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Dietary Fiber Intake Is Inversely Associated with Periodontal Disease among US Adults[1,2]

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Abstract

Background: Approximately 47% of adults in the United States have periodontal disease. Dietary guidelines recommend a diet providing adequate fiber. Healthier dietary habits, particularly an increased fiber intake, may contribute to periodontal disease prevention.

Objective: Our objective was to evaluate the relation of dietary fiber intake and its sources with periodontal disease in the US adult population (≥30 y of age).

Methods: Data from 6052 adults participating in NHANES 2009–2012 were used. Periodontal disease was defined (according to the CDC/American Academy of Periodontology) as severe, moderate, mild, and none. Intake was assessed by 24-h dietary recalls. The relation between periodontal disease and dietary fiber, whole-grain, and fruit and vegetable intakes were evaluated by using multivariate models, adjusting for sociodemographic characteristics and dentition status.

Results: In the multivariate logistic model, the lowest quartile of dietary fiber was associated with moderate-severe periodontitis (compared with mild-none) compared with the highest dietary fiber intake quartile (OR: 1.30; 95% CI: 1.00, 1.69). In the multivariate multinomial logistic model, intake in the lowest quartile of dietary fiber was associated with higher severity of periodontitis than dietary fiber intake in the highest quartile (OR: 1.27; 95% CI: 1.00, 1.62). In the adjusted logistic model, whole-grain intake was not associated with moderate-severe periodontitis. However, in the adjusted multinomial logistic model, adults consuming whole grains in the lowest quartile were more likely to have more severe periodontal disease than were adults consuming whole grains in the highest quartile (OR: 1.32; 95% CI: 1.08, 1.62). In fully adjusted logistic and multinomial logistic models, fruit and vegetable intake was not significantly associated with periodontitis.

Conclusions: We found an inverse relation between dietary fiber intake and periodontal disease among US adults ≥30 y old. Periodontal disease was associated with low whole-grain intake but not with low fruit and vegetable intake. *J Nutr* 2016;146:2530–6.

Keywords: periodontal disease, dietary fiber, whole grains, NHANES, nutrition, epidemiology

Introduction

The burden of periodontal disease is substantial. Among adults age ≥30 y in the United States, nearly 65 million (47%) have mild, moderate, or severe periodontitis (1). Periodontal disease is a chronic inflammatory condition that affects the hard and soft tissues surrounding and supporting the teeth. Disease progression is dependent on the varying effects of putative microorganisms and a changing oral ecology as well as the host immune response. In the United Sates periodontitis prevalence increases with age and is higher among men, some race/ethnicity groups, and those with low socioeconomic status (1). A number of health behaviors and conditions are associated with periodontal disease, including poor oral hygiene, smoking, and diabetes (2). Additionally, evidence—mainly from cross-sectional and a few longitudinal studies—suggests that periodontitis is associated with cardiovascular disease, although causality is not established (3, 4).

Periodontal disease and cardiovascular disease share many common risk factors with chronic inflammation, which is considered a key factor in the development and progression for both diseases. Hypertension is the leading risk factor for many vascular diseases, such as atherosclerosis and stroke (5, 6), and it affects ~1 in 3 adults in the United States (7). Hypertension may be associated with periodontal disease (8–11), although results are not consistent across studies. The proposed pathophysiological mechanisms supporting an association between hypertension and periodontal disease focus on the adverse effects of inflammation and bacteremia on endothelial integrity (12).

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To lower blood pressure, lifestyle changes such as improving diet quality are often recommended. In 2013, new guidelines for preventing heart disease and stroke from the AHA and the American College of Cardiology were established, recommending the Dietary Approaches to Stop Hypertension (DASH)[6] diet for the at-risk population, which emphasizes fruits, vegetables, whole grains, low-fat dairy products, poultry, fish, and nuts consumption and is consequently high in fiber, potassium, magnesium, and calcium (13, 14). Previous cross-sectional as well as longitudinal research suggests that diet may play a role in preventing periodontal disease (15). Fiber consumption, such as whole-grain intake, may reduce the risk of periodontitis (16). In addition, high-fiber foods, specifically fruit and grains, reduce periodontal disease progression, especially among older adults (17). A pilot intervention study among 21 participants shows that high-fiber diets improve periodontal disease in high-risk subjects (18). In another study among patients with chronic generalized periodontitis who were undergoing nonsurgical periodontal treatment, fruit and vegetable intake was associated with increased periodontal healing after 8–16 wk among nonsmokers but not among smokers (19).

National public health initiatives, such as Healthy People 2020 and the 2015–2020 Dietary Guidelines for Americans (DGA), aim to promote healthy choices to improve health and reduce chronic disease in the United States (14, 20). Additionally, one of the key health promotion activities for the Million Hearts Initiative, a public-private partnership that aims to prevent 1 million heart attacks and strokes in the United States, is encouragement of healthy dietary choices, including choosing diets high in fiber (21). This article examines the relation of total dietary fiber and its sources with periodontal disease in the US population aged ≥30 y.

Methods

Sample. Data from 6052 adults participating in NHANES 2009–2010 and 2011–2012 were used for this study. NHANES uses a multistage probability design capable of producing a nationally representative sample of the civilian noninstitutionalized population of the United States, including the District of Columbia. Between 2009 and 2012, NHANES oversampled individuals who were Hispanic, non-Hispanic black, or low-income white. Adults aged >60 y were oversampled in 2009–2010, and this was changed to >80 y in 2011–2012. Details describing the survey, including sampling design, oral health data collection protocols, and data availability, can be found online (22). All data collection protocols for NHANES 2009–2012 were approved by the CDC National Center for Health Statistics Research Ethics Review Board (equivalent to Institutional Review Boards), and all survey participants provided written, informed consent.

Periodontal disease variables. Trained dentists conducted the oral health examinations in mobile examination centers (MEC), and the survey's expert examiner periodically calibrated the examiners. Adults aged ≥30 y who had ≥1 natural tooth (excluding third molars) and did not have a health condition that required antibiotic prophylaxis before periodontal probing were eligible for a full-mouth periodontal examination. A Hu-Friedy PCP 2 periodontal probe with 2-4-6-8-10-12-mm graduations was used to assess periodontal health. Measurements were made at 6 sites around each tooth (mesio-, mid-, and distobuccal; mesio-, mid-, and distolingual) for all teeth, excluding third molars. Two measurements were made at each periodontal site: one for gingival recession, distance from the free gingival margin to the cemento-enamel junction, and the second for pocket depth (PD), distance from the free gingival margin to the bottom of the sulcus or periodontal pocket. Clinical attachment loss (AL) was calculated as PD minus gingival recession. Additional information describing oral health data collection and quality starting with the 2009–2010 cycle are described elsewhere (23).

TABLE 1 Sociodemographic, behavioral, and dietary characteristics of participants with a periodontal exam (n = 6052)[1]

Characteristics	n	Mean ± SD
Sex, %		
Men	2945	48.2 ± 0.8
Women	3107	51.8 ± 0.8
Age, %		
30–39 y	1414	25.3 ± 1.2
40–49 y	1404	25.2 ± 0.9
50–64 y	1935	33.2 ± 1.2
≥65 y	1299	16.3 ± 0.9
Race/ethnicity, %		
Non-Hispanic white	2720	69.5 ± 2.5
Non-Hispanic black	1272	10.7 ± 1.2
Hispanic	1491	13.3 ± 1.9
Other	569	6.5 ± 0.7
Education, %		
Less than high school	1435	15.2 ± 1.1
Graduated from high school	1281	21.2 ± 1.3
Some college	3326	63.7 ± 1.8
Smoking, %		
Never smoked	3390	56.3 ± 1.4
Former smoker	1570	26.7 ± 1.3
Current smoker	1090	17.0 ± 0.9
Poverty status, %		
<130% federal poverty guidelines	1577	18.0 ± 1.2
≥130% federal poverty guidelines	3990	82.0 ± 1.2
Dietary fiber, g/d		
1st quartile (≤11.9)	1732	8.7 ± 0.07
2nd quartile (>11.9–16.6)	1486	14.2 ± 0.06
3rd quartile (>16.6–23.3)	1458	19.7 ± 0.08
4th quartile (>23.3)	1376	31.2 ± 0.32
Whole grains, ounce equivalents[2]		
1st quartile (0)	1731	0
2nd quartile (>0–0.62)	1494	0.33 ± 0.006
3rd quartile (>0.62–1.48)	1459	1.01 ± 0.007
4th quartile (>1.48)	1368	2.70 ± 0.054
Fruits and vegetables, cup equivalents		
1st quartile (0–8.3)	1660	4.9 ± 0.07
2nd quartile (>8.3–14.0)	1514	11.1 ± 0.06
3rd quartile (>14.0–22.0)	1483	17.7 ± 0.08
4th quartile (>22.0)	1395	32.0 ± 0.46
Fruits and vegetables (without potatoes and starchy vegetables), cup equivalents		
1st quartile (0–4.5)	1649	2.1 ± 0.05
2nd quartile (>4.5–9.3)	1503	6.8 ± 0.04
3rd quartile (>9.3–16.8)	1489	12.6 ± 0.07
4th quartile (>16.8)	1411	26.3 ± 0.41
Dentition status, %		
1–10 teeth present	423	5.0 ± 0.5
11–19 teeth present	700	7.4 ± 0.4
20–28 teeth present	4919	87.6 ± 0.8
Periodontal disease, %		
None	2799	55.5 ± 1.7
Mild	399	6.4 ± 0.6
Moderate	2152	29.7 ± 1.4
Severe	702	8.5 ± 0.6

[1] Participants in NHANES, 2009–2012.
[2] 28.35 g = 1 ounce equivalent.

[6] Abbreviations used: AL, attachment loss; DASH, Dietary Approaches to Stop Hypertension; DGA, 2015–2020 Dietary Guidelines for Americans; MEC, mobile examination center; PD, pocket depth.

Periodontal disease was defined based on the suggested CDC/American Academy of Periodontology case definitions for surveillance of periodontitis (1, 24). Severe periodontitis was defined as having ≥2 interproximal sites with ≥6 mm of AL (not on the same tooth) and ≥1 interproximal site with ≥5 mm of PD. Moderate periodontitis was defined as ≥2 interproximal sites with ≥4 mm of clinical AL (not on the same tooth) or ≥2 interproximal sites with PD ≥5 mm, also not on the same tooth. Mild periodontitis was defined as ≥2 interproximal sites with ≥3 mm of AL and ≥2 interproximal sites with ≥4 mm of PD or 1 site with ≥5 mm (not on the same tooth).

Any periodontitis was the sum of severe, moderate, and mild periodontitis. For regression analyses using logistic models, severe and moderate periodontitis were compared with mild and none. When multinomial logistic modeling was performed, 3 categories were used: severe periodontitis, mild and moderate periodontitis, and none.

Dietary variables. During the MEC examination, participants completed a dietary interview with a trained registered dietitian, recording the type and amount of food and beverages they consumed in the past 24 h. A second 24-h recall was administered to participants over the phone 3–8 d after their MEC examination. In this study, food and nutrient calculations derived from both 24-h recalls were included. To ascertain the sources of dietary fiber consumed, information from the USDA Food Patterns Equivalents Database was used. The database disaggregates foods and beverages into their ingredients, including fruits, vegetables, and grains (25). The grain component consists of whole and refined grains. The fruit component consists of fruit juice, citrus, melon and berries, and other fruit. The vegetable component consists of red and orange vegetables, dark green vegetables, potatoes, other starch vegetables, and other vegetables.

Total fiber and fiber from whole grains and fruits and vegetables were the sources of dietary fiber we examined. Fiber consumption was defined as the mean total fiber intake derived from the 24-h dietary recalls. Whole grains consist of all grain-based products made from 100% whole grains or their flour. Fruit and vegetables consisted of all fruits (but not fruit juice) and red and orange vegetables, dark green vegetables, potatoes, and other starchy vegetables (but not other vegetables). An additional analysis of fruits and vegetables without potatoes and starchy vegetables was also examined, specifically all fruit (but not fruit juice) and red and orange vegetables and dark green vegetables. Three dietary variables were analyzed: quartiles of fiber consumption, quartiles of whole-grain consumption, and quartiles of fruit and vegetable consumption.

Covariates. A number of independent variables based on the literature were considered for inclusion to control for the potential effects of confounding. Variables including sex, age, race/ethnicity, education, smoking status, and income were obtained through interviews, and tooth count was assessed at the clinical examination. Age was categorized into four groups: 30–39 y, 40–49 y, 50–64 y, and ≥65. Race or Hispanic origin was based on self-report, and 3 categories were used (non-Hispanic white, non-Hispanic black, and Hispanic). The level of educational attainment was categorized as less than high school, graduated from high school, or some college. Smoking status was classified as never, former, or current smoker. Income was dichotomized into below (<130%) or equal to or above (≥130%) the Federal poverty guidelines. Dentate status was determined by classifying participants into 3 groups: having 1–10 teeth, 11–19 teeth, or 20–28 teeth. Because fasting blood glucose was determined from NHANES participants examined during morning sessions only, this information was not used as a covariate because of

TABLE 2 Association between dietary fiber and periodontal disease status in the US adult population, NHANES 2009–2012[1]

	Moderate-severe[3] vs. mild-none (logistic) modeling		None/mild-moderate/severe[4] (multinomial logistic) modeling	
Covariates[2]	Unadjusted	Fully adjusted[5]	Unadjusted	Fully adjusted[5]
Dietary fiber, quartile				
1st (lowest)	1.62 (1.30, 2.04)	1.30 (1.00, 1.69)	1.58 (1.26, 1.98)	1.27 (1.00, 1.62)
2nd	1.12 (0.87, 1.45)	0.99 (0.73, 1.33)	1.17 (0.91, 1.50)	1.05 (0.80, 1.38)
3rd	1.09 (0.88, 1.36)	1.00 (0.77, 1.29)	1.05 (0.83, 1.32)	0.98 (0.76, 1.26)
Sex				
Men	1.92 (1.67, 2.21)	2.32 (1.99,2.71)	2.09 (1.77, 2.47)	2.47 (2.12, 2.89)
Age, y				
40–49	1.98 (1.53, 2.57)	2.67 (1.97, 3.61)	1.84 (1.45, 2.32)	2.45 (1.94, 3.10)
50–64	3.53 (2.83, 4.40)	6.09 (4.63, 8.00)	2.82 (2.29, 3.47)	4.64 (3.71, 5.80)
≥65	6.61 (5.02, 8.72)	14.1 (9.63, 20.6)	4.44 (3.53, 5.57)	8.63 (6.42, 11.6)
Race/ethnicity				
Non-Hispanic black	1.94 (1.47, 2.57)	2.17 (1.48, 3.19)	2.22 (1.71, 2.88)	2.28 (1.68, 3.09)
Hispanic	1.78 (3.50, 5.34)	2.24 (1.67, 3.02)	2.06 (1.59, 2.66)	2.42 (1.83, 3.19)
Education				
Less than high school	3.71 (3.00, 4.60)	2.42 (1.77, 3.31)	3.65 (3.07, 4.34)	2.08 (1.62, 2.66)
Graduated from high school	2.21 (1.71, 2.85)	1.69 (1.31, 2.19)	2.32 (1.89, 2.84)	1.74 (1.45, 2.09)
Smoking status				
Former	1.83 (1.55, 2.16)	1.48 (1.20, 1.82)	1.66 (1.37, 2.01)	1.40 (1.14, 1.72)
Current	3.79 (3.19, 4.52)	4.53 (3.31, 6.21)	3.89 (3.38, 4.48)	3.98 (3.17, 4.99)
Poverty status				
<130% federal poverty guidelines	2.18 (1.78, 2.66)	1.41 (1.10, 1.82)	2.32 (1.95, 2.77)	1.45 (1.17, 1.81)
Tooth count, *n*				
1–10	4.71 (3.10, 7.15)	1.40 (0.83, 2.38)	3.41 (2.66, 4.36)	1.11 (0.78, 1.59)
11–19	4.59 (3.65, 5.77)	1.97 (1.46, 2.66)	4.33 (3.53, 5.32)	2.03 (1.64, 2.52)

[1] Values are ORs (95% CIs).
[2] Reference for covariates: 4th quartile for dietary fiber, women, age 30–39 y, non-Hispanic white, some college, nonsmoker, ≥130% federal poverty guidelines, having ≥20 teeth, and 4th quartile for fiber.
[3] Moderate-severe periodontal disease (reference level is mild/no periodontal disease).
[4] Mild-moderate periodontal disease and severe periodontal disease (reference level is no periodontal disease).
[5] Adjusted for all covariates.

the substantial reduction of the available sample size. Less than half of the sample had fasting plasma glucose information.

Statistical methods. All statistical analyses used SAS 9.3 (SAS Institute Inc.) and SUDAAN version 10 (RTI International). All analyses used the day 2 dietary sample weights to account for differential probabilities of selection, nonresponse, and noncoverage, as well as day of the week. Both day 1 and day 2 dietary data were examined; day 2 dietary sample weights were used because both days of data were analyzed. To examine the relation between the dietary intake variables and periodontal disease, SUDAAN was used to compute proportional ORs for the multinomial logistic models. This cumulative logistic function uses an ordinal categorical outcome variable of 2 or more categories to produce a proportional odds model. SUDAAN was also used to compute ORs for the standard logistic models. Both modeling techniques (logistic and multinomial logistic) adjusted for the major potential confounders per the literature including sex, age, race/ethnicity origin, educational level, income, smoking status, and dentate status. Nonautomated regression modeling was performed, and a few prespecified potential interactions were explored. Including self-reported diabetes in the model made no difference, so it was left out for simplicity. Statistical significance was assessed by using 95% CIs.

Results

In NHANES 2009–2012, 9402 individuals aged ≥30 y were examined. Of those, 7783 individuals had 2 d of dietary intake information. Of those 7783 individuals, 6052 participants had periodontal disease data. Approximately half were female and <50 y old (**Table 1**). The majority of the population was non-Hispanic white, graduated from college, never smoked, and had income ≥130% federal poverty guidelines. Nearly 45% had some form of periodontitis.

Dietary fiber. In the unadjusted logistic model, the lowest quartile of fiber consumption was associated with increased odds of having moderate-severe periodontitis compared with the highest fiber consumption quartile (**Table 2**). After adjusting for age, sex, race/ethnicity, education, income, and smoking, the lowest quartile (≤11.9 g fiber/d) was associated with moderate-severe periodontitis compared with those with dietary fiber intake in the highest quartile (>23.25 g fiber/d) (OR: 1.30; 95% CI: 1.00,1.69).

Multinomial logistic modeling also resulted in similar findings produced by standard logistic regression. In an unadjusted model, the lowest quartile of fiber consumption was associated with increased odds of having more severe periodontal disease compared with the highest fiber consumption quartile. In a model controlling for age, sex, race/ethnicity, education, income, and smoking status, the lowest quartile of fiber intake was associated with increasing severity of periodontitis compared with the highest quartile (OR: 1.27; 95% CI: 1.00,1.62).

Whole grains. Only the lowest quartile of whole-grain intake was associated with increased odds of having moderate-severe periodontitis compared with the highest quartile of whole-grain

TABLE 3 Association between whole grains and periodontal disease status in the US adult population, NHANES 2009–2012[1]

	Moderate-severe[3] vs. mild-none (logistic) modeling		None/mild-moderate/severe[4] (multinomial logistic) modeling	
Covariates[2]	Unadjusted	Fully adjusted[5]	Unadjusted	Fully adjusted[5]
Whole grains, quartile				
1st (lowest)	1.39 (1.10, 1.75)	1.14 (0.89, 1.45)	1.63 (1.31, 2.03)	1.32 (1.08, 1.62)
2nd	1.06 (0.82, 1.37)	1.01 (0.73, 1.39)	1.13 (0.90, 1.41)	1.06 (0.81, 1.38)
3rd	0.88 (0.73, 1.07)	0.87 (0.71, 1.07)	0.93 (0.78, 1.10)	0.95 (0.81, 1.12)
Sex				
Men	1.92 (1.67, 2.21)	2.23 (1.91, 2.60)	2.09 (1.77, 2.47)	2.38 (2.02, 2.79)
Age, y				
40–49	1.98 (1.53, 2.57)	2.68 (1.99, 3.61)	1.84 (1.45, 2.32)	2.48 (1.95, 3.14)
50–64	3.53 (2.83, 4.40)	6.06 (4.66, 7.89)	2.82 (2.29, 3.47)	4.67 (3.76, 5.80)
≥65	6.61 (5.02, 8.72)	14.3 (9.81, 20.7)	4.44 (3.53, 5.57)	8.90 (6.62, 12.0)
Race/ethnicity				
Non-Hispanic black	1.94 (1.47, 2.57)	2.22 (1.51, 3.26)	2.22 (1.71, 2.88)	2.30 (1.70, 3.13)
Hispanic	1.78 (1.34, 2.35)	2.19 (1.63, 2.93)	2.06 (1.59, 2.66)	2.34 (1.77. 3.08)
Education				
Less than high school	3.71 (3.00, 4.60)	2.40 (1.73, 3.34)	3.65 (3.07, 4.34)	2.05 (1.58, 2.65)
Graduated from high school	2.21 (1.71, 2.85)	1.71 (1.31, 2.24)	2.32 (1.89, 2.84)	1.75 (1.46, 2.11)
Smoking status				
Former	1.83 (1.55, 2.16)	1.48 (1.21, 1.82)	1.66 (1.37, 2.07)	1.39 (1.14, 1.71)
Current	3.79 (3.19, 4.52)	4.54 (3.35, 6.17)	3.89 (3.38, 4.48)	3.95 (3.18, 4.90)
Poverty status				
<130% federal poverty guidelines	2.18 (1.78, 2.66)	1.43 (1.11, 1.85)	2.32 (1.95, 2.77)	1.45 (1.17, 1.80)
Tooth count, *n*				
1–10	4.71 (3.10, 7.15)	1.43 (0.85, 2.41)	3.41 (2.66, 4.36)	1.13 (0.79, 1.63)
11–19	4.59 (3.65, 5.77)	2.02 (1.50, 2.73)	4.33 (3.53, 5.32)	2.08 (1.68, 2.58)

[1] Values are ORs (95% CIs).
[2] Reference for covariates: 4th quartile for whole grains, women, age 30–39 y, non-Hispanic white, some college, nonsmoker, ≥130% federal poverty guidelines, and having ≥20 teeth.
[3] Moderate-severe periodontal disease (reference level is mild-no periodontal disease).
[4] Mild-moderate periodontal disease and severe periodontal disease (reference level is no periodontal disease).
[5] Adjusted for all covariates.

intake in an unadjusted logit model (**Table 3**). After adjusting for age, sex, race/ethnicity, education, income, and smoking, whole-grain intake was not associated with moderate-severe periodontitis in a logistic regression model.

However, multinomial logistic modeling produced some different results. In an unadjusted model, the lowest quartile of whole-grain intake was associated with increasing severity of periodontitis compared with the highest quartile of whole-grain intake. In a model controlling for age, sex, race/ethnicity, education, income, and smoking, the lowest quartile remained statistically significant with an increasing likelihood of having periodontal disease. Adults consuming whole grains in the lowest quartile (0 ounce equivalents) were more likely to have more severe periodontal disease than adults consuming whole grains in the highest quartile (OR: 1.32; 95% CI :1.08,1.62).

Fruits and vegetables. In both the unadjusted logistic model and the fully adjusted logistic model, fruit and vegetable intake was not significantly associated with an increase in moderate-severe periodontitis (**Table 4**). In the multinomial logistic regression model, individuals consuming the lowest quartile range of fruit and vegetables (≤8.3 cup equivalents) were more likely to have increasing periodontal disease. However, after controlling for all of the other covariates, fruit and vegetable intake was not associated with periodontitis severity in a fully adjusted multinomial logistic model.

Additional analyses of fruit and vegetable intake without potatoes and starchy vegetables yielded differing results in the unadjusted models but similar results in the fully adjusted models. (**Table 5**). In the unadjusted logistic model individuals consuming the lowest quartile of fruit and vegetables(≤4.5 cup equivalents) were more likely to have an increase in moderate-severe periodontal disease. However, in the fully adjusted model fruit and vegetable intake was not significantly associated with an increase in moderate-severe periodontitis. In the multinomial logistic regression model, individuals consuming the lowest quartile of fruit and vegetables were more likely to have increasing periodontal disease. However, after controlling for all of the other covariates, fruit and vegetable intake was not associated with periodontitis severity in a fully adjusted multinomial logistic model.

Discussion

We examined the association between dietary fiber, whole-grain, and fruit and vegetable consumption with periodontal disease. In a model adjusting for important potential confounders, individuals consuming fiber in the range of 0–11.9 g were 27% more likely to have increasing severity of periodontitis (OR: 1.27; 95% CI: 1.00,1.62). When we examined the 2 main dietary sources of fiber, low whole-grain consumption was associated with periodontal disease, but fruit and vegetable consumption was not associated with periodontal disease. In an adjusted model examining

TABLE 4 Association between fruit and vegetables and periodontal disease status in the US adult population, NHANES 2009–2012[1]

	Moderate-severe[3] vs. mild-none (logistic) modeling		None/mild-moderate/severe[4] (multinomial logistic) modeling	
Covariates[2]	Unadjusted	Fully adjusted[5]	Unadjusted	Fully adjusted[5]
Fruit and vegetables, quartile				
1st (lowest)	1.28 (0.96, 1.71)	1.11 (0.80, 1.54)	1.31 (1.01, 1.71)	1.11 (0.85, 1.44)
2nd	0.93 (0.70, 1.19)	0.88 (0.66, 1.19)	0.98 (0.76, 1.27)	0.99 (0.76, 1.28)
3rd	1.10 (0.84, 1.45)	1.06 (0.78, 1.44)	1.06 (0.85, 1.33)	1.02 (0.81, 1.29)
Sex				
Men	1.92 (1.67, 2.21)	2.26 (1.93, 2.64)	2.09 (1.77, 2.47)	2.41 (2.04, 2.83)
Age, y				
40–49	1.98 (1.53, 2.57)	2.66 (1.97, 3.58)	1.84 (1.45, 2.32)	2.46 (1.95, 3.11)
50–64	3.53 (2.83, 4.40)	5.95 (4.61, 7.69)	2.82 (2.29, 3.47)	4.60 (3.69, 5.72)
≥65	6.61 (5.02, 8.72)	14.0 (9.68, 20.2)	4.44 (3.53, 5.57)	8.64 (6.44, 11.6)
Race/ethnicity				
Non-Hispanic black	1.94 (1.47, 2.57)	2.24 (1.51, 3.33)	2.22 (1.71, 2.88)	2.33 (1.70, 3.20)
Hispanic	1.78 (1.34, 2.35)	2.21 (1.65, 2.98)	2.06 (1.59, 2.66)	2.38 (1.81, 3.13)
Education				
Less than high school	3.71 (3.00, 4.60)	2.45 (1.79, 3.36)	3.65 (3.07, 4.34)	2.11 (1.65, 2.69)
Graduated from high school	2.21 (1.71, 2.85)	1.73 (1.33, 2.27)	2.32 (1.89, 2.84)	1.77 (1.46, 2.15)
Smoking status				
Former	1.83 (1.55, 2.16)	1.48 (1.20, 1.83)	1.66 (1.37, 2.01)	1.39 (1.13, 1.72)
Current	3.79 (3.19, 4.52)	4.60 (3.36, 6.30)	3.89 (3.38, 4.48)	4.03 (3.22, 5.05)
Poverty status				
<130% federal poverty guidelines	2.18 (1.78, 2.66)	1.44 (1.11, 1.87)	2.32 (1.95, 2.77)	1.47 (1.17, 1.84)
Tooth count, *n*				
1–10	4.71 (3.10, 7.15)	1.44 (0.86, 2.41)	3.41 (2.66, 4.36)	1.13 (0.79, 1.61)
11–19	4.59 (3.65, 5.77)	1.99 (1.48, 2.67)	4.33 (3.53, 5.32)	2.06 (1.66, 2.54)

[1] Values are ORs (95% CIs).
[2] Reference for covariates: 4th quartile for fruits and vegetables, women, age 30–39 y, non-Hispanic white, some college, nonsmoker, ≥130% federal poverty guidelines, and having ≥20 teeth.
[3] Moderate-severe periodontal disease (reference level is mild-no periodontal disease).
[4] Mild-moderate periodontal disease and severe periodontal disease (reference level is no periodontal disease).
[5] Adjusted for all covariates.

TABLE 5 Association between fruit and vegetables (excluding potatoes and starchy vegetables) and periodontal disease status in the US adult population, NHANES 2009–2012[1]

	Moderate-severe[3] vs. mild-none (logistic) modeling		None/mild-moderate/severe[4] (multinomial logistic) modeling	
Covariates[2]	Unadjusted	Fully adjusted[5]	Unadjusted	Fully adjusted[5]
Fruit and vegetables,[6] quartile				
1st (lowest)	1.52 (1.15, 2.00)	1.22 (0.90, 1.66)	1.60 (1.25, 2.06)	1.23 (0.95, 1.60)
2nd	1.25 (0.96, 1.61)	1.14 (0.87, 1.50)	1.31 (1.04, 1.65)	1.20 (0.94, 1.53)
3rd	1.27 (0.96, 1.67)	1.13 (0.81, 1.58)	1.27 (0.99, 1.61)	1.16 (0.88, 1.52)
Sex				
Men	1.92 (1.67, 2.21)	2.27 (1.94, 2.65)	2.09 (1.77, 2.47)	2.42 (2.07, 2.83)
Age, y				
40–49	1.98 (1.53, 2.57)	2.67 (1.98, 3.60)	1.84 (1.45, 2.32)	2.47 (1.95, 3.12)
50–64	3.53 (2.83, 4.40)	6.06 (4.72, 7.78)	2.82 (2.29, 3.47)	4.66 (3.76, 5.77)
≥65	6.61 (5.02, 8.72)	14.1 (9.86, 20.3)	4.44 (3.53, 5.57)	8.72 (6.51, 11.7)
Race/ethnicity				
Non-Hispanic black	1.94 (1.47, 2.57)	2.22 (1.50, 3.29)	2.22 (1.71, 2.88)	2.32 (1.69, 3.18)
Hispanic	1.78 (1.34, 2.35)	2.22 (1.66, 2.96)	2.06 (1.59, 2.66)	2.39 (1.82, 3.14)
Education				
Less than high school	3.71 (3.00, 4.60)	2.41 (1.76, 3.29)	3.65 (3.07, 4.34)	2.07 (1.63, 2.64)
Graduated from high school	2.21 (1.71, 2.85)	1.69 (1.29, 2.20)	2.32 (1.89, 2.84)	1.74 (1.44, 2.10)
Smoking status				
Former	1.83 (1.55, 2.16)	1.48 (1.20, 1.83)	1.66 (1.37, 2.01)	1.39 (1.14, 1.71)
Current	3.79 (3.19, 4.52)	4.54 (3.31, 6.21)	3.89 (3.38, 4.48)	3.97 (3.17, 4.98)
Poverty status				
<130% federal poverty guidelines	2.18 (1.78, 2.66)	1.44 (1.10, 1.87)	2.32 (1.95, 2.77)	1.47 (1.16, 1.85)
Tooth count, *n*				
1–10	4.71 (3.10, 7.15)	1.43 (0.85, 2.41)	3.41 (2.66, 4.36)	1.12 (0.78, 1.61)
11–19	4.59 (3.65, 5.77)	2.00 (1.48, 2.70)	4.33 (3.53, 5.32)	2.06 (1.67, 2.54)

[1] Values are ORs (95% CIs).
[2] Reference for covariates: 4th quartile for fruits and vegetables, women, age 30–39 y, non-Hispanic white, some college, nonsmoker, ≥130% federal poverty guidelines, and having ≥20 teeth.
[3] Moderate-severe periodontal disease (reference level is mild-no periodontal disease).
[4] Mild-moderate periodontal disease and severe periodontal disease (reference level is no periodontal disease).
[5] Adjusted for all covariates.
[6] Fruit and vegetables do not include potatoes or starchy vegetables.

the association of whole grain consumption with increasing periodontal disease severity, individuals consuming low amounts of whole grain were 32% more likely to have increasing severity of periodontitis (OR: 1.32; 95% CI: 1.08,1.62).

Our findings confirmed a previous study by Merchant and colleagues (16) that found higher levels of whole-grain consumption were inversely associated with periodontal disease. Schwartz et al. (17) also found that higher levels of fiber intake were inversely associated with periodontal disease. They also reported that fruit consumption was inversely associated with periodontal disease, which was not confirmed in our analyses. Kondo et al. (18) also showed that intervention with a high-fiber and low-fat diet improved periodontal disease markers but without distinguishing between the different sources of fiber. However, it seems that their dietary intervention consisted of increasing whole-grain and vegetable intake but not fruit, and it remains unclear which dietary component contributed to improvement in periodontal disease markers. Nevertheless, our study supports the general findings the intervention by Kondo et al. (18) on total dietary fiber and whole grains. In contrast, our current analysis did not find an inverse association between fruit and vegetable consumption and periodontal disease. Interestingly, Dodington et al. (19) found an association between dietary intake of fruits and vegetables, β-carotene, vitamin C, α-tocopherol, EPA, and DHA and reduced periodontal disease among nonsmokers following scaling and root planning but not among smokers.

The DGA state that a healthy eating pattern includes eating a variety of vegetables (such as dark green, red and orange, legumes, starchy and other), fruits (especially whole fruits), and grains, with at least half derived from whole grains (20). The DGA state that higher intake of fruits and vegetables has been consistently identified as part of a healthy eating pattern, whereas whole grains have been slightly less consistently identified as part of a healthy eating pattern (20). Nevertheless, Americans are encouraged to consume more fruits and vegetables and whole grains, especially enriched whole grains, to reflect evidence that suggests that whole-grain consumption may reduce the risk of cardiovascular disease (20). In the current analyses, consumption of fruits and vegetables is much higher than whole-grain intake. The inverse relation between dietary fiber and periodontal disease might be stronger if Americans were consuming greater amounts of whole grains.

Similarly, the AHA encourages healthy eating to help manage blood pressure. Healthy eating includes following the DASH diet, which encourages consumption of foods higher in fiber, including fruits, vegetables, and whole grains (26). In addition, in comparison with the DGA recommendations for a 2000-kcal diet, the AHA DASH diet is plant-based and recommends higher amounts of fruit (4–5 servings compared with 2 cup equivalents), vegetables (4–5 servings compared with 2.5 cup equivalents), and slightly higher recommendations for grains and

grain products (7–8 servings compared with 6 ounce equivalents) (20, 26). Both the DASH diet and the DGA encourage choosing whole grains over refined grains (20, 26).

This study has a number of strengths. We examined total dietary fiber consumption and periodontal disease using 4 y of contemporary data from a nationally representative sample of adults in the United States. This sample was not selected based on periodontal disease, fiber consumption, or any other pre-existing condition. Data on periodontal status were collected by using the gold-standard periodontal examination, which includes assessments at 6 dental sites around each natural tooth present. Dietary intake was assessed from two 24-h recalls, which is an improvement over just 1 d of recall conducted in previous NHANES examinations. We were also able to better elucidate the source of dietary fiber, including fruits and vegetables and whole grains. However, a limitation of the study is that a distinction between soluble and insoluble fiber was not possible. Another limitation of this study is the inability to assess for a temporal relation between fiber consumption and a diagnosis of periodontal disease. Nevertheless, overall the NHANES sample size and study design provides a very good opportunity to cross-sectionally examine the relation between fiber consumption and periodontal disease in the United States.

We found a relation between periodontal disease and dietary fiber intake among adults aged ≥30 y in the United States. Although an association between low fiber consumption and periodontal disease was observed, this relation was predominately a result of the low whole-grain consumption in the sample rather than from low fruit and vegetable consumption. These findings are important because periodontal disease, which is a chronic inflammatory disease, has been found to be associated with vascular diseases and hypertension. The AHA recommends increasing consumption of whole grains to benefit vascular health and help improve blood pressure. Enhancing our understanding of the relation between dietary fiber intake and periodontitis and the relation with the inflammatory process (including C-reactive protein and IL-6 levels) could contribute to future dietary recommendations, thus impacting public health.

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KJ and BAD designed the research; SJN and BAD conducted the research and provided essential materials; SJN, MAT-F, KJ, and BAD analyzed the data or performed the statistical analysis, and wrote the manuscript; and SJN had primary responsibility for the final content. All authors read and approved the final manuscript.

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