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The Relation Between Periodontal Disease and Vitamin D

Colin Bonnet, *DMD, MDent;* **Rasheda Rabbani**, *PhD*; **Michael EK Moffatt**, *MD, MSc,* **Anastasia Kelekis-Cholakis,** *DMD, MDent*; **Robert J Schroth**, *DMD, MSc, PhD*

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Abstract

Background: There is conflicting evidence regarding the association between vitamin D and periodontal disease. The purpose of this study was to explore that relation.

Methods: This cross-sectional study used data from the Canadian Health Measures Survey for respondents 13–79 years of age. Vitamin D status was determined by measuring plasma 25-hydroxyvitamin D (25(OH)D) concentrations. Periodontal disease was defined by gingival index (GI) and calculated loss of attachment (LOA). Statistical analyses included bivariate tests and multiple logistic regression.

Results: At the bivariate level, 25(OH)D concentrations below the cutoff levels of 50 nmol/L and 75 nmol/L were associated with GI. However, multiple regression analyses for GI revealed no association with mean 25(OH)D level or either concentration. Although no significant association between LOA and 25(OH)D status was identified at the bivariate level, a statistically significant association was observed between LOA and 25(OH)D levels < 75 nmol/L on multiple regression analysis. However, mean 25(OH)D concentrations and those < 50 nmol/L were not associated with LOA on multiple regression analysis.

Conclusion: Vitamin D status was inversely associated with GI at the bivariate level, but not at the multivariate level. Conversely, vitamin D status was not associated with LOA at the bivariate level, but it was inversely associated with LOA at the multivariate level. These results provide modest evidence supporting a relation between low plasma 25(OH)D concentrations and periodontal disease as measured by GI and LOA.

Chronic periodontitis is an inflammatory condition of the periodontium initiated by microbial biofilms that form on the teeth.[1] Bacterial products, as well as the host's immune response to these products, result in destruction of the tissues that support the teeth, including alveolar bone. Because of this tissue destruction, chronic periodontitis is a major cause of tooth loss in adults.[2,3] Prevention of this disease is important because tooth loss can affect one's nutritional status[4] and quality of life.[5] Chronic periodontitis has also been associated with systemic conditions, such as cardiovascular disease[6] and type II diabetes mellitus.[7]

Vitamin D is a fat-soluble vitamin obtained from exposure to sunlight, diet and nutritional supplements.[8] Vitamin D is metabolized in the liver to 25-hydroxyvitamin D (25(OH)D) and then metabolized in the kidneys to its active form, 1,25-dihydroxyvitamin D (1,25-(OH)2D).[8] As the major circulating metabolite in the blood, 25(OH)D is used to determine a patient's vitamin D status.[8] Although there is no consensus on optimal levels of 25(OH)D, most experts define < 50 nmol/L (20 ng/mL) as vitamin D insufficiency.[8] Recent evidence suggests that 25(OH)D levels may need to be as high as 75 nmol/L (30 ng/mL) to achieve optimal vitamin D status.[8]

Vitamin D is involved in regulating calcium absorption from the intestines, maintaining plasma calcium concentration and bone mineralization.[9] Studies have found significant positive associations between 25(OH)D levels and bone mineral density[10] as well as between vitamin D supplementation and a lower risk of fractures.[11]

More recent evidence indicates that vitamin D also has a regulatory effect on the immune response, stimulating immune response at times, while inhibiting it at others. One study[12] demonstrated that increased production of the antibacterial proteins cathelicidin and beta-defensins followed exposure to antigens. The authors concluded that the ability to produce active vitamin D improved bactericidal activity. There are many examples of vitamin D's ability to inhibit the immune response. *In vitro* studies have shown that 1,25-(OH)2D inhibits the proliferation, maturation and differentiation of dendritic cells from monocytes.[13] The active form of vitamin D also inhibits the production of inflammatory cytokines in monocytes.[13] Some studies have also reported that 1,25-(OH)2D has the ability to suppress the proliferation and cytokine production of T-lymphocytes.[13]

Because chronic periodontitis is characterized by bone loss triggered by a host immune response reaction to bacterial plaque, vitamin D deficiency may have an effect on the development and progression of periodontal disease.[14-19] Two large cross-sectional studies[14,15,17] have found an association between low vitamin D levels and markers of periodontal disease. However, the largest prospective study to date,[19] as well as the most recent cross-sectional study,[20] found no relation between these two entities. It is clear that further research is needed to determine what impact vitamin D status has on the progression of periodontal disease. The aim of this study was to explore the relation between 25(OH)D concentration and periodontal disease measured by gingival index (GI) and loss of attachment (LOA) using data derived from the Canadian Health Measures Survey (CHMS).

Materials and Methods

Study Sample

Data were obtained from people 6–79 years of age participating in cycle 1 of the CHMS. Cycle 1, which was undertaken from 2007 to 2009, was a national, cross-sectional survey, conducted by Statistics Canada, of a representative sample of 97% of the Canadian population in all provinces and territories.[21] Data collection involved physical measurements and interviews (household questionnaire) completed by 5604 participants.[21] All participants provided informed consent. The CHMS excluded full-time members of the Canadian Forces and residents of First Nations reserves, Crown land, certain remote regions of Canada and institutions.

Statistics Canada used a probability sampling approach, incorporating aspects of stratification and cluster sampling. From a possible 257 identified sites, 15 were selected and stratified by region. For the purposes of this investigation, we restricted the analysis to those 13–79 years of age for GI and 20–79 years of age for LOA.

Clinical Oral Examination

Dental examinations were completed by 14 Canadian Forces dentists calibrated to World Health Organization (WHO) standards (Cohen's Kappa ≥ 0.6). GI on the buccal, lingual, mesial and distal surfaces of each of 6 indicator teeth (16, 12, 24, 36, 32 and 44) was recorded. GI was scored using Löe's gingival index, the highest GI score for each participant was used and the data were dichotomized into "no or mild inflammation" (groups 0 and 1 combined) and "moderate to severe inflammation" (groups 2 and 3 combined).

The Williams probe was used to measure LOA, which was defined as the distance from the cemento-enamel junction to the bottom of the periodontal pocket, at 6 sites on each of the WHO's indicator teeth that were present (17, 16, 11, 26, 27, 37, 36, 31, 46 and 47). Examiners recorded the highest LOA measurement for each sextant. The highest score for LOA for each participant was used and then LOA was grouped into 3 categories: slight (≤ 3 mm), moderate (4–5 mm) and severe (> 5 mm).

Using Green and Vermillion's simplified oral hygiene index, examiners recorded plaque on the labial surfaces of maxillary teeth and mandibular incisors and the lingual surfaces of mandibular molars on the same indicator teeth

used for LOA, recording the highest score for each sextant; a mean plaque score was calculated for each participant.

Assessment of Plasma 25(OH)D

Plasma vitamin D levels were measured by a chemiluminescence assay, the LIAISON 25-hydroxyvitamin D TOTAL assay (DiaSorin, Ltd., Stillwater, MN, USA).[21] Two vitamin D cutoff levels were examined in this investigation: 50 nmol/L (based on the Institute of Medicine's threshold for vitamin D sufficiency) as well as 75 nmol/L (based on emerging evidence for optimal vitamin D). Mean 25(OH)D levels were also examined.

Data on Other Covariates

To account for other confounding factors affecting GI and LOA, additional independent variables were considered. Smoking was included using the household questionnaire. Respondents were classified as "never smokers" (smoked < 100 cigarettes during lifetime), "former smokers" (smoked ≥ 100 cigarettes during lifetime, but not currently smoking) and "current smokers" (smoked ≥ 100 cigarettes in lifetime and currently smoking). For the analysis, current smokers and former smokers were combined and compared with never smokers. Smoking was also analyzed using pack-years. This statistic was calculated by taking the number of cigarettes smoked each day times the number of years smoked divided by 20; this statistic has been found to correlate with LOA.[22]

Diabetic status was determined based on the self-reported household questionnaire. Diabetes status has been shown to correlate with gingival inflammation[23] as well as with extent and severity of periodontal disease.[24-26] An analysis of percentage of glycosylated hemoglobin (HbA1c) was also performed. HbA1c is a measure of long-term diabetic control and values indicative of poor diabetic control have been previously correlated with prevalence, severity and extent of periodontitis.[26,27] Values ≤ 7.0% were considered to be good control, whereas values > 7.0% were considered to be moderate to poor control.

Body mass index (BMI) may have an influence on GI and LOA.[28,29] Mean and classes of BMI were compared with markers of gingival and periodontal infection. BMI was calculated using kg/m^2 and participants were classified as underweight (BMI < 18.5), normal (BMI 18.5–24.9), overweight (BMI 25–29.9) or obese (BMI ≥ 30).

Annual household income was explored and categorized as < $20 000, $20 000–60 000 or > $60 000. Other covariates considered included daily vitamin D and multivitamin supplement use, annual dental professional visit (yearly or not), tooth-brushing frequency (twice a day or not), flossing frequency, age and sex.

Statistical Methods

Data were accessed and analyzed at the Research Data Centre (RDC) at the University of Manitoba using SPSS 20 (IBM, Armonk, NY), SAS 9.2 (SAS, Cary, NC), and Stata 13 MP (StataCorp LP, College Station, Tex.). As per RDC restrictions, original sample sizes were suppressed. Bootstrap weights for variance estimation and weighted results are presented with degrees of freedom fixed to 11. Descriptive statistics include means and frequencies with 95% confidence intervals (CI). χ^2 tests were used to determine the unadjusted correlation of each categorical independent variable with GI and LOA. Student *t* tests were used to determine the unadjusted correlation of each continuous independent variable with GI and LOA. Three multiple logistic regression models for GI and for LOA were developed to determine the adjusted association between 25(OH)D levels and GI and LOA, controlling for potential confounders. Model A used 25(OH)D concentration of < 50 nmol/L, model B used 25(OH)D concentration < 75 nmol/L, and model C used mean 25(OH)D concentration. Variables with a *p* value of ≤ 0.075 were included in the multiple logistic regression analysis for GI and LOA, with the exception of plasma vitamin D concentration and known risk factors for periodontal disease, such as smoking. A *p* value ≤ 0.05 was significant.

Results

The mean 25(OH)D concentrations (95% CI) in the GI and LOA samples were 90.8 (77.5–104.2) and 85.6 (74.6–97.2) nmol/L, respectively. Although mean 25(OH)D levels were above the thresholds for vitamin D sufficiency, 63% of each sample had concentrations below the 75 nmol/L threshold and 25% of each population had 25(OH)D levels < 50 nmol/L.

Bivariate analysis of GI (**Table 1**) showed that several variables were significantly associated with 25(OH)D concentrations below the thresholds for vitamin D sufficiency. Participants with 25(OH)D concentrations < 50 nmol/L and < 75 nmol/L had significantly increased odds of having more GI (odds ratio (OR) 1.63 and 1.44, respectively). Those taking vitamin D supplements had significantly lower odds for GI (OR 0.56), while those with diabetes had increased odds of having moderate to severe GI (OR 1.33). Mean BMI was significantly higher among those with the worst GI. Meanwhile, those who reported frequenting a dental professional ≥ 1 time a year, brushing their teeth twice daily and flossing daily had significantly lower odds for GI. Increased scores for plaque were associated with increased odds for moderate to severe GI. Males had increased odds for GI compared with females, while those in higher-income categories had lower odds for GI than those in lower-income categories.

However, when confounding variables were controlled for, multiple logistic regression analysis of GI (**Table 2**) showed that only plaque and sex were significantly associated with GI. Females had lower odds of moderate to

Table 1: Bivariate analysis of factors affecting gingival inflammation (GI).

Variable	Proportion of none–mild GI (95% CI)	Proportion of moderate–severe GI (95% CI)	*p*	Unadjusted odds ratio (95% CI)
25(OH)D level* < 50 nmol/L ≥ 50 nmol/L	 0.60 (0.51–0.68) 0.71 (0.64–0.77)	 0.40 (0.32–0.49) 0.29 (0.24–0.36)	0.010	 1.63 (1.15–2.30)
25(OH)D level* < 75 nmol/L ≥ 75 nmol/L	 0.65 (0.58–0.72) 0.73 (0.67–0.78)	 0.35 (0.28–0.42) 0.27 (0.22–0.33)	0.014	 1.44 (1.09–1.90)
Mean 25(OH)D level, nmol/L†	88.75 (79.63–97.87)	94.80 (71.57–118.04)	0.43	1.00 (0.999–1.001)
Vitamin D supplement use* Yes No	 0.81 (0.73–0.87) 0.70 (0.64–0.75)	 0.19 (0.13–0.27) 0.30 (0.25–0.36)	0.007	 0.56 (0.37–0.85)
Multivitamin or vitamin D supplement use* Yes No	 0.73 (0.68–0.79) 0.69 (0.62–0.75)	 0.26 (0.21–0.33) 0.31 (0.25–0.38)	0.087	 0.78 (0.58–1.05)
Smoking* Former or current Never	 0.59 (0.50–0.68) 0.69 (0.61–0.75)	 0.41 (0.32–0.50) 0.31 (0.25–0.39)	0.057	 1.51 (0.97–2.35)
Mean pack-years of smoking†	11.12 (9.64–12.60)	13.72 (10.23–17.21)	0.17	1.01 (1.00–1.03)
Diabetes* Yes No	 0.62 (0.53–0.70) 0.68 (0.62–0.74)	 0.38 (0.29–0.47) 0.32 (0.26–0.38)	0.036	 1.33 (1.01–1.74)
Mean glycosylated hemoglobin, %†	5.6 (5.4–5.7)	5.6 (5.5–5.7)	0.23	Unable to calculate
Glycosylated hemoglobin* ≤ 7% > 7%	 0.69 (0.63–0.74) 0.58 (0.45–0.71)	 0.31 (0.26–0.37) 0.42 (0.29–0.55)	0.10	 1.61 (0.90–2.89)
Mean body mass index, kg/m^2†	25.71 (25.11–26.32)	26.37 (25.76–26.98)	0.049	1.02 (1.00–1.05)
Body mass index, kg/m^2* < 18.5 18.5 to < 25 25 to < 30 ≥ 30	 0.65 (0.51–0.77) 0.69 (0.64–0.74) 0.70 (0.62–0.78) 0.63 (0.54–0.71)	 0.35 (0.23–0.49) 0.31 (0.26–0.36) 0.30 (0.22–0.38) 0.37 (0.29–0.46)	0.15	 0.84 (0.49–1.43) 0.80 (0.46–1.37) 1.11 (0.63–1.95)
Visit to dental professional 1/year* Yes No	 0.73 (0.66–0.79) 0.52 (0.45–0.59)	 0.27 (0.21–0.34) 0.48 (0.41–0.55)	0.000	 0.40 (0.31–0.53)
Brushes teeth ≥ 2/day* Yes No	 0.72 (0.65–0.78) 0.56 (0.50–0.62)	 0.28 (0.22–0.35) 0.44 (0.38–0.50)	0.000	 0.50 (0.40–0.63)
Flosses ≥ 1/day* Yes No	 0.72 (0.66–0.78) 0.56 (0.48–0.63)	 0.28 (0.22–0.34) 0.44 (0.37–0.52)	0.000	 0.47 (0.37–0.62)
Presence of plaque 0 1 2 3	 0.93 (0.86–0.97) 0.73 (0.65–0.80) 0.51 (0.40–0.62) 0.28 (0.21–0.37)	 0.07 (0.03–0.14) 0.27 (0.20–0.35) 0.49 (0.38–0.60) 0.72 (0.63–0.79)	< 0.001	 5.13 (2.80–9.39) 13.33 (5.28–33.65) 35.43 (13.17–95.30)
Mean age, years†	40.94	40.63	0.67	1.00 (0.99–1.00)
Sex* Male Female	 0.63 (0.57–0.69) 0.73 (0.65–0.79)	 0.37 (0.31–0.43) 0.27 (0.21–0.35)	0.012	 0.65 (0.47–0.89)
Annual income, $* < 20 000 20 000–60 000 > 60 000	 0.49 (0.40–0.59) 0.64 (0.56–0.72) 0.73 (0.67–0.79)	 0.51 (0.41–0.61) 0.36 (0.28–0.44) 0.27 (0.21–0.33)	0.001	 0.54 (0.39–0.74) 0.36 (0.22–0.56)

Note: 25(OH)D = 25-hydroxyvitamin D, CI = confidence interval.
*χ^2 test
†*t* test

severe GI, while high values for the plaque index increased the odds of moderate to severe GI. No significant relation between 25(OH)D and GI was observed in models A, B or C in the multiple logistic regression analysis of GI.

Several variables were significant in the bivariate analysis of LOA (**Table 3**). Surprisingly, taking a multivitamin or a vitamin D supplement was associated with increased odds of more severe LOA. Higher mean HbA1c values were associated with increased odds of more severe LOA as was HbA1c > 7%. Older age was associated with increased odds of more severe LOA, while an income of > $60 000 was associated with lower odds of more severe LOA. No significant association was found between 25(OH)D levels and LOA in the bivariate analysis.

After multiple logistic regression analysis, few variables were found to be significantly and independently associated with more severe LOA (**Table 4**). However, 25(OH)D concentrations < 75 nmol/L were found to be statistically significant ($p = 0.05$); levels below this threshold were associated with an increased relative risk ratio (RRR 2.09) of severe versus slight LOA. Age and smoking were also found to be significant, with increased age and former or current smoking status increasing the relative risk of moderate versus slight LOA.

Discussion

In this first study on the association between 25(OH)D levels and markers of periodontal disease in a Canadian population, observations supporting the hypothesis that lower 25(OH)D levels would be associated with higher measures for GI and LOA were mixed. Although we found significant associations between low 25(OH)D thresholds and increased odds of GI, these relations were not observed after multiple regression analysis. Conversely, although no significant associations were found between 25(OH)D levels and LOA using bivariate analysis, we did observe a significant association between the 25(OH)D threshold of < 75 nmol/L and increased relative risk of LOA after multiple regression analysis.

One must exercise caution in interpreting this latter finding, as it may or may not represent a true association. Because 25(OH)D levels were a key independent variable of interest, they were included in the various logistic regression models for LOA even though they were not associated with LOA at the bivariate level. Furthermore, it was not possible to perform backward elimination in the multiple regression analysis using the available software while using a bootstrapping command. The fact that stronger associations between 25(OH)D levels and GI or LOA were not observed may seem counter-intuitive based on vitamin D's roles in bone homeostasis and immune system regulation. However, currently there is conflicting evidence in the literature regarding the relation between vitamin D and periodontal disease.

Table 2: Multiple logistic regression analysis for moderate-to-severe versus none-to-mild gingival Inflammation (GI).

Variable	Adjusted odds ratio	95% confidence interval	*p*
Model A: vitamin D < 50 nmol/L			
Vitamin D < 50 nmol/L	1.12	0.77–1.62	0.53
Vitamin D supplement use	0.95	0.67–1.34	0.75
Smoking (former or current)	1.18	0.70–1.98	0.51
Diabetes	1.14	0.75–1.75	0.51
Presence of plaque 1 2 3	 3.67 8.44 23.57	 1.80–7.50 3.45–20.70 7.04–78.91	 0.00 0.00 0.00
Sex (female)	0.61	0.38–0.99	0.05
Annual income, $ 20 000–60 000 > 60 000	 0.60 0.50	 0.33–1.10 0.22–1.14	 0.09 0.09
Mean BMI, kg/m^2	1.02	0.99–1.05	0.16
Model B: vitamin D < 75 nmol/L			
Vitamin D < 75 nmol/L	1.06	0.74–1.51	0.73
Vitamin D supplement use	0.94	0.67–1.33	0.71
Smoking (former or current)	1.18	0.70–1.98	0.50
Diabetes	1.13	0.74–1.72	0.54
Presence of plaque 1 2 3	 3.70 8.47 23.78	 1.78–7.67 3.44–20.87 6.97–81.08	 0.00 0.00 0.00
Sex (female)	0.61	0.38–0.98	0.04
Annual income, $ 20 000–60 000 > 60 000	 0.60 0.49	 0.33–1.07 0.22–1.08	 0.08 0.07
Mean BMI, kg/m^2	1.02	0.99–1.05	0.15
Model C: mean vitamin D*			
Mean vitamin D nmol/L	1.00	1.00–1.00	0.74
Vitamin D supplement use	0.93	0.66–1.30	0.64
Smoking (former or current)	1.18	0.70–1.98	0.50
Diabetes	1.13	0.74–1.73	0.53
Presence of plaque 1 2 3	 3.73 8.56 24.14	 1.78–7.78 3.47–21.15 7.00–83.25	 0.00 0.00 0.00
Sex (female)	0.61	0.38–0.97	0.04
Annual income, $ 20 000–60 000 > 60 000	 0.60 0.49	 0.33–1.07 0.22–1.06	 0.08 0.07
Mean BMI (kg/m^2)	1.02	0.99–1.05	0.14

Note: BMI = body mass index, CI = confidence interval.

One of the first studies to support an association between 25(OH)D levels and periodontal disease used cross-sectional data from 11 202 participants in the National Health and Nutritional Examination Survey III (NHANES III).[14] It reported an inverse relation between 25(OH)D levels and attachment loss in participants ≥ 50 years that was independent of confounding variables. This same group performed a separate analysis on a sample of 6700 participants from NHANES III and found that sites in participants in the lowest 25(OH)D quintile were 20% less likely to bleed on gingival probing than sites in participants in the highest 25(OH)D quintile.[15]

Table 3: Bivariate analysis of factors affecting loss of attachment (LOA).

Variable	Proportion slight LOA (≤ 3 mm)	Proportion moderate LOA (4–5 mm)	Proportion severe LOA (> 5 mm)	p	Unadjusted odds ratio (95% CI)
25(OH)D level* < 50 nmol/L ≥ 50 nmol/L	 0.83 (0.78–0.87) 0.82 (0.76–0.86)	 0.11 (0.09–0.13) 0.13 (0.10–0.18	 0.06 (0.03–0.10) 0.05 (0.04–0.06)	0.21	0.80‡ 1.24§
25(OH)D level* < 75 nmol/L ≥ 75 nmol/L	 0.82 (0.77–0.87) 0.82 (0.75–0.87)	 0.12 (0.09–0.15) 0.14 (0.10–0.20)	 0.06 (0.04–0.08) 0.04 (0.03–0.06)	0.26	0.83‡ 1.33§
Mean 25(OH)D, nmol/L†	86.9 (76.4–97.4)	82.9 (63.6–102.1)	77.1 (55.5–98.7)	0.55 0.18	1.00 (0.99–1.00) 1.00 (0.99–1.00)
Vitamin D supplement use* Yes No	 0.74 (0.62–0.84) 0.84 (0.79–0.88)	 0.19 (0.11–0.31) 0.12 (0.09–0.15)	 0.07 (0.03–0.15) 0.04 (0.03–0.07)	0.10	1.79‡ 1.75§
Multivitamin or vitamin D supplement use* Yes No	 0.78 (0.70–0.85) 0.86 (0.82–0.89)	 0.15 (0.10–0.22) 0.11 (0.08–0.14)	 0.07 (0.04–0.11) 0.03 (0.02–0.05)	0.04	1.49‡ 2.31§
Smoking* Former or current Never	 0.81 (0.74–0.86) 0.86 (0.80–0.90)	 0.14 (0.10–0.20) 0.10 (0.07–0.14)	 0.05 (0.04–0.07) 0.04 (0.03–0.08)	0.098	1.53‡ 1.23§
Mean pack years of smoking†	12.4 (11.1–13.7)	17.3 (11.4–23.3)	14.3 (6.4–22.2)	0.09 0.61	1.01 (1.00–1.03) 1.01 (0.98–1.04)
Diabetes* Yes No	 0.78 (0.66–0.86) 0.82 (0.77–0.86)	 0.13 (0.08–0.22) 0.13 (0.10–0.17)	 0.09 (0.05–0.17) 0.05 (0.04–0.07)	0.10	1.10‡ 1.97§
Mean glycosylated hemoglobin, %†	5.6 (5.5–5.7)	5.7 (5.6–5.8)	6.0 (5.7–6.2)	0.005 0.007	Unable to calculate
Glycosylated hemoglobin* ≤ 7% > 7%	 0.83 (0.77–0.87) 0.73 (0.60–0.83)	 0.12 (0.09–0.16) 0.15 (0.09–0.24)	 0.05 (0.04–0.07) 0.13 (0.07–0.23)	0.0044	1.33‡ (0.77–2.31) 2.93§ (1.36–6.33)
Mean body mass index, kg/m²†	26.4 (25.9–26.9)	26.5 (25.8–27.2)	26.6 (25.0–28.1)	0.75 0.86	1.00 (0.99–1.02) 1.00 (0.95–1.06)
Body mass index, kg/m²* < 25 25 to < 30 ≥ 30	 0.82 (0.75–0.88) 0.82 (0.76–0.86) 0.81 (0.76–0.86)	 0.12 (0.09–0.16) 0.14 (0.10–0.19) 0.13 (0.10–0.16)	 0.05 (0.03–0.09) 0.04 (0.03–0.06) 0.06 (0.04–0.09)	0.65	1.13 (0.87–1.49)‡¶ 1.05 (0.80–1.39)‡** 0.82 (0.40–1.71)§¶ 1.13 (0.52–2.44)§**
Visits dental professional once/yr. or more* Yes No	 0.81 (0.76–0.86) 0.84 (0.79–0.88)	 0.13 (0.10–0.17) 0.12 (0.09–0.17)	 0.06 (0.04–0.08) 0.04 (0.03–0.06)	0.20	1.08‡ 1.49§
Brushes twice/d or more* Yes No	 0.82 (0.76–0.86) 0.84 (0.79–0.87)	 0.14 (0.10–0.18) 0.11 (0.08–0.13)	 0.05 (0.03–0.07) 0.06 (0.04–0.09)	0.080	1.32‡ 0.84§
Flosses once/d or more* Yes No	 0.81 (0.76–0.86) 0.84 (0.79–0.88)	 0.14 (0.11–0.18) 0.11 (0.08–0.16)	 0.05 (0.03–0.07) 0.06 (0.04–0.08)	0.29	1.29‡ 0.90§
Presence of plaque					0.99 (0.53–1.84)‡[1] 1.46 (0.82–2.62)‡[2] 1.29 (0.54–3.09)‡[3]
0 1 2 3	0.82 (0.73–0.89) 0.82 (0.76–0.88) 0.77 (0.72–0.81) 0.74 (0.68–0.79)	0.13 (0.08–0.20) 0.13 (0.08–0.19) 0.17 (0.15–0.21) 0.15 (0.10–0.22)	0.05 (0.02–0.12) 0.05 (0.03–0.07) 0.06 (0.03–0.11) 0.11 (0.07–0.18)	0.18	1.04 (0.25–4.26)§[1] 1.26 (0.28–5.70)§[2] 2.60 (0.60–11.17)§[3]
Mean age, years†	43.7 (43.1–44.3)	53.2 (50.6–55.7)	54.4 (49.9–58.9)	< 0.001	1.04 (1.03–1.06) 1.05 (1.02–1.07)
Sex* Male Female	 0.81 (0.76–0.85) 0.84 (0.78–0.88)	 0.14 (0.11–0.17) 0.12 (0.09–0.17)	 0.06 (0.04–0.08) 0.04 (0.03–0.06)	0.16	0.86‡ 0.69§
Annual income, $* < 20 000 20 000–60 000 > 60 000	 0.81 (0.73–0.87) 0.80 (0.75–0.84) 0.84 (0.78–0.89)	 0.12 (0.08–0.20) 0.13 (0.11–0.16) 0.13 (0.09–0.19)	 0.06 (0.04–0.11) 0.07 (0.05–0.11) 0.03 (0.02–0.05)	0.04	1.06‡¶ 1.01‡** 1.16§¶ 0.50§**

Note: CI = confidence interval.
*χ^2 test.
†General linear model.
‡LOA 4–5 mm versus LOA ≤ 3 mm.
§LOA > 5 mm versus LOA ≤ 3 mm.
§[1] = OR of plaque category 1 vs. reference category 0.
§[2]= OR of plaque category 2 vs. reference category 0.
§[3]= OR of plaque category 3 vs. reference category 0.
¶Annual income $20 000–$60 000 versus income < $20 000 or BMI 25 to < 30 kg/m².
**Annual income > $60 000 versus Income < $20 000 or BMI ≥ 30 kg/m².

Table 4: Multiple logistic regression for loss of attachment.

Independent variable	Loss of attachment					
	Moderate versus slight			Severe versus slight		
	Relative risk ratio	95% CI	*p*	Relative risk ratio	95% CI	*p*
Model A: Vitamin D < 50 nmol/L						
Vitamin D < 50 nmol/L	0.65	0.33–1.29	0.20	1.24	0.56–2.72	0.56
Age	1.06	1.04–1.08	0.000	1.04	0.99–1.08	0.11
Mean glycosylated hemoglobin, %	0.0002	5.41^{e-21}–5.35^{e12}	0.63	4.25^{e11}	2.05^{e-20}–8.78^{e42}	0.43
Multivitamin or vitamin D supplement use	1.11	0.65–1.92	0.68	2.34	0.84–6.51	0.095
Smoking (former or current)	1.79	1.17–2.74	0.01	1.60	0.59–4.29	0.32
Brushes ≥ 2 times/day	1.49	0.84–2.64	0.15	0.79	0.25–2.51	0.66
Annual income, $ 20 000–60 000 > 60 000	 0.98 0.69	 0.62–1.56 0.41–1.16	 0.94 0.15	 1.64 0.67	 0.72–3.73 0.27–1.69	 0.21 0.37
Model B: Vitamin D < 75 nmol/L						
Vitamin D < 75 nmol/L	0.91	0.63–1.31	0.58	2.09	1.02–4.30	0.05
Age	1.06	1.04–1.08	0.000	1.04	0.99–1.09	0.09
Mean glycosylated hemoglobin, %	0.0001	4.18^{e-21}–2.36^{e12}	0.60	4.44^{e10}	1.18^{e-20}–1.67^{e41}	0.46
Multivitamin or vitamin D supplement use	1.13	0.67–1.91	0.62	2.52	0.92–6.92	0.07
Smoking (former or current)	1.76	1.16–2.67	0.01	1.59	0.59–4.31	0.33
Brushes ≥ 2 times/day	1.50	0.85–2.64	0.14	0.80	0.25–2.59	0.69
Annual income, $ 20 000–60 000 > 60 000	 1.01 0.74	 0.64–1.58 0.46–1.19	 0.97 0.19	 1.70 0.71	 0.78–3.68 0.30–1.67	 0.16 0.39
Model C: Mean vitamin D						
Mean vitamin D, 85.6	1.00	1.00–1.00	0.67	1.00	0.98–1.02	0.76
Age	1.06	1.04–1.08	0.000	1.04	0.99–1.08	0.11
Glycosylated hemoglobin, %	0.0001	4.55^{e-21}–2.01^{e12}	0.60	3.03^{e11}	1.24^{e-20}–7.39^{e42}	0.44
Multivitamin or vitamin D supplement use	1.14	0.66–1.97	0.60	2.33	0.86–6.28	0.09
Smoking (former or current)	1.75	1.16–2.65	0.01	1.61	0.60–4.30	0.31
Brushes ≥ 2 times/day	1.50	0.85–2.65	0.14	0.79	0.25–2.50	0.66
Annual income, $ 20 000–60 000 > 60 000	 1.02 0.75	 0.65–1.58 0.48–1.18	 0.94 0.19	 1.62 0.66	 0.74–3.51 0.27–1.62	 0.20 0.33

Note: CI = confidence interval.

Millen et al.[17] also reported an association between 25(OH)D levels and periodontal disease in a sample of 920 postmenopausal women by measuring alveolar crestal height, tooth loss, clinical attachment level, probing depth and percentage bleeding on gingival probing. They categorized participants as vitamin D adequate (≥ 50 nmol/L) and inadequate (< 50 nmol/L) and also found that vitamin D status was inversely associated with periodontal disease as measured by bleeding on probing and clinical categories that incorporated probing depth as a parameter.

Millen et al.[19] also published the largest and longest longitudinal study to date analyzing the relation between vitamin D and periodontal disease. Their 5-year cohort study of 655 postmenopausal women measured 25(OH)D concentrations at baseline and follow up as well as multiple periodontal parameters. This study found no significant associations between baseline 25(OH)D concentrations and change in periodontal disease measures after 5 years. Antonoglou et al.[20] also reported no significant association between 25(OH)D and selected indicators of periodontal disease among 1262 Finnish participants in their cross-sectional study.

The results of our study contain mixed evidence supporting an association between low 25(OH)D levels and periodontal disease. Our observation of associations between low 25(OH)D thresholds and increased odds of GI at the bivariate level are consistent with other studies supporting a relation between 25(OH)D levels and periodontal disease.[14,15,17] Likewise, our observation of a significant association between the 25(OH)D threshold of < 75 nmol/L and increased relative risk of LOA in the multiple logistic regression analysis is also consistent with these other studies.[14,15,17] Conversely, our observation of no association between low 25(OH)D thresholds and LOA at the bivariate level and low 25(OH)D thresholds and GI in the multiple regression analysis is more in line with results from published longitudinal studies.[19,20]

Limitations of the present study include the cross-sectional design as well as how the markers of periodontal disease

were defined in the CHMS. The cross-sectional design does not permit the determination of causality or the determination of 25(OH)D levels at the time when attachment loss occurred. Measurements for GI and LOA were performed on 6 and 10 indicator teeth. Furthermore, the worst score for each participant was then used to categorize participants into 1 of the categories for GI or LOA resulting in greater potential to overestimate or underestimate the severity and extent of periodontal disease than if full-mouth probing had been used. The use of GI may increase the subjectivity in this assessment compared with an assessment of bleeding on probing. However, data on bleeding on probing were not available. This subjectivity could lead to the overestimation or underestimation of periodontal disease. An additional limitation is that fact that our samples included participants spanning considerable age ranges: 13–79 years for GI and 20–79 years for LOA. Youth and younger adults are likely to have better oral health than older adults, which may have affected our analysis of selected periodontal outcome measures. The possibility that unaccounted residual confounding variables is another limitation of this study.

Strengths of this study include the large size and representative nature of the sample under investigation and the examiner calibration. Another advantage is the availability of actual 25(OH)D levels, which is the recognized gold standard in determining a person's overall vitamin D status, instead of relying on dietary intake estimates.

Conclusions

Although cross-sectional studies[14,15,17] have provided strong evidence supporting a relation between vitamin D status and periodontal disease, the largest and longest longitudinal study[19] as well as a recent cross-sectional study[20] failed to find an association between these two entities. The results of our study, performed on a representative sample of Canadian adults, provide modest evidence supporting a relation between low 25(OH)D concentrations and periodontal disease as measured by GI and LOA. Prospective studies with longer follow up are likely required to fully elucidate what effect, if any, vitamin D levels have on the progression of periodontal disease.

THE AUTHORS

Dr. Bonnet *is a periodontist and former graduate periodontology resident, College of Dentistry, Rady Faculty of Health Sciences, University of Manitoba.*

Dr. Rabbani *is assistant professor, department of community health sciences, Max Rady College of Medicine, and George and Fay Yee Centre for Healthcare Innovation, Rady Faculty of Health Sciences, University of Manitoba.*

Dr. Moffatt *is professor, department of community health sciences and pediatrics and child health, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba.*

Dr. Kelekis-Cholakis *is associate professor and graduate program director, division of periodontology, College of Dentistry, Rady Faculty of Health Sciences, University of Manitoba.*

Dr. Schroth *is associate professor and clinician scientist, department of preventive dental science, College of Dentistry and department of pediatrics and child health, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba.*

Correspondence to: *Dr. Robert J. Schroth, 507—715 McDermot Ave., Winnipeg MB R3E 3P4; robert.schroth@umanitoba.ca*

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