochemical investigation was carried out by a single, trained laboratory assistant. Each participant had a 5 mL sample of venous blood drawn from the antecubital fossa under strict aseptic conditions, which was then transferred into sterile ethylenediaminetetraacetic acid tubes. The test tubes were sent to the laboratory for analysis. Chemiluminescence immunoassay was utilized to measure the amount of serum 25-hydroxyvitamin D (Advia Centaur, Seimens, Germany). Fully automated High-Performance Liquid Chromatography utilizing the Biorad Variant II Turbo (Bio-Rad, Montreal, Quebec, Canada) was used to measure HbA1c. Assessment of the biochemical parameters was done by a trained and qualified laboratory professional.

A single trained examiner carried out the clinical examination. The following clinical parameters were documented for every subject: plaque index (PI), gingival index (GI), sites with gingival bleeding (bleeding on probing [BOP]), probing pocket depth (PPD), and clinical attachment level (CAL). All the teeth, except the third molar, were examined with a mouth mirror and a calibrated periodontal probe (University of North Carolina-15 Probe, Hu-Friedy Manufacturing Co., Chicago, IL, USA). The Ainamo Bay index was used to calculate BOP.[17] PI and GI were recorded on mesiobuccal, buccal, distobuccal, and whole lingual margins of each tooth, with scores computed based on the criteria provided by Silness and Loe for PI and Loe and Silness for GI.[18] PPD and CAL were measured at six sites per tooth: mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual. All the measurements were rounded off to the closest millimeter.

Before the start of the baseline examinations, calibration exercises for the variables PPD and CAL were carried out on five randomly chosen patients with PD who were unrelated to the study. At six points within a randomly chosen quadrant, measurements were taken and recorded 24 h apart. The intraclass correlation for PPD was 0.85, while the intraexaminer reliability for CAL was 0.80.

Statistical analysis

First, all the data were compiled into Excel format and a descriptive analysis of the demographic, clinical, and biochemical parameters was performed. Frequency (%), ratio, and mean with standard deviation were used to compile the data. A Chi-square test was performed to compare the categorical variables. Comparisons between the three groups for continuous variables, i.e., age, body mass index (BMI), clinical parameters (PI, GI, BOP, PPD, and CAL), and biochemical parameters (HbA1c and 25[OH]D) were done by using either the Kruskal–Wallis test or one-way analysis of variance test after normality check. Clinical and biochemical indicators were *post hoc* adjusted (Bonferroni test) across the three groups. The association between clinical parameters and 25(OH)D and SES was examined using Pearson's correlation coefficient test. Linear regression analyses were performed to assess the effect of periodontal parameters and HbA1c levels on 25(OH)D. The relationship between 25(OH)D and demographic factors, including SES, was also studied using linear regression analysis. The *P* value was set at <0.05. The IBM the Statistical Package for the Social Sciences (SPSS) (Version 20.0; IBM Corp, Armonk, NY, USA) was used for analyses.

Results and Discussion

A total of 105 subjects were included in the present research: 35 subjects having generalized Stage III Grade B PD and systemic health (PD), 35 subjects with generalized Stage III Grade B PD and T2DM (PD-DM), and 35 subjects who were both systemically and periodontally healthy (control group).

From the data presented in **Table 1**, the mean BMI was 20.52 ± 1.53, 21.95 ± 1.59, and 20.63 ± 1.36 for the PD group, PD-DM group, and control group, respectively, and the difference in BMI between the groups was statistically significant ($P < 0.001$). However, the groups did not differ significantly in terms of other characteristics such as age, gender, location, outdoor activity, amount of sun exposure, extent of exercise, diet, dental visit, family type, house type, and SES.

Table 1: Characteristics of the participant study population

Variable	Control	PD	PD-DM	*P**
Age (years), mean±SD	40.0±6.49	43.1±8.25	48.5±9.5	0.19
Gender distribution (%)†				
Male	22 (62.8)	17 (48.6)	23 (71.8)	0.29
Female	13 (37.2)	18 (51.4)	12 (28.2)	
Location, *n* (%)†				
Rural	4 (18)	13 (37.1)	2 (5.8)	0.06
Peri urban	16 (38)	10 (28.6)	11 (31.4)	
Urban	15 (44)	12 (34.3)	22 (62.8)	
Outdoor activity, *n* (%)†				
1–5 times/week	7 (20)	11 (31.4)	9 (25.7)	0.54
>5 times/week	28 (80)	24 (68.6)	26 (74.3)	
Sun exposure (h/day) (mean±SD)#	1.53±0.83	1.47±1.10	1.30±0.59	0.52
Extent of exercise, *n* (%)†				
Regularly	10 (28)	8 (22.9)	5 (14.3)	0.36
Sometimes	25 (72)	27 (77.1)	30 (85.7)	
BMI (kg/m^2)#, mean±SD	20.63±1.36	20.52±1.53	21.95±1.59	0.00**
Diet, *n* (%)†				
Vegetarian	26 (74.2)	22 (62.8)	28 (80)	0.26
Mixed	9 (25.8)	13 (37.2)	7 (20)	
Dental visit, *n* (%)†				
Only if problem is there	32 (91.4)	32 (91.4)	34 (97.1)	0.54
Once in 6 months	3 (8.6)	3 (8.6)	1 (2.9)	
Family type, *n* (%)†				
Joint family	11 (31.5)	12 (34.3)	7 (20)	0.27
Nuclear family	24 (68.5)	23 (65.7)	28 (80)	
House type, *n* (%)†				
Pucca	22 (62.8)	23 (65.7)	22 (62.8)	0.87
Apartment	10 (28.5)	11 (31.4)	10 (28.5)	
Independent house	3 (8.7)	1 (2.9)	3 (8.7)	
SES, *n* (%)†				
Upper	0	6 (17.1)	0	0.40
Upper middle	21 (62)	23 (65.7)	29 (82.9)	
Lower middle	14 (38)	6 (17.1)	6 (17.1)	
Upper lower	0	0	0	
Lower	0	0	0	

*P<0.05 is considered statistically significant; **P<0.01 is considered highly statistically significant; †Chi-square test was done; #One-way ANOVA was done. PD – Generalized Stage III Grade B periodontitis; PD-DM – Generalized stage III Grade B periodontitis with type 2 diabetes mellitus; SD – Standard deviation; *n* – Counts; % – Percentage; BMI – Body mass index, SES – Socioeconomic status; *P* – p value; kg/m2 – kilogram per square meter

All the periodontal metrics – PI, GI, BOP, PPD, and CAL – were significantly greater in the two case groups as opposed to the healthy controls ($P < 0.001$). All the periodontal parameters were significantly higher in the PD-DM group in comparison to the PD group ($P = 0.04$ for BOP and $P < 0.001$ for other parameters) **(Table 2)**.

Table 2: Comparison of periodontal parameters among the three groups

Periodontal parameters	PD, mean (SD)	PD-DM, mean (SD)	Control, mean (SD)	*P**	*P*1‡	*P*2‡	*P*3‡
GI	2.10 (0.21)	2.30 (0.28)	1.88 (0.29)	0.000**	0.003**	0.006**	0.000**
PI	2.10 (1.00)	2.77 (1.21)	0.50 (0.15)	0.000**	0.000**	0.000**	0.000**
BOP	0.85 (0.21)	0.96 (0.23)	0.06 (0.01)	0.000**	0.000**	0.040*	0.000**
PPD (mm)	6.41 (0.69)	6.84 (0.53)	2.22 (0.30)	0.000**	0.000**	0.004**	0.000**
CAL (mm)	4.28 (0.34)	4.74 (0.78)	0.00 (0.00)	0.000**	0.000**	0.000**	0.000**

*P<0.05 is considered statistically significant; **P<0.01 is considered highly statistically significant; ‡*Post hoc* adjustment (Bonferroni test) was done.

PD – Generalized Stage III Grade B periodontitis; PD-DM – Generalized stage III Grade B periodontitis with type 2 diabetes mellitus; SD – Standard deviation; GI – Gingival index; PI – Plaque index; BOP – Bleeding on probing; PPD – Probing pocket depth; CAL – Clinical attachment level; mm – Millimeter; *P* – Among the groups; *P*1 – Between healthy controls and subjects with PD; *P*2 – Between subjects with PD and PD-DM; *P*3 – Between healthy controls and subjects with PD-DM

Table 3 shows that the mean HbA1c was 5.50 ± 0.45 for the PD group, 8.67 ± 1.84 for the PD-DM group, and 5.62 ± 0.49 for healthy controls, and it was statistically significant ($P < 0.0001$) between the groups. Intergroup comparisons revealed a significant difference between the two case groups (PD and PD-DM) ($P < 0.0001$) and also when the values of the two case groups were compared to the healthy subjects ($P < 0.001$ for PD vs. healthy, $P < 0.001$ for PD-DM vs. healthy group). The mean value of serum 25(OH)D was lowest in the PD-DM group (13.54 ± 3.31 ng/mL) followed by the PD group (15.72 ± 6.60 ng/mL), and it was highest in the healthy control group (22.0 ± 9.26 ng/mL), which was statistically significant ($P < 0.001$). *Post hoc* adjustment revealed no significant difference between the case groups (PD and PD-DM). The frequency of patients with 25(OH)D deficiency was highest in the PD-DM group followed by subjects with PD only and the healthy controls, with $P < 0.001$.

Table 3: Comparison of biochemical parameters among the three study groups

Biochemical parameters	PD, mean (SD)	PD-DM, mean (SD)	Healthy control, mean (SD)	*P**	*P*1‡	*P*2‡	*P*3‡
HbA1c (%)	5.50 (0.45)	8.67 (1.84)	5.62 (0.49)	0.000**	1.000	0.000**	0.000**
25(OH)D (ng/mL)	15.72 (6.60)	13.54 (3.31)	22.0 (9.26)	0.000**	0.000**	0.56	0.000**
Frequency (%) of patients with Vitamin D deficiency	26 (74.2)	35 (100)	17 (48.5)	0.000**		-	-

*P<0.05 is considered statistically significant; **P<0.01 is considered highly statistically significant; ‡*Post hoc* adjustment (Bonferroni test) was done. PD – Generalized Stage III Grade B periodontitis; PD-DM – Generalized stage III Grade B periodontitis with type 2 diabetes mellitus; SD – Standard deviation; 25(OH)D – 25 hydroxy Vitamin D; HbA1c – Glycated hemoglobin; % – Percentage; ng/mL – ng/mL; *P* – Among the groups; *P*1–Between healthy controls and subjects with PD; *P*2 – Between subjects with PD and PD-DM; *P*3 – Between healthy controls and subjects with PD-DM; 25(OH)D – 25 Hydroxyvitamin D

The data about the correlation of 25(OH)D with periodontal parameters in the three groups are furnished in **Table 4**. While PI, PPD, and CAL showed a significant ($P < 0.01$) moderate negative correlation with 25(OH)D, GI and BOP exhibited a significantly weak negative correlation with 25(OH)D. However, no significant correlation of 25(OH)D level with

periodontal parameters within the groups was demonstrated. The correlation of SES with clinical parameters among the groups did not show any significant correlation **(Table 5)**.

Table 4: Correlation of 25 hydroxyvitamin D with clinical parameters

Among Groups		25(OH) D	BOP	GI	PI	PPD	CAL
25(OH) D	Pearson Correlation	1	-0.354**	-0.346**	-0.459**	-0.442**	-0.474**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
	n	105	105	105	105	105	105
Control Group							
25(OH) D	Pearson Correlation	1	-0.098	-0.309	-0.176	-0.086	.a
	Sig. (2-tailed)		0.574	0.071	0.313	0.625	.
	n	35	35	35	35	35	35
PD							
25(OH) D	Pearson Correlation	1	0.006	0.263	-0.211	0.242	0.050
	Sig. (2-tailed)		0.971	0.126	0.224	0.162	0.777
	n	35	35	35	35	35	35
PD-DM							
25(OH) D	Pearson Correlation	1	-0.020	-0.236	0.105	0.015	-0.257
	Sig. (2-tailed)		0.908	0.173	0.550	0.932	0.137
	n	35	35	35	35	35	35

**Correlation is significant at the 0.01 level (two-tailed). − – Value indicates negative correlation. PD – Generalized Stage III Grade B periodontitis; PD-DM – Generalized Stage III Grade B periodontitis with type 2 diabetes mellitus; 25(OH) D – 25 Hydroxyvitamin D; GI – Gingival index; PI – Plaque index; BOP – Bleeding on probing; PPD – Probing pocket depth; CAL – Clinical attachment level; *n* – number of subjects; a – baseline group

Table 5: Correlation of socioeconomic status with periodontal parameters

SES	BOP	GI	PPD	CAL	PI	SES
Pearson's correlation	0.172	−0.105	0.176	0.296	−0.071	1
Significant (two-tailed)	0.324	0.549	0.311	0.084	0.684	
n	35	35	35	35	35	35

SES – Socioeconomic status; GI – Gingival index; PI – Plaque index; BOP – Bleeding on probing; PPD – Probing pocket depth; CAL – Clinical attachment level; *n* – number of subjects; P< 0.05 is considered statistically significant, P- p value

An increase in periodontal metrics (PI, GI, PPD, and CAL) was associated with a decrease in 25(OH)D levels as per regression analysis (25[OH] D = 25.793 – 1.247 [GI] −1.580 [PPD] −2.317 [CAL] −0.436 [PI]) **(Table 6)**. In addition, the regression model demonstrated that a rise in HbA1c is associated with a 25(OH)D drop (25[OH] D = 25.394–1.247 [HbA1c]) **(Table 7)**. The serum Vitamin D value was also not affected by demographic parameters, including SES, among the groups as indicated by the linear regression analyses **(Table 8).**

Table 6: Linear regression coefficients between Vitamin D and periodontal parameters

Model	Unstandardized coefficients		*t*	Significant	95.0% CI for *B*	
	B	SE			Lower bound	Upper bound

Constant	25.793	5.668	4.550	0.000	14.543	37.043
GI	−3.236	2.636	−1.227	0.223	−8.468	1.997
PI	−0.436	0.637	−0.685	0.495	−1.701	0.828
PPD	−1.580	1.326	0.962	0.339	−1.356	3.906
CAL	−2.317	1.459	−1.588	0.115	−5.212	0.578

P<0.05 is considered statistically significant. GI – Gingival index; PI – Plaque index; PPD – Probing pocket depth; CAL – Clinical attachment level; CI – Confidence interval; *t*- t value; *P* – p value; *B* – Regression coefficient; SE – Standard error

Table 7: Linear regression coefficients between Vitamin D and glycated hemoglobin

Model	Unstandardized coefficients		*t*	Significant	95.0% CI for *B*	
	B	SE			Lower bound	Upper bound
Constant	25.394	2.682	9.470	0.000	20.076	30.712
HbA1C	−1.247	0.391	−3.186	0.002	−2.023	−0.471

P<0.05 is considered statistically significant. HbA1c – Glycated hemoglobin; CI – Confidence interval; *t* – t value; *P* – p value; *B* – Regression coefficient; SE – Standard error

Table 8: Linear regression coefficients between Vitamin D and demographic details

Model	Unstandardized coefficients		Standardized coefficients (β)	*t*	Significant
	B	SE			
Constant	10.931	10.895		1.003	0.318
Family type	−1.506	1.893	−0.088	−0.796	0.428
House type	−0.312	1.422	−0.025	−0.219	0.827
Location	−0.048	1.135	−0.005	−0.042	0.966
Dentist visit	2.142	1.653	0.139	1.296	0.198
Outdoor activity	−0.067	0.498	−0.015	−0.135	0.893
Exercise	1.907	2.127	0.095	0.896	0.372
Dietary habit	1.399	0.949	0.163	1.474	0.144
SES	1.41	0.872	0.764	1.071	0.621

P<0.05 is considered statistically significant. SES – Socioeconomic status; *t* – t value; *P* – p value; *B* – Regression coefficient; SE – Standard error

Discussion

The reciprocal relationship between PD and T2DM and the manifestation of the ill effects of the two when they are concurrently present has been well established through numerous studies.[3, 15] T2DM is not only a well-recognized factor that may increase the risk of PD, but PD also affects glycemic control.[3] Although we still have little insight into the biological processes governing neutrophils, cytokines, and immune system dynamics, they do emulate the association between these two diseases.[3] Studies have also shown a possible link between PD, T2DM, and 25(OH)D deficiency.[15]

The principal findings of the current research are that the serum 25(OH)D values were lowest in the subjects with PD-DM, followed by subjects with PD only and healthy individuals. Moreover, serum 25(OH)D and periodontal markers showed an inverse correlation between the groups. However, the periodontal parameters and 25(OH)D values did not exhibit any correlation with socioeconomic and demographic parameters in the study.

The three groups included in the research did not show any significant difference concerning the characteristics of subjects such as age, gender, location, outdoor activity, amount of sun exposure, extent of exercise, diet, dental visit, family type, and house type. This could assure the homogeneity of the study participants and conduct of the study under controlled conditions. The mean BMI of the subjects under study indicated that none of the subjects were overweight. Although the difference in BMI observed between and among the groups was statistically significant, the BMI values were too close and within normal limits to make an extrapolation of the observed findings.

In the study, there was no significant difference in HbA1c between healthy controls and subjects with PD. The finding is in line with the studies by Kebede *et al*. and Wahi *et al*.[19, 20] The HbA1c level was very slightly lower in subjects with PD than in the healthy group. This could be due to the lesser BMI observed in the subjects with PD than in the healthy controls.[21] Nonetheless, both groups had a propensity toward prediabetes. The progressive b-cell dysfunction that characterizes prediabetes occurs due to diverse reasons, including genetic predisposition, increased insulin secretory demand, and decreasing b-cell bulk.[22]

The study shows that the markers of periodontal tissue destruction (GI, PI, BOP, PPD, and CAL) and HbA1c levels were substantially greater for the PD-DM group. Like other infections, chronic periodontal diseases are brought on by Gram-negative bacteria, which also tend to worsen diabetes-associated systemic inflammation in addition to increasing insulin resistance in the body.[3] This ongoing hyperglycemia, brought on by periodontal inflammation, can aggravate the glycemic status and increase the risk of diabetes-related complications in such individuals.[3] These results conform with the existing proven research findings and establish the bilateral link between PD and T2DM.[2, 3]

The study revealed the lowest 25(OH)D level in participants with PD-DM, followed by patients with PD, and the least in healthy individuals. The comparable difference between and among the groups validates the hypothesis of the study. In all groups, including the healthy participants, the mean serum 25(OH)D value was lesser than the range considered normal. The control group had "insufficient" 25(OH)D values, whereas the case groups were deficient in 25(OH)D. Although majority of the participants reported getting enough sun exposure and engaging in outdoor activities, certain genetic factors such as elevated 25(OH)D-24-hydroxylase disintegrating 25(OH)D to inactive metabolites and might contribute to insufficient 25(OH)D values even in healthy participants.[23] Other factors include darker skin tone and vegetarian diets low in calcium and high in phytates and oxalates, which cause Vitamin D depletion.[23] Moreover, the percentage of individuals with 25(OH)D deficiency was greatest in the PD-DM group, followed by subjects with PD and the healthy controls. Further, all the periodontal parameters showed an inverse correlation with 25(OH)D in the populace studied. The regression analysis also shows that an increase in periodontal metrics (PI, GI, PPD, CAL) is linked with decreased 25(OH)D. These results corroborate the results of previous studies done by Joseph *et al*., Wang *et al*., and Agrawal *et al*. that signify the probable association between PD in T2DM patients and serum 25(OH)D values.[15, 24, 25] The increased inflammatory burden and cytokine activation in subjects with PD-DM may explain the least 25(OH)D in this group.

Due to the persistent inflammation induced by PD, low values of Vitamin D might arise from Vitamin D-associated endocrine dysfunction.[9] The synthesis of cytokines is hypothesized to be influenced by intracellular bacteria, and the transcription of the 1,25-dihydroxyvitamin-D (1-25(OH) 2D)/Vitamin D receptor (VDR) gene in the monocyte-macrophage system is suppressed by cytokine activation.[9] To activate the VDR and promote the transcription of antimicrobial peptides such as cathelicidin and beta-defensins to attack bacteria, excess 1, 25(OH) 2D is formed.[9] As a result, 25(OH)D is quickly metabolized, causing a reduced blood value.[9] These results are in line with research by Dietrich *et al*., Bhargava *et al*., and Laky *et al*. which links PD to low Vitamin D levels.[6, 26, 27]

The outcomes additionally validate the conclusions of other prior investigations that highlighted the connection between Type 2 diabetes and low levels of Vitamin D.[28-30] Vitamin D deficiency has been connected in experimental and epidemiological studies to lower insulin release, increased insulin resistance, changed insulin signaling, and type 2 diabetes.[30] Since low levels of Vitamin D are linked to an elevated inflammatory cascade, there is a possibility that the relationship between low levels of Vitamin D and insulin resistance arises from increased oxidative stress, inflammation, and altered epigenetic regulation of gene expression.[31]

In the current investigation, the PI was significantly greater in the PD-DM group than in the PD group. This could have led to an increased bacterial load and an increase in cytokine levels, thus masking the effect of diabetes in the PD-DM group. Matching the PI in the PD and PD-DM groups or incorporating a study group with participants who had diabetes but no PD was not done in the study, which would have helped in understanding the impact of DM better and is a study limitation. In addition, the length of time the participants had diabetes was not taken into account. However, we used linear regression analysis to investigate the relationship between these factors further and discovered that a higher HbA1c is linked to a lower 25(OH)D. These results imply that, even after accounting for other significant variables, the relationship between HbA1c and Vitamin D levels remains significant.

The reduced levels of 25(OH)D are possibly a sequel of health conditions rather than the source of the disease.[32] Using a Mendelian randomization approach, Ye *et al*. also revealed that the link between 25(OH)D levels and T2DM is improbable to be causative.[33] Similarly, it is unknown if low Vitamin D levels arise from PD or if Vitamin D deficiency is the risk factor for the development of PD. Few cross-sectional clinical studies have advocated the benefits of Vitamin D supplementation in improving insulin resistance.[34, 35] Short-term studies have also demonstrated that Vitamin D supplementation alone or with calcium may help to maintain periodontal health.[36, 37] However, since the published results have been inconclusive with weak evidence, introducing Vitamin D supplements to the broader public still seems to be dubious.

The correlation of SES with periodontal parameters among the groups did not show any significant correlation. The result is in contrast with the studies done by Kim *et al*., Lee and Han, and Javed *et al*.[38-40] According to the linear regression model, neither demographic factors, including SES within the groups, nor the blood Vitamin D level were related to each other. The result is in variance from the studies conducted by Puri *et al*., Mechenro *et al*., and Lin *et al*.[41-43] Majority of the subjects in all three study groups belonged to the upper middle class regarding their SES. There were no subjects in the lower class. So also, there was no one in the upper class in the control and PD + DM groups. It is an indication that those belonging to the lower class and upper class are not availing of government dental hospital services and facilities. The difficulty in accessing free government services and lack of awareness could be the reason for its nonutilization by the lower class. It might also be due to the relatively smaller sample size of the groups. This justifies more elaborate studies with larger samples which include participants from lower class and rural areas to better appreciate the effect of SES on serum Vitamin D levels.

The study also has other limitations. The seasonal variation that can occur in 25(OH)D level could not be considered the samples were taken throughout the year. The results might not apply to a larger population as it focuses on specific demographics within Chhattisgarh, India. Periodontal treatment outcomes on serum 25(OH)D level could not be performed. The design of the present study could not bring about the cause-effect relationship or establish the mechanisms behind the observed association.

Conclusion

Within the given constraints, it can be appreciated from the study that the serum Vitamin D values do get negatively affected by the synergistic effect of PD and T2DM or by the presence of PD alone. The study thus emphasizes the significance of increasing knowledge about periodontal diseases' prevention, diagnosis, and treatment among the medical community and the general public. However, the association of SES on serum Vitamin D values in individuals with PD and T2DM or PD alone could not be demonstrated, warranting further research.

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