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The association between coeliac disease and periodontitis: Results from NHANES 2009–2012

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Abstract

Aim: To investigate whether coeliac disease (CD) was associated with periodontitis among a nationally representative sample of US adults.

Materials and Methods: The National Health and Nutrition Examination Survey (NHANES) 2009–2012 enrolled 6,661 subjects with full-mouth periodontal examination and serological testing for antitissue transglutaminase (tTg) and antiendomysial (EMA) antibodies. CD was defined as (i) self-reported physician diagnosis while on a gluten-free diet; or (ii) tTg levels >10.0 U/ml and positive EMA results. Positive serology without self-reported diagnosis was defined as undiagnosed CD (UdxCD). Periodontitis was defined according to the CDC/AAP definition. Multivariable linear and logistic models were used to regress the mean probing depth (PD) or attachment loss (AL) outcomes across CD categories (none, diagnosed and undiagnosed).

Results: The prevalence of moderate/severe periodontitis and diagnosed/undiagnosed CD was 40% and 0.74%, respectively. Mean AL was lower among those with CD although results were not statistically significant (p = .67). The odds of periodontitis among individuals with diagnosed and undiagnosed CD were: 0.5(0.22, 1.16) and 0.62(0.1, 3.75), respectively. Mean PD levels among those without CD or with diagnosed or undiagnosed CD were 1.49 ± 0.02, 1.36 ± 0.11 and 1.31 ± 0.11 (p = .03).

Conclusion: CD is associated with modestly lower levels of mean PD but was not associated with mean AL or periodontitis. Larger studies are necessary to enhance precision and strengthen conclusions.

KEYWORDS

cross-sectional Studies, digestive system and oral physiology, digestive system diseases, oral health, periodontal diseases, periodontics, Sprue, wheat hypersensitivity

1 | INTRODUCTION

Periodontitis is a highly prevalent chronic inflammatory disease affecting the teeth-supporting tissues, ultimately leading to tooth loss if not diagnosed and treated. In the United States, ~50% of the population >30 years of age have periodontitis (Eke et al., 2015). Periodontitis also has strong links to overall health and ranks among the top 100 causes of disability-adjusted life years globally (Marcenes et al., 2013). Chronic polyinfection with pathogenic microbes colonizing dysbiotic dental plaques adjacent to the periodontium and eliciting a host inflammatory immune response in susceptible individuals is a central feature of periodontitis (Cekici, Kantarci, Hasturk, & van Dyke, 2014; Haffajee & Socransky, 1994; Loesche & Grossman, 2001; Nishihara & Koseki, 2004; Palmer, 2014; Socransky & Haffajee, 1994, 2005). Several risk factors have been implicated in the pathobiology of periodontitis including poor oral hygiene and tobacco use (Tonetti et al.,

2015). Periodontitis is also linked to several systemic conditions with underlying pathophysiological features related to chronic inflammation or altered immune system function including rheumatoid arthritis, atherosclerotic cardiovascular disease and diabetes mellitus. In the case of RA and DM, there is some evidence to suggest that the relationships are causally bidirectional in which the presence of each disease phenotype increases risk for development of the other condition or exacerbation of an established disease phenotype (Taylor, 2001).

Coeliac disease (CD) is a chronic inflammatory autoimmune disease with a prevalence of up to 1% (Lebwohl, Ludvigsson, & Green, 2015; Mardini, Westgate, & Grigorian, 2015; Rewers, 2005). It is triggered by gluten, a glutamine- and proline-rich protein found in wheat, rye and barley. Gluten exposure in susceptible individuals induces a T-cell- and IFN-γ-mediated inflammatory reaction in the small intestine leading to a destruction of the small intestine lining. Furthermore, intraepithelial lymphocytes might play a role in the process of epithelial cell damage (Koning, 2014).

While CD has a strong genetic component, the role of host genetics in periodontitis is equivocal and disease risk is largely driven by the intra-oral shift from bacterial symbiosis to dysbiosis. Due to the underlying chronic immune system activation and subsequent damage to mucosal barrier surfaces in the digestive tract central to CD pathophysiology, CD might increase risk for periodontitis. Alternatively, it is plausible that the underlying immune system abnormalities observed in CD might contribute to subgingival dysbiosis and/or destructive immune response to subgingival microbial exposures and subsequent clinical disease.

We are unaware of any prior investigation of the association between CD and periodontitis. The aim of this cross-sectional study was to assess whether there is an increased disease prevalence and/or severity of periodontitis among people with CD, particularly those with undiagnosed disease, among the nationally representative sample of adult men and women enrolled in The National Health and Nutrition Examination Survey (NHANES) 2009–2012.

Clinical Relevance

Scientific Rationale for the Study: This study adds to the literature concerning the dental manifestations of CD. It is the first study assessing a possible association between coeliac disease (CD) and periodontitis. While periodontitis is associated with numerous inflammatory diseases, CD, on the other hand, is associated with dental enamel defects and an altered oral microbiome.

Principal Findings: Individuals with CD have lower mean probing depths attachment levels, and the prevalence of periodontitis was not different among by coeliac status.

Practical Implications: These findings show trends towards reduced periodontal inflammation among individuals with CD although no differences in periodontitis were observed although the study has low statistical power due to a small number of CD cases. Further research is necessary to confirm these results, and the data presented currently can inform the design of future research studies.

2 | METHODS

The NHANES is a complex, multistage probability sample of US non-institutionalized civilians beginning in 1999 and consisting of six unique data sets that have been generated in 2-year cycles (Centers for disease control and prevention; National Center for Health Statistics). Each 2-year survey cycle examines a nationally representative sample of approximately 10,000 persons and collects a variety of health-related data via questionnaire, physical examination and laboratory assessments. Presently, we combined data from the 2009 to 2010 and 2011 to 2012 cross-sections. Participation rates for these survey cycles were 77.3% and 69.5% for the unweighted MEC-examined sample and 79.4% and 72.5% for the unweighted interviewed sample.

In 2009–2010, 10,253 participants were examined and interviewed, while in 2011–2012, 9,338 participants were examined and interviewed, yielding a sample of 19,591 participants enrolled in the interview and examination component of NHANES 2009–2012. Individuals were excluded if they were missing periodontal data (n = 12,503 missing, largely by design as only adults 30+ years were eligible for periodontal examinations) or serological data to test EMA or TTG (n = 427). Therefore, n = 6,661 respondents, aged 30–80 years, were included (Figure S1).

2.1 | Coeliac disease

Coeliac disease as the independent variable was defined as described previously (Digiacomo, Tennyson, Green, & Demmer, 2013; Rubio-Tapia, Ludvigsson, Branter, Murray, & Everhart, 2012b; Rubio-Tapia, Ludvigsson, Brantner, Murray, & Everhart, 2012a) by (i) a self-report physician diagnosis of CD while on a gluten-free diet and/or (ii) an antitissue transglutaminase (tTg) antibody value >10.0 U/ml with corresponding positive/slightly positive antiendomysial (EMA) antibody (Vande Voort et al., 2009). Serologies were employed sequentially so as to first maximize sensitivity (tTG, with a sensitivity estimated at 98%), followed by specificity (EMA, with a specificity estimated at 99%) (Leffler & Schuppan, 2010; Rubio-Tapia et al., 2012a,b). Individuals classified as having CD were further classified as undiagnosed if they had serological evidence of CD without a self-report history of disease. Therefore, participants were defined as healthy (n = 6,661), undiagnosed CD (n = 34) and diagnosed CD (n = 15).

2.2 | Periodontal examination and classification

The dependent variables periodontal probing depth (PD) and clinical attachment loss (AL) were obtained by trained, registered hygienists in the full-mouth (excluding 3rd molars) at six sites per tooth (Eke, Dye, Wei, Thornton-Evans, & Genco, 2012). Periodontal examiners received intense training followed by periodic monitoring and

recalibration against a reference examiner. The reference examiner made three visits to each dental examination team per year to observe field operations and to replicate 20–25 oral health examinations. A three-level definition of periodontitis was utilized in the primary analyses based on the 2003 case definitions proposed by an American Academy of Periodontology (AAP) and the Centers for Disease Control and Prevention (CDC) workgroup (Page & Eke, 2007). Mean full-mouth PD, AL and tooth loss were derived for each participant as continuous measures of current or historical periodontal disease. Additionally, we considered extent of periodontal disease defined as either (i) the per cent of periodontal sites with ≥4 mm of PD (%PD ≥ 4); or (ii) the per cent of periodontal sites with ≥3 mm of AL (%AL ≥ 3).

2.3 | Risk factor assessment

We considered multiple risk factors potentially relevant to both periodontitis and CD based on previous work (Arora et al., 2014; Demmer et al., 2012; Digiacomo et al., 2013; Kotsakis, Thai, Ioannou, Demmer, & Michalowicz, 2015). These included the demographic variables age, race/ethnicity, sex, education (<high school, high school, some college, college graduate) and poverty income ratio (calculated by dividing family income by the poverty guidelines, specific to family size, as well as the appropriate year and state according to the Department of Health and Human Services guidelines). Assessed behaviours included physical activity (none, low [0–499 METs], moderate [500–999 METs] and vigorous [≥1,000 METs] physical activity), which are based on occupational and recreational physical activities performed in a typical week. Smoking status was defined as current smokers (smoked 100+ cigarettes in lifetime and currently smoke), former smokers (smoked 100+ cigarettes in lifetime but not currently smoking) or non-smokers (subjects who have never smoked or smoked less than 100+ cigarettes in lifetime). Alcohol consumption was defined as non-drinker (0 drinks per week), moderate drinker (1–4 drinks per week) and severe drinker (>4 drinks per week) (Thai, Papapanou, Jacobs, Desvarieux, & Demmer, 2014).

The Healthy Eating Index (HEI) score was used to assess diet quality based on participant responses to a food frequency questionnaire. HEI-2010 total and component scores were calculated following standards set by the NIH and NCI(Wang, Leung, & Li, 2014). The Food Patterns Equivalents Database (FPED) datasets available from the USDA were combined with NHANES dietary total nutrient intakes from the first and second day to convert foods and beverages in the Food and Nutrient Database for Dietary Studies to 37 USDA Food Patterns components. HEI-2010 serving equivalents and score were then calculated and subsequently placed into quartiles as defined by the NIH and NCI. A higher HEI score indicates healthier dietary intake relative to a lower score. Participants were also questioned about the frequency of visiting a dentist. We transformed their responses into a binary variable: dental visit within the past year versus dental visit greater than 1 year or never. We also examined the regularity of flossing as a variable of significance, categorizing it into a 4-level variable: never, rarely (1–2 times per week), moderately (3–5 times per week) and frequently (6–7 times per week).

Trained NHANES personnel performed height, weight and blood pressure measures according to standardized protocols. Body Mass Index (BMI) was calculated as weight (kilograms)/height (meters^2), and participants were categorized as underweight/normal weight (<25 kg/m^2), overweight (25–29.9 kg/m^2) or obese (≥30 kg/m^2). A self-reported physician diagnosis of diabetes or a haemoglobin A1C level of 6.5% or greater was used to define diabetes. Participant self-report of physician diagnosed myocardial infarction, congestive heart failure and/or coronary heart disease defined coronary artery disease. Health insurance signified having any type of healthcare coverage during the year of the administration of the survey.

2.4 | Statistical analysis

Analyses were performed using SAS 9.4TM. PROC SURVEYREG and PROC SURVEYLOGISTIC were used to account for the complex survey design and to generate the correct variance estimates. Sampling weights provided by NHANES were used in all analyses to account for oversampling, non-response and post-stratification; doing so ensures generalizability of findings to the US population. Means and frequencies of important risk factors were calculated for all participants and according to CD status. *p* vales comparing differences in risk factor distributions across CD status were derived from t tests or chi-square statistics. Multivariable polytomous logistic regression was used to model the association between CD status (defined above) and the odds of CDC/AAP defined moderate/severe periodontitis. 95% confidence intervals (CI) obtained from logistic regression models were reported as were *p* values derived from Wald chi-square tests corresponding to any difference in the odds of periodontitis across levels of CD. Similarly, multivariable linear regression models were used to evaluate continuous measures of periodontitis by comparing mean full-mouth PD or AL levels by CD status. A series of multivariable models are presented to inform the influence of potential confounders. All regression models were performed on $n = 6{,}278$ participants with complete information on all potential confounders to ensure that comparison of results across models was made on the same participants. To help with the interpretation of statistical significance, we also calculated the necessary number of individuals with CD required to have 80% power to detect an odds ratio of 0.53 in our aforementioned logistic regression analysis assuming two-tailed hypothesis test and alpha = 0.05. $n = 80$ patients with CD would be necessary to have 80% power suggesting that null results for logistic regression analyses have a high likelihood to arise from type 2 error (i.e., failure to reject a truly null hypothesis).

3 | RESULTS

3.1 | General characteristics

Participants had a mean age ± *SD* of 52 ± 14, and 51% were female. The overall weighted prevalence of CD in this sample was

TABLE 1 General characteristics according to coeliac disease status among 6,661 Participants enrolled in NHANES 2009–2012

	Binary exposure		Categorical (3 level) exposure	
	Healthy (6,612)	Coeliac disease (*n* = 49)	Undiagnosed coeliac (*n* = 34)	Diagnosed coeliac (*n* = 15)
Variables				
Age				
30–39	25%	21%	23%	10%
40–49	26%	31%	35%	19%
50–59	24%	22%	28%	0%
60–69	15%	19%	11%	50%
70+	10%	7%	4%	21%
Gender				
Male	49.2%	58.4%	57.7%	61.4%
Female	50.8%	41.6%	42.3%	38.6%
Race[*]				
Hispanic	13.4%	6.61%	3.05%	20.7%
White people	69.5%	88.5%	93.3%	69.6%
Black people	10.2%	2.74%	1.64%	7.08%
Other	6.97%	2.12%	1.99%	2.62%
Smoking status				
Never	55.9%	58.8%	61.9%	46.5%
Current (smoked 100 cigs)	17.4%	22.5%	21.8%	25.6%
Not current (smoked 100 cigs)	26.7%	18.7%	16.3%	27.9%
Education level				
<High school	16.1%	9.69%	4.03%	32.0%
High school	21.1%	15.2%	14.9%	16.4%
Some college	29.2%	33.0%	39.0%	8.96%
College +	33.6%	42.2%	42.0%	42.7%
Flossing				
Never	28.9%	27.1%	31.5%	9.96%
Rarely	17.6%	28.5%	33.2%	9.93%
Moderately	19.8%	15.3%	15.1%	16.3%
Frequently	33.8%	29.0%	20.3%	63.8%
Diabetes				
No	88.7%	83.7%	86.7%	71.7%
Yes	11.3%	16.3%	13.3%	28.3%
AHEI[b]				
Quartile 1	23.7%	21.0%	26.3%	0.00%
Quartile 2	25.4%	36.2%	41.0%	17.1%
Quartile 3	24.5%	22.4%	19.5%	33.7%
Quartile 4	26.5%	20.4%	13.2%	49.2%
Dental visit[c]				
<1 year	64.5%	51.5%	45.3%	71.0%
≥1 year	35.5%	48.5%	54.7%	29.0%
Cardiovascular disease				
No	95.1%	100%	100%	100%
Yes	4.90%	0.00%	0.00%	0.00%

(Continues)

TABLE 1 (Continued)

	Binary exposure		Categorical (3 level) exposure	
	Healthy (6,612)	Coeliac disease (*n* = 49)	Undiagnosed coeliac (*n* = 34)	Diagnosed coeliac (*n* = 15)
Alcohol consumption[d]				
0 (drinks per week)	16.8%	15.9%	9.40%	47.6%
1–4(drinks per week)	65.8%	65.8%	72.1%	34.7%
≥5 (drinks per week)	17.5%	18.4%	18.5%	17.7%
Physical activity				
Low physical activity	67.2%	74.7%	70.2%	92.3%
Moderate physical activity	7.14%	1.76%	1.15%	4.15%
Vigorous physical activity	25.7%	23.6%	28.6%	3.59%
Insurance				
No	18.8%	9.03%	6.76%	18.0%
Yes	81.2%	91.0%	93.2%	82.0%

[a]Could not obtain a value.
[b]294 missing data for AHEI.
[c]Time since last dental visit. 3,568 missing data for dental visit because the interview was not administered in 2009–2010.
[d]1,316 missing data for alcohol consumption.
*$p < .05$.

1.08%, and the weighted prevalence estimates of diagnosed and undiagnosed CD in this sample were 0.22% and 0.86%, respectively. Participants with CD were more likely to be White people ($p = .001$). Among the undiagnosed CD population, >90% were white people whereas only 70% of diagnosed patients with CD were white people and higher percentages of those diagnosed with CD were Hispanic (20.7%) and Black people(7.08%) as shown in Table 1. Participants with CD, undiagnosed and diagnosed CD in particular had a lower prevalence of diabetes (Table 1) although this difference was not statistically significant (Table 1). Those with undiagnosed and diagnosed CD were more likely to have health insurance. The prevalence of moderate/severe periodontitis was 40%. People with diagnosed CD tended to floss more frequently than healthy and undiagnosed participants ($p = .07$), and those with diagnosed CD were also more likely to visit a dentist in the past year. Periodontitis was related to a number of risk factors including age, gender, race/ethnicity, smoking status, educational level, oral hygiene behaviours, dietary pattern, alcohol consumption and diabetes status (Tables S1 and S2). Mean PD, AL and tooth loss were all higher among those with less than one dental visit per year and those who see a dentist more frequently ($p < .001$).

3.2 | Coeliac disease and periodontal health

Mean AL tended to be lower among individuals with CD, although this pattern was not statistically significant (Table 2). After full multivariable adjustment (Table 2, Model 4), mean levels of %AL ≥ 3 among individuals without CD, with undiagnosed CD or with diagnosed CD were 18%, 15% and 16% and these differences were not statistically significant ($p = .72$). After multivariable adjustment, mean PD values among healthy, diagnosed and undiagnosed patients with CD were 1.49, 1.36 and 1.31 mm, respectively ($p = .03$ for any difference, Table 3). Similarly, mean values of %PD ≥ 4 were 3.4%, 1.5% and 1.7%, respectively ($p = .02$). Multivariable logistic regression models considering CDC/AAP defined moderate/severe periodontitis produced similar results. The odds of periodontitis were reduced among those with undiagnosed or diagnosed CD relative to healthy participants: ORs (95% CIs) = 0.5(0.22, 1.16) and 0.62(0.1, 3.75) as shown in Table 4. Multivariable adjustment, even for markers of healthy lifestyle including health insurance status, tobacco use, physical activity level and dietary pattern, had minimal influence on the observed odds ratios (Tables 2–4). After multivariable adjustments (per Model 4, Table 4), mean tooth loss values among participants without CD, with undiagnosed CD or with diagnosed CD were 5.0, 6.3 and 6.6 (p for any difference = .72).

4 | DISCUSSION

To our knowledge, this is the first assessment of a possible association between periodontitis and CD. The analysis of two nationally representative samples yielded no positive but actually a consistent trend towards a negative association between CD and periodontitis. Still, results should be interpreted with caution due to the low sample size in the CD group, which can be explained by the low disease prevalence and the study design. Anyway, the current results suggest, counter to our hypothesis, that levels of periodontal disease severity (assessed via PD) are modestly reduced among people with CD while no apparent association was observed between CD and AL levels or prevalence of periodontitis.

TABLE 2 Mean attachment loss (±*SE*) levels across coeliac disease categories (independent variable) among *n* = 6,278 participants enrolled in The Continuous National Health and Nutrition Examination Survey (NHANES) 2009–2012

	No coeliac disease (*n* = 6,232)	Coeliac disease (*n* = 46)	Undiagnosed coeliac disease (*n* = 33)	Diagnosed coeliac disease (*n* = 13)
	Mean ± *SE*	Mean ± *SE*	Mean ± *SE*	Mean ± *SE*
Model 1	1.64 ± 0.03	1.51 ± 0.11	1.44 ± 0.12	1.82 ± 0.28
Model 2	1.64 ± 0.03	1.55 ± 0.13	1.55 ± 0.14	1.53 ± 0.29
Model 3	1.64 ± 0.03	1.52 ± 0.14	1.52 ± 0.15	1.51 ± 0.31
Model 4	1.64 ± 0.03	1.51 ± 0.14	1.51 ± 0.16	1.49 ± 0.30

Model 1: crude; Model 2: adjusted for age, sex, race, education; Model 3: Model 2+ smoking, AHEI score, insurance, flossing; Model 4: model 3+ diabetes.
No statistically significant differences were observed in any model for mean attachment loss across CD category. Results arise from the adjusted least squared means obtained from linear regressions modelling mean attachment loss as the dependent variable and coeliac status as the independent variable.

TABLE 3 Mean probing depth (±*SE*) levels across coeliac disease categories (independent variable) among *n* = 6,278 participants enrolled in The Continuous National Health and Nutrition Examination Survey (NHANES) 2009–2012

	No coeliac disease (*n* = 6,232)	Coeliac disease (*n* = 46)	Undiagnosed coeliac disease (*n* = 33)	Diagnosed coeliac disease (*n* = 13)
	Mean ± *SE*	Mean ± *SE*	Mean ± *SE*	Mean ± *SE*
Model 1	1.49 ± 0.02*	1.34 ± 0.06**	1.33 ± 0.06***	1.38 ± 0.14
Model 2	1.50 ± 0.02*	1.38 ± 0.04**	1.40 ± 0.05***	1.31 ± 0.10
Model 3	1.49 ± 0.02*	1.36 ± 0.05**	1.37 ± 0.05***	1.32 ± 0.11
Model 4	1.49 ± 0.02*	1.35 ± 0.05**	1.36 ± 0.05***	1.31 ± 0.11

Model 1: crude; Model 2: adjusted for age, sex, race, education; Model 3: Model 2+ smoking, AHEI score, insurance, flossing; Model 4: model 3+ diabetes.
*$p < .05$ for any difference in mean probing depth values across No CD, CD, Undiagnosed CD (columns 1, 3 and 4 in table). **$p < .05$ for CD versus No CD. ***$p < .05$ for No CD versus Undiagnosed CD. Results arise from the adjusted least squared means obtained from linear regressions modelling mean attachment loss as the dependent variable and coeliac status as the independent variable.

TABLE 4 Odds ratios for moderate/severe periodontitis among participants with diagnosed and undiagnosed coeliac disease relative to participants free of coeliac disease among *n* = 6,278 participants enrolled in The Continuous National Health and Nutrition Examination Survey (NHANES) 2009–2012

	No coeliac disease (*n* = 6,232)	Coeliac disease (*n* = 46)	Undiagnosed coeliac disease (*n* = 33)	Diagnosed coeliac disease (*n* = 13)
		OR [95% CI]	OR [95% CI]	OR [95% CI]
Model 1	Ref.	0.64 [0.34, 1.21]	0.52 [0.24, 1.10]	1.36 [0.40, 4.64]
Model 2	Ref.	0.62 [0.33, 1.16]	0.58 [0.28, 1.20]	0.74 [0.15, 3.5]
Model 3	Ref.	0.54 [0.27, 1.09]	0.50 [0.22, 1.13]	0.65 [0.12, 3.56]
Model 4	Ref.	0.53 [0.25, 1.11]	0.50 [0.22, 1.16]	0.62 [0.10, 3.75]

Model 1: crude; Model 2: adjusted for age, sex, race, education; Model 3: Model 2+ smoking, AHEI score, insurance, flossing; Model 4: model 3+ diabetes. Results arise from logistic regressions modelling periodontitis status as the dependent variable and coeliac status as the independent variable.

The fact that our results were statistically significant for PD outcomes but not for the CDC/AAP periodontitis definition may seem counter-intuitive as the definition is based, in part on PD. However, it is notable that the observed odds ratios also demonstrated a strong trend towards lower odds of periodontitis among individuals with versus without CD which is consistent with the PD results. The lack of statistical significance is possibly due to low statistical power for a dichotomous outcome coupled with the low prevalence of CD (see Methods). A similar issue exists for the AL analysis, as mean AL was consistently lower among participants with diagnosed or undiagnosed CD versus those without CD although statistical significance was lacking.

Overall, the results show a trend towards improved periodontal health in CD subjects. Interesting, these findings were consistent even after multivariable adjustment for potential confounding related to demographic and healthy lifestyle-related variables. Behavioural changes with respect to oral health measures due to an increased awareness and changes in diet after diagnosis may be the reason for these findings. Once diagnosed with CD, patients are supposed to adhere to a strict gluten-free diet. They are usually thoroughly informed about the disease aetiology, risks and nutritional changes necessary to avoid symptoms. It has been shown with respect to intestinal failure that such detailed information may have an impact on the patients' knowledge and furthermore a positive effect on the clinical outcome (Culkin,

Gabe, & Madden, 2009). Nevertheless, our multivariable models comparing undiagnosed and diagnosed CD subjects did not support this notion. Among people with undiagnosed CD and elevated measures of immune activity, we also observed lower levels of periodontitis, although it is possible that undiagnosed, yet symptomatic individuals may go through a similar process of behavioural adaptation despite a lack of knowledge about the aetiology of their symptoms.

People with diagnosed CD were also more likely to have seen a dentist within the past year when compared to the healthy and undiagnosed patients with CD, and more recent dental visits were associated with lower prevalence of moderate/severe periodontitis. While 72.2% of the subjects without periodontitis had seen a dentist within the past year, only 52.8% did so in the moderate/severe periodontitis group ($p < .001$).

Unfortunately, we were unable to more robustly evaluate the role of access to health care due to limited data collection in this regard. Nevertheless, our findings did account for health insurance status and a number of health behaviours of relevance to periodontal disease. Even if unmeasured confounding were to explain the current findings, it is worth emphasizing that any increased risk for periodontitis conferred by CD appears to be potentially offset by lifestyle modifications.

This study adds to the literature concerning the dental manifestations of CD. We and others have identified patients with CD to have increased rates of dental enamel defects (Cheng, Malahias, Brar, Minaya, & Green, 2010). These colour and structural changes may be subtle or marked (Aine, Maki, Collin, & Keyrilainen, 1990) and could in fact drive patients to have more intensive dental care. Furthermore, in a recent study, the oral microbiomes of healthy subjects and patients CD were compared (Tian et al., 2017). Results showed that the microbial species that were elevated in the CD patient group were not periodontal pathogens, but primarily harmless commensal microorganisms (Bacillus, Leptotrichia, Veillonella). These observations are consistent with the findings in this study where the CD group shows no evidence for displaying more periodontitis than the healthy control group.

The current analysis demonstrates that in a cross-sectional setting, CD is associated with reduced PD s. However, despite trends for lower levels of periodontitis defined by both AL and PD, statistical significance is lacking. These results remain after adjustment for important confounders among a nationally representative sample of US men and women. Future research in longitudinal settings can inform the temporal ordering of the emergence of autoimmunity present in CD and the development of gingival inflammation and subsequent periodontitis. Designs that can enrol larger numbers of people with CD will also be informative to enhance statistical power for detecting small effects, if they exist.

CONFLICT OF INTERESTS

The authors report no conflict of interests.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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