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# The association between a dietary inflammatory index and periodontal disease in the national health and nutrition examination survey 2009-2014

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BOSTON UNIVERSITY  
SCHOOL OF MEDICINE

Thesis

**THE ASSOCIATION BETWEEN A DIETARY INFLAMMATORY  
INDEX AND PERIODONTAL DISEASE IN THE NATIONAL HEALTH  
AND NUTRITION EXAMINATION SURVEY 2009–2014**

by

**MILENA PETKOVA**

B.A., Clark University, 2013

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Approved by

First Reader

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Lynn L. Moore, D.Sc., M.P.H.  
Associate Professor of Medicine

Second Reader

---

Raul Garcia, D.M.D., M.Med.Sc.  
Professor of Health Policy & Health Services Research  
Boston University Henry M. Goldman School of Dental Medicine

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**MILENA PETKOVA**

**ABSTRACT**

**Background:** The effects of pro-inflammatory diets, as measured by the Dietary Inflammatory Index (DII), on periodontal disease among Americans have not been evaluated.

**Objectives:** This study examines whether the DII is associated with periodontitis in U.S. adults participating in the National Health and Nutrition Examination Surveys (NHANES) 2009-2014. In particular, it evaluates whether an anti-inflammatory dietary pattern is associated with lower prevalence of periodontitis in NHANES and lower severity of periodontitis.

**Methods:** Dietary Inflammatory Index score was derived from taking the mean of two 24-hour dietary recall interviews. The sample population included 7,480 subjects (3,628 men and 3,852 women), who were 30-80 years old from all racial/ethnic groups. The exclusion criteria were incomplete or missing data regarding clinical periodontal and dental examinations. In addition, participants were also excluded who had diabetes, cancer, pregnancy or breastfeeding status, unreliable dietary information, or elevated alcohol intake. The DII score was classified as Low DII/anti-inflammatory (DII: -

5.16 $\leq$ DII $\leq$ 0.54) and High DII/pro-inflammatory (DII: 0.54<DII $\leq$ 4.82).

Outcome was measured using case definitions of periodontitis and classified as mild, moderate, severe, and total periodontitis. The prevalence for each was calculated in the overall sample population and sex-specific subgroups. Logistic regression models were used to calculate crude ORs (and 95% CI) for the presence of total periodontitis. Multivariate regression analysis was used to adjust for age, sex, alcohol consumption, and smoking. Chi-square test was used to calculate the ORs for mild, moderate, and severe periodontitis.

**Results:** The prevalence of total periodontitis among subjects with Low DII is 42% and the prevalence of total periodontitis among subjects with High DII is 47.5%. The prevalence of total periodontitis among men with Low DII is 49.8%, while the prevalence of total periodontitis among men with High DII is 57.7%. The prevalence is 32.1% and 41.4% for women with Low DII and High DII, respectively. Based on adjusted logistic regression models, consuming a diet that scores High DII results in 35% increased risk of total periodontitis; for men the risk is 25% and for women 44%. Based on the subtype analysis, consuming a diet that scores High DII results in a statistically significant 21% increased risk of moderated periodontitis and 48% increased risk of severe periodontitis.

**Conclusions:** Pro-inflammatory diet (High DII) is associated with higher prevalence of moderate, severe, and total periodontitis in both men and women. The prevalence of mild

periodontitis is higher among women adhering to High DII, but not among men. The overall cohort has increased odds of having moderate, severe, and total periodontitis when consuming pro-inflammatory foods and nutrients, with women being at greater risk for total periodontitis. Subjects whose diet was pro-inflammatory had statistically-significant increased risk of having moderate or severe periodontitis, but not mild.

**Keywords:** Dietary Inflammatory Index, periodontitis, periodontal disease, epidemiology, National Health and Nutrition Examination Surveys, mild periodontitis, moderate periodontitis, severe periodontitis, pro-inflammatory diet, anti-inflammatory diet

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## LIST OF ABBREVIATIONS

BMI	Body Mass Index
CAL	Clinical Attachment Loss
CDC	Centers for Disease Control and Prevention
CEJ	Cemento-Enamel Junction
CVD	Cardio Vascular Disease
DDS	Doctor of Dental Surgery
DII	Dietary Inflammatory Index
DMD	Doctor of Dental Medicine
DOH	Division of Oral Health
FGM	Free Gingival Margin
GPAQ	Global Physical Activity Questionnaire
hBD-2	Human Beta-Defensin-2
HEI	Healthy Eating Index
hsCRP	High Sensitivity C-reactive Protein
IL	Interleukin
INF- $\beta$	Interferon-Beta
INF- $\gamma$	Interferon-Gamma
MEC	Mobile Examination Center
MUFA	Monounsaturated Fatty Acid
NCD	Non-Communicable Diseases

NCHS	National Center of Health Statistics
NDS	Nutrition Data System
NIDCR	National Institute of Dental and Craniofacial Research
OR	Odds Ratio
PPD	Probing Pocket Depth
PUFA	Polyunsaturated Fatty Acid
se	Standard Error
TNF- $\alpha$	Tumor-necrosis Factor- $\alpha$
USDA	United States Department of Agriculture
US NHANES	United States National Health and Nutrition Examination Survey

## **INTRODUCTION**

Chronic periodontitis is a multifactorial inflammatory disease that originates from a dysbiotic oral microbiota and results in the destruction of the structure surrounding the teeth and ultimately tooth loss<sup>1</sup>. Periodontal diseases encompass plaque-induced gingivitis and periodontitis, which although largely preventable, are a great public health concern globally<sup>2</sup>. It is estimated that up to 50% of the worldwide population is affected by periodontitis<sup>1</sup>. In the United States National Health and Nutrition Examination Surveys (US NHANES) of 2009 to 2014, it has been estimated that 42.2% of dentate adults aged 30 years and older suffer from some category of periodontitis. Specifically, 7.8% had severe periodontitis and 34.4% had non-severe periodontitis (i.e., moderate and mild periodontitis combined)<sup>3</sup>.

### **Periodontal Disease and Inflammation**

The immune and inflammatory responses are central to the pathogenesis of periodontitis being formed by both intrinsic and induced host-related factors<sup>4</sup>. The initial presence of a bacterial infection leads to the release of both bacterial products and inflammatory mediators into the bloodstream triggering a local inflammatory reaction known as gingivitis, which in turn activates the innate immune system<sup>2,4</sup>. Amplification of this early localized response results in the release of various cytokines and mediators that drive propagation of the inflammatory state through the gingival tissue. The inflammatory process then leads to the destruction of connective tissue and alveolar bone

which are the characteristic manifestations of periodontal disease<sup>4</sup>. Periodontitis is predominantly associated with gram-negative infectious organisms; however, the destruction of periodontal tissue is mediated by the host response. Even though there are different clinical manifestations of periodontitis, including early onset, adult onset, and necrotizing forms, the diagnosis of periodontitis is defined by the severity of the disease and rate of progression, rather than its pathogenesis<sup>5</sup>.

In animal models, experimentally induced arthritis leads to adverse effects on the periodontium, showing that systemic inflammation intensifies periodontal inflammation and destruction<sup>6</sup>. At the same time, a number of studies have shown that biomarkers of inflammation are elevated in subjects suffering from periodontitis compared to healthy ones<sup>7-9</sup>.

### **Periodontal Bone Loss**

Loss of the tooth-supporting alveolar bone is a hallmark of periodontal disease and is the result of at least two major factors. First, a sufficient concentration of inflammatory mediators is needed in the gingival tissue to activate pathways leading to bone resorption. Second, those mediators need to transmit through the gingival tissue and extend within a critical distance of the alveolar bone<sup>3</sup>. The concentration of inflammatory mediators that lead to bone resorption depends on the expression of pro-inflammatory cytokines and kinins, such as interleukin (IL)-1, -6, -11, and -17, tumor-necrosis factor- $\alpha$  (TNF-  $\alpha$ ), leukemia inhibitory factor, oncostatin M, bradykinin, kallidin, and thrombin<sup>10</sup>.

In contrast, anti-inflammatory cytokines and other mediators, such as IL-4, -10, -12, -13, -18, interferon-beta (INF- $\beta$ ) and  $\gamma$  (INF- $\gamma$ ) serve to inhibit bone resorption<sup>10</sup>.

### **Systemic Inflammation and Chronic Disease**

It is now known that periodontal diseases contribute to systemic inflammation and have been associated with other non-communicable diseases (NCD) such as diabetes, chronic respiratory disease, cardiovascular disease, and cancer<sup>2,11</sup>. These chronic disease are leading causes of death in the 21<sup>st</sup> century and are an enormous burden to Westernized society contributing to increasing medical costs and human suffering<sup>12</sup>. Presently, there is overwhelming evidence showing that physical activity and diet consumption can be effective interventions, for what Booth and colleagues have named “the war on chronic disease”<sup>12,13</sup>.

### **Diet and Inflammation**

Diet can modulate inflammation, which has been shown by the response of markers of inflammation to dietary change. Such markers are TNF- $\alpha$ , high sensitivity C-reactive protein (hsCRP), and cell adhesion molecules<sup>14</sup>. For example the Western dietary pattern, which is high in red meat, high-fat dairy products and refined grains, has been associated with higher levels of hsCRP, interleukin-6 and fibrinogen<sup>15-17</sup>. Different nutrients can play different roles in altering periodontal status. Specialized pro-resolving lipid mediators, metabolites of n-3 and n-6 polyunsaturated fatty acids (PUFAs), have been shown to significantly inhibit the inflammation associated with chronic diseases<sup>18</sup>.

These pro-resolving lipid mediators include lipoxins, resolvins, protectins, and maresins. They prevent tissue damage in the inflammatory state by activating wound healing with tissue regeneration instead of fibrosis and scarring, and directly improve bone healing and regeneration in periodontitis<sup>19</sup>.

There are multiple studies in different racial groups showing that Vitamin A deficiency is associated with higher severity of periodontal disease<sup>20</sup>. Also, lycopene, which is a red pigment carotenoid, found in fruits and vegetables has the potential to improve periodontal health when used locally or systemically<sup>20</sup>. In another study, a vitamin B cocktail containing vitamin B 12, folate, thiamine HCl, riboflavin, niacinamide, d-calcium pantothenate, pyridoxine HCl, and D-biotin, was shown to improve clinical attachment level in patients with chronic periodontitis who had undergone a periodontal surgery, compared with a placebo<sup>21</sup>. Another nutrient that has been well recognized historically for its beneficial role in oral health is Vitamin C (ascorbic acid). The connection between consumption of vitamin C-rich fruits and vegetables and periodontal pathology has been described since the 18<sup>th</sup> century. During those times, sailors were found to suffer from scurvy, a vitamin C deficiency with main symptoms including gingival bleeding and tooth mobility. The literature contains many other studies showing evidence that particular nutrients, such as vitamin D, vitamin E, coenzyme Q10, and others can interact with periodontal disease<sup>20</sup>.

## **Dietary Inflammatory Index**

The Dietary Inflammatory Index (DII®) is a literature-derived, population-based index that was developed as a standardized scoring system to assess the inflammatory potential of a diet. It is constructed using 45 food and nutrient-related parameters and whether they increase, decrease, or have no effect on six inflammatory biomarkers: IL-1 $\beta$ , IL-4, IL-6, IL-10, TNF- $\alpha$ , and C-reactive protein. A few examples of the DII components are carbohydrates, folic acid, protein, fiber, niacin, n-3 and n-6 fatty acids, alcohol, cholesterol, caffeine, and vitamins A, C, D, and E<sup>22</sup>. Over the past 4 years, the DII has been used in more than 200 studies and 12 meta-analyses to examine the role of diet in relation to health outcomes varying from blood concentrations of inflammatory biomarkers to chronic diseases<sup>23</sup>. Higher scores on the DII have been shown to be pro-inflammatory. Multiple studies have shown significant positive associations between DII and inflammatory markers such as IL-6 and homocysteine, and the DII was predictive of risk of having elevated hs-CRP levels<sup>15-17</sup>. In addition, a pro-inflammatory diet has been linked with an increased risk of all-cause, CVD, all-cancer, and digestive-tract cancer mortality among pre-diabetic subjects, as well as increased all-cause and CVD mortality in metabolically unhealthy overweight/obese individuals<sup>24,25</sup>.

## **Purpose and aims of the study**

The United States (US) Department of Health and Human Services has identified oral health as one of 42 important health topic areas in Healthy People 2020<sup>26</sup>. One of the oral health objectives is to “reduce the proportion of adults aged 45-74 years with

moderate or severe periodontitis”<sup>27</sup>. Applying updated periodontitis case definitions by the Centers for Disease Control and Prevention (CDC) and the American Academy of Periodontology, the current goal is a reduction in periodontal diseases from 47.5% to 40.8%<sup>3</sup>. To improve and monitor the progress toward this goal, there is need for ongoing national disease surveillance that includes monitoring periodontal prevalence, oral health promoting activities, and novel approaches. Currently, the federally funded NHANES are the only sources of data for assessing periodontal disease on a nationally representative level<sup>3</sup>.

Periodontal diseases are largely preventable, but they are widespread and their development has a negative impact on overall health and quality of life. While there is evidence about the effects of individual nutrients with respect to oral health, their synergistic effects will be better understood through studies on the effects of dietary patterns on periodontal diseases. Improvements in diet to reduce inflammation may be simple, but effective methods for reducing the global burden of periodontal disease. Despite the increasing awareness of the applications of the DII in clinical studies, to our knowledge, there is no prior study examining the association between DII and periodontal disease.

The aims of this study are to evaluate whether the DII is associated with periodontal disease in NHANES 2009-2014. We hypothesized that an anti-inflammatory

dietary pattern in NHANES will be associated with a) lower prevalence of periodontitis and b) lower severity of periodontitis.

## METHODS

### Study Sample

The study will use data from the cross-sectional survey NHANES 2009-2014. NHANES is a stratified multistage probability sample of a civilian non-institutionalized population in the 50 states of the US and the District of Columbia<sup>28</sup>. It is a program administered by the National Center for Health Statistics (NCHS), which is a part of the CDC<sup>29</sup>. NHANES combines interviews and physical examinations and enrolls approximately 5,000 individuals every year<sup>30</sup>. Prior to 2004, NHANES used partial-mouth periodontal examination protocols to evaluate oral health. This approach was found to underestimate periodontal disease in the population<sup>3</sup>. As a result, periodontal examinations were eliminated following the 2003-2004 exam cycle. With input from the CDC and the American Academy of Periodontology Periodontal Disease Surveillance Project, NHANES reinstated periodontal examinations in 2009, implementing full-mouth periodontal examination protocols<sup>3</sup>.

The current analyses include participants from 2009 to 2014. A total of 30,468 subjects had completed demographics for the chosen cycles. Of those, 14,071 had periodontal examinations among adults ages 30-80 years with one or more natural teeth and no health condition requiring antibiotic prophylaxis before periodontal probing. All racial/ethnic groups were included. Participants were excluded due to incomplete or missing data regarding periodontal or dental exam, diabetes, cancer, pregnant or breastfeeding status, unreliable dietary information, or elevated alcohol intake.

Individuals were considered to have elevated alcohol consumption when they reported 84 or more grams of alcohol or the equivalent to 6 or more standard drinks<sup>31</sup>. The final cohort that was analyzed had 7,480 subjects.

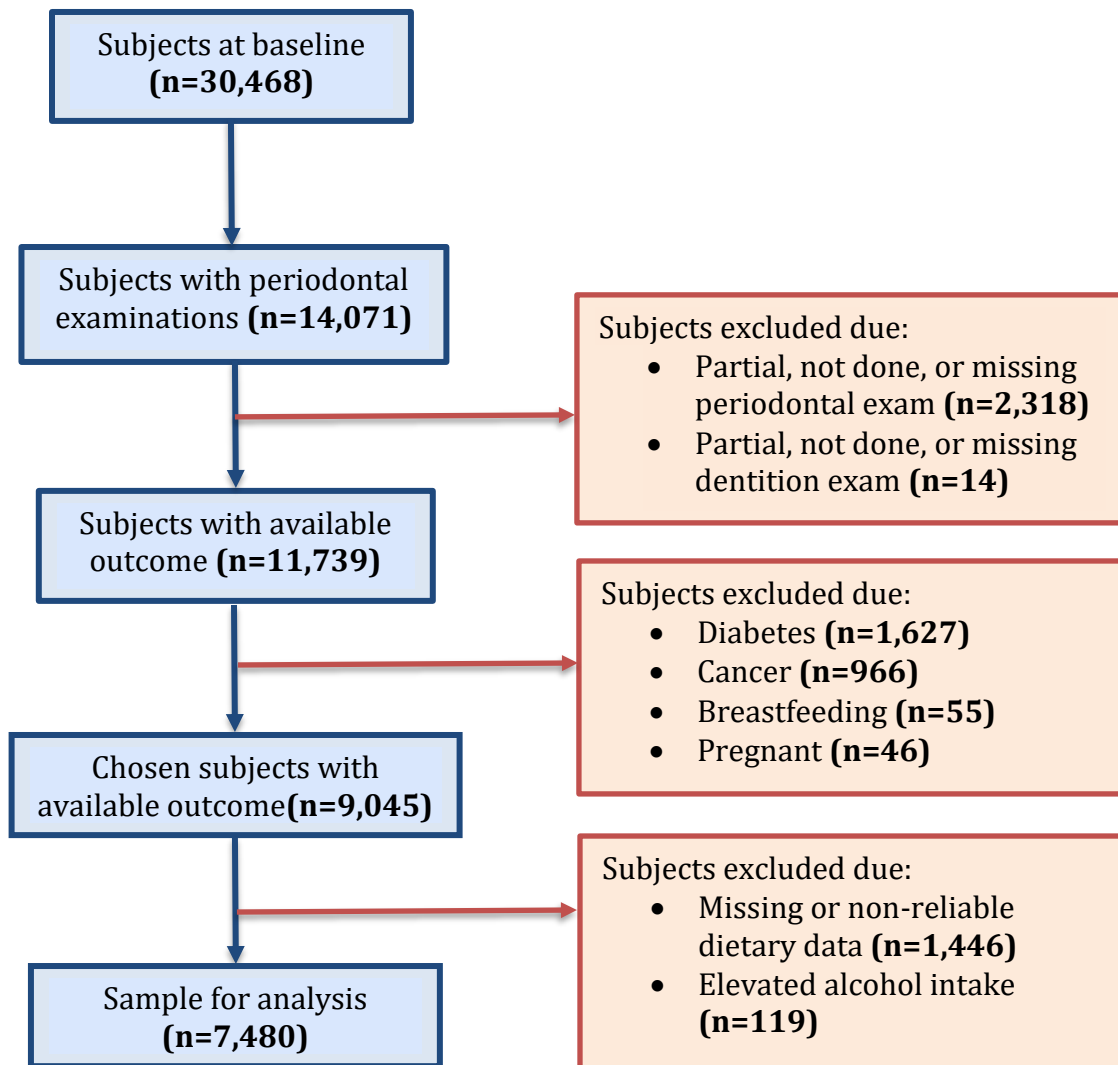


Figure 1. Diagram of the study sample

## **Assessment of the Dietary Inflammatory Index (DII)**

NHANES includes an interview-based three-part dietary assessment including the following: 24-hour dietary recall, supplement and antacid assessment, and a Post-Recall section. Here, we will include dietary data from the two 24-hour recalls, collected on two different days. The 24-hour recalls have been analyzed by the USDA for food and nutrient consumption using the Nutrition Data System (NDS) of the University of Minnesota<sup>32</sup>. The dietary recall asks subjects to report the types and amounts of foods and beverages consumed during the 24 hours prior to the interview, and it is used to estimate intakes of energy, nutrients, and other food components from those foods and beverages. All participants are eligible for two interviews, one of which is collected in-person in the NHANES Mobile Examination Center (MEC) and the second interview is done over the phone 3-10 days after the first interview. Two types of data files are derived from the interviews – individual food files and total nutrient intakes file<sup>33</sup>.

In this study, total nutrient intake is derived from the mean values of interview day 1 and interview day 2 for all subjects. The individuals' dietary inflammatory potential is calculated using a standard DII. The development of DII is described elsewhere<sup>22</sup> and summarized below. There are 45 food parameters that contribute to the calculation of DII, shown on Table 1. For the development of the index, a total of approximately 6500 articles were screened to assess whether each dietary parameter increases, decreases, or has no effect on six inflammatory biomarkers: IL-1 $\beta$ , IL-4, IL-6, IL-10, TNF- $\alpha$ , and C-reactive protein.

Using that information, ‘overall inflammatory effect score’ was calculated for each parameter<sup>22</sup>. In addition, eleven food consumption data sets from countries around the world were identified in order to create a standard global mean and standard deviation allowing to express individuals’ intake relative to the 45 food parameters observed across diverse populations<sup>22</sup>. The present study used 27 out of the 45 parameters that were available from the NDS analyses. After each person’s mean intake for each parameter was calculated from the two interviews, intake was converted to a Z-score to express an individual’s exposure relative to the standard global mean. This was done by subtracting the standard mean from the reported amount and dividing by its standard deviation. The global means and standard deviations from the original development of the DII are shown in Table 1. To minimize right skewing and ensure symmetrical distribution, the Z-scores are converted to centered percentiles. This is done by converting to a percentile score and then each percentile score is doubled and 1 is subtracted from it. This ensures that each parameter will have values centered on 0 and bounded between -1 (maximally anti-inflammatory) and +1 (maximally pro-inflammatory). Then for each parameter, the centered percentile value is multiplied by the respective ‘overall food parameter-specific inflammatory effect score’ to obtain the ‘food parameter-specific DII score’. Lastly, all of the ‘food parameter-specific DII scores’ are summed to calculate the ‘overall DII score’ for an individual<sup>22</sup>.

**Table 1. Food parameters included in DII**

<b>Food parameter</b>	<b>Weighted number of articles</b>	<b>Raw inflammatory effect score</b>	<b>Overall inflammatory effect score</b>	<b>Global daily mean intake (units/d)</b>	<b>sd</b>
<b>Alcohol (g)</b>	417	-0.278	-0.278	13.98	3.72
<b>Vitamin B<sub>12</sub> (µg)</b>	122	0.205	0.106	5.15	2.70
<b>Vitamin B<sub>6</sub> (mg)</b>	227	-0.379	-0.365	1.47	0.74
<b>β-Carotene (µg)</b>	401	-0.584	-0.584	3718	1720
<b>Caffeine (g)</b>	209	-0.124	-0.110	8.05	6.67
<b>Carbohydrate (g)</b>	211	0.109	0.097	272.2	40.0
<b>Cholesterol (mg)</b>	75	0.347	0.110	279.4	51.2
<b>Energy (kcal)</b>	245	0.180	0.180	2056	338
<b>Eugenol (mg)</b>	38	-0.868	-0.140	0.01	0.08
<b>Total fat (g)</b>	443	0.298	0.298	71.4	19.4
<b>Fiber (g)</b>	261	-0.663	-0.663	18.8	4.9
<b>Folic acid (µg)</b>	217	-0.207	-0.190	273.0	70.7
<b>Garlic (g)</b>	277	-0.412	-0.412	4.35	2.90
<b>Ginger (g)</b>	182	-0.588	-0.453	59.0	63.2
<b>Fe (mg)</b>	619	0.032	0.032	13.35	3.71
<b>Mg (mg)</b>	351	-0.484	-0.484	310.1	139.4
<b>MUFA (g)</b>	106	-0.019	-0.009	27.0	6.1
<b>Niacin (mg)</b>	58	-1.000	-0.246	25.90	11.77
<b><i>n</i>-3 Fatty acids (g)</b>	2588	-0.436	-0.436	1.06	1.06
<b><i>n</i>-6 Fatty acids (g)</b>	924	-0.159	-0.159	10.80	7.50
<b>Onion (g)</b>	145	-0.490	-0.301	35.9	18.4
<b>Protein (g)</b>	102	0.049	0.021	79.4	13.9
<b>PUFA (g)</b>	4002	-0.337	-0.337	13.88	3.76
<b>Riboflavin (mg)</b>	22	-0.727	-0.068	1.70	0.79

<b>Saffron (g)</b>	33	-1.000	-0.140	0.37	1.78
<b>Saturated fat (g)</b>	205	-0.429	0.373	28.6	8.0
<b>Se (µg)</b>	372	-0.191	-0.191	67.0	25.1
<b>Thiamin (mg)</b>	65	-0.354	-0.098	1.70	0.66
<b>Trans fat (g)</b>	125	0.432	0.229	3.15	3.75
<b>Turmeric (mg)</b>	814	-0.785	-0.785	533.6	754.3
<b>Vitamin A (RE)</b>	663	-0.401	-0.401	983.9	518.6
<b>Vitamin C (mg)</b>	733	-0.424	-0.424	118.2	43.46
<b>Vitamin D (µg)</b>	996	-0.446	-0.446	6.26	2.21
<b>Vitamin E (mg)</b>	1495	-0.419	-0.419	8.73	1.49
<b>Zn (mg)</b>	1036	-0.313	-0.313	9.84	2.19
<b>Green/black tea (g)</b>	735	-0.536	-0.536	1.69	1.53
<b>Flavan-3-ol (mg)</b>	521	-0.415	-0.415	95.8	85.9
<b>Flavones (mg)</b>	318	-0.616	-0.616	1.55	0.07
<b>Flavonols (mg)</b>	887	-0.467	-0.467	17.70	6.79
<b>Flavonones (mg)</b>	65	-0.908	-0.250	11.70	3.82
<b>Anthocyanidins (mg)</b>	69	-0.449	-0.131	18.05	21.14
<b>Isoflavones (mg)</b>	484	-0.593	-0.593	1.20	0.20
<b>Pepper (g)</b>	78	-0.397	-0.131	10.00	7.07
<b>Thyme/oregano (mg)</b>	24	-1.000	-0.102	0.33	0.99
<b>Rosemary (mg)</b>	9	-0.333	-0.013	1.00	15.00

### Periodontitis Outcome

The oral health examination protocol was developed by the CDC Division of Oral Health (DOH), National Center for Health Statistics (NCHS), Ethics Review Board, and

the National Institute of Dental and Craniofacial Research (NIDCR)<sup>34</sup>. The periodontal assessment and questionnaire were established in collaboration with the American Academy of Periodontology and the CDC Periodontal Disease Surveillance Workgroup<sup>34</sup>. All participants provided written informed consent.

All periodontal examinations were performed in mobile examination centers (MECs) by trained examiners who were either registered dental hygienists in 2009-2010 or licensed dentists (D.M.D./D.D.S.) in 2011-2014<sup>35</sup>. The assessments were done using a dental mirror and Hu-Friedy periodontal probe on the full-mouth. Periodontitis will be defined by examining clinical attachment loss (CAL), which is automatically calculated in NHANES data as the difference between probing pocket depth and recession. The examiners recorded the two specific measurements: gingival recession [distance between the free gingival margin (FGM) and the cemento-enamel junction (CEJ)] and probing pocket depth (PPD) [distance from FGM to the bottom of the sulcus or periodontal pocket] at six sites per tooth for all teeth, except third molars<sup>34,35</sup>. Mild, moderate, severe, and total periodontitis were defined based on case definitions of the Centers for Disease Control and Prevention and the American Academy of Periodontology, as described by Eke and colleagues<sup>3,36</sup>. The criteria are summarized in Table 2.

**Table 2. Periodontitis case definitions as outlined by Centers for Disease Control and Prevention and the American Academy of Periodontology for use in surveillance**

<b>Category</b>	<b>Definition</b>
<b><i>Severe</i></b>	$\geq 2$ interproximal sites with $\geq 6$ mm CAL (not on the same tooth) AND $\geq 1$ interproximal site(s) with $\geq 5$ mm PPD
<b><i>Moderate</i></b>	Among those without severe periodontitis: $\geq 2$ interproximal sites with $\geq 4$ mm CAL (not on the same tooth) OR $\geq 2$ interproximal sites with PPD $\geq 5$ mm (not on the same tooth)
<b><i>Mild</i></b>	Among those without severe or moderate periodontitis: $\geq 2$ interproximal sites with $\geq 3$ mm CAL AND [ $\geq 2$ interproximal sites with $\geq 4$ mm PPD (not on the same tooth) OR 1 site with $\geq 5$ mm PPD]
<b><i>None</i></b>	Meets neither the severe nor moderate nor mild periodontitis case definitions
<b><i>Total Periodontitis</i></b>	Severe Periodontitis + Moderate Periodontitis + Mild Periodontitis

### **Covariates**

Age, gender, race, education, waist circumference, body mass index, fasting glucose, alcohol consumption, flossing, hours TV/video watching, and smoking were all assessed as potential confounders. Information about age (in years), race, gender, and education was collected from the demographics questionnaire. Waist circumference and BMI were obtained from body measures examinations performed at MEC by trained health technicians. Fasting glucose was obtained from laboratory data on individuals and alcohol consumption was obtained from the dietary interviews. Flossing data was collected from questionnaire on oral health. Hours TV/video watching were assessed during questionnaire on physical activity based on the Global Physical Activity Questionnaire (GPAQ), which has questions related to daily activities, leisure time

activities, and sedentary activities<sup>37</sup>. Smoking was assessed using information from a questionnaire on recent tobacco use. Participants were considered smokers if they had used any product containing nicotine including cigarettes, pipes, cigars, chewing tobacco, snuff, nicotine patches, nicotine gum, little cigars or cigarillos, water pipes, hookahs, e-cigarettes, or any other product containing nicotine in the last 5 days.

### **Statistical Analyses**

Statistical analyses were performed using SAS statistical software (version 9.4). Overall DII score was normally distributed and divided into quintiles. The prevalence of the outcomes was measured according to quintiles and the results were analyzed to determine effect of DII values on outcomes. Then, tests were done combining categories and changing cut off points to choose the optimal exposure groups. Ultimately, two exposure categories were created – low DII score and high DII score. The low category was composed of participants in the first three quintiles and the high exposure category was composed of the top two quintiles. The outcomes were mild, moderate, severe, and total periodontitis. Prevalence for each was calculated in the overall sample population and sex-specific subgroups. Logistic regression models were used to calculate ORs (and 95% CI) for the presence of total periodontitis. Chi-square test was used to calculate the ORs for mild, moderate, and severe periodontitis. The list of potential confounders was examined to evaluate to what extent each covariate affects the unadjusted parameter estimate.

## RESULTS

Baseline characteristics of subjects are shown in Table 3 according to DII category. Among those with a more anti-inflammatory diet, more than half of the subjects were men (56.0%), compared with only 37.3% of those in the pro-inflammatory diet category. The mean age was similar between the two groups, 50.6 years in the anti-inflammatory group and 51.8 years in the pro-inflammatory group. Overall, those with a more pro-inflammatory diet were more often Non-Hispanic black while those with a more strongly anti-inflammatory diet had higher levels of education. The anti-inflammatory diet group had a lower mean BMI, lower mean waist circumference, and lower mean fasting glucose compared with the pro-inflammatory diet group. Among the anti-inflammatory group, only 16.6% used tobacco/nicotine in the last 5 days compared with 27.9% in the pro-inflammatory group. Mean alcohol consumption was 8.0g in the anti-inflammatory group versus 5.0g in the pro-inflammatory group. In terms of oral hygiene, those in the anti-inflammatory group more frequently flossed (32.6% vs. 27.4% flossing seven days a week in the two groups, respectively). The pro-inflammatory diet group, also watched more TV and video.

**Table 3. Baseline Characteristics (mean ( $\pm$ SD), or n (column percentage)) according to DII category**

	<b>Low DII 4486 (59.97)</b>	<b>High DII 2994 (40.03)</b>
<b>Characteristics</b>		
<b>Sex</b>		
<i>Men</i>	2512 (56.0)	1116 (37.3)
<i>Women</i>	1974 (44.0)	1878 (62.7)
<b>Age</b>	50.6 (13.6)	51.8 (14.4)
<b>Race</b>		
<i>Mexican American</i>	664 (14.8)	361 (12.1)
<i>Other Hispanic</i>	448 (10.0)	314 (10.5)
<i>Non-Hispanic White</i>	2031 (45.3)	1287 (43.0)
<i>Non-Hispanic Black</i>	746 (16.6)	775 (25.9)
<i>Other Race-Including Multi Racial</i>	597 (13.3)	257 (8.6)
<b>Education</b>		
<b>Less than 9th grade</b>	381 (8.5)	297 (9.9)
<i>9-11th grade</i> <i>(Includes 12th grade with no diploma)</i>	455 (10.1)	562 (18.8)
<i>High school graduate/GED or equivalent</i>	862 (19.2)	787 (26.3)
<i>Some college or AA degree</i>	1246 (27.8)	845 (28.2)
<i>College graduate or above</i>	1540 (34.3)	497 (16.6)
<i>Refused/Don't know/Missing</i>	2 (0.0)	6 (0.2)
<b>BMI (kg/m<sup>2</sup>)<sup>a</sup></b>	28.7 (6.2)	29.7 (6.9)
<b>Waist circumference (cm)<sup>b</sup></b>	98.4 (14.7)	100.0 (15.6)
<b>Fasting glucose (mmol/L)<sup>c</sup></b>	101.8 (19.6)	103.0 (22.6)
<b>Used tobacco/nicotine in the last 5 days</b>		
<i>No</i>	3498 (78.0)	1997 (66.7)
<i>Yes</i>	746 (16.6)	836 (28.0)
<i>Missing</i>	242 (5.4)	161 (5.4)
<b>Alcohol consumption (g)</b>	8.0 (15.1)	5.0 (12.6)
<b>Days using dental floss/device</b>		
<i>0 Days</i>	1342 (29.9)	1170 (39.1)
<i>1-2 Days</i>	738 (16.5)	447 (14.9)
<i>3-4 Days</i>	651 (14.5)	357 (11.9)
<i>5-6 Days</i>	248 (5.5)	131 (4.4)
<i>7 Days</i>	1563 (32.6)	821 (27.4)
<i>Refused/Don't know/Missing</i>	44 (1.0)	68 (2.3)
<b>Hours watched TV/video in the past 30 days</b>		
<i>1 Hour and less or not watching at all</i>	1017 (22.7)	502 (16.8)
<i>2 Hours</i>	765 (17.1)	445 (14.9)

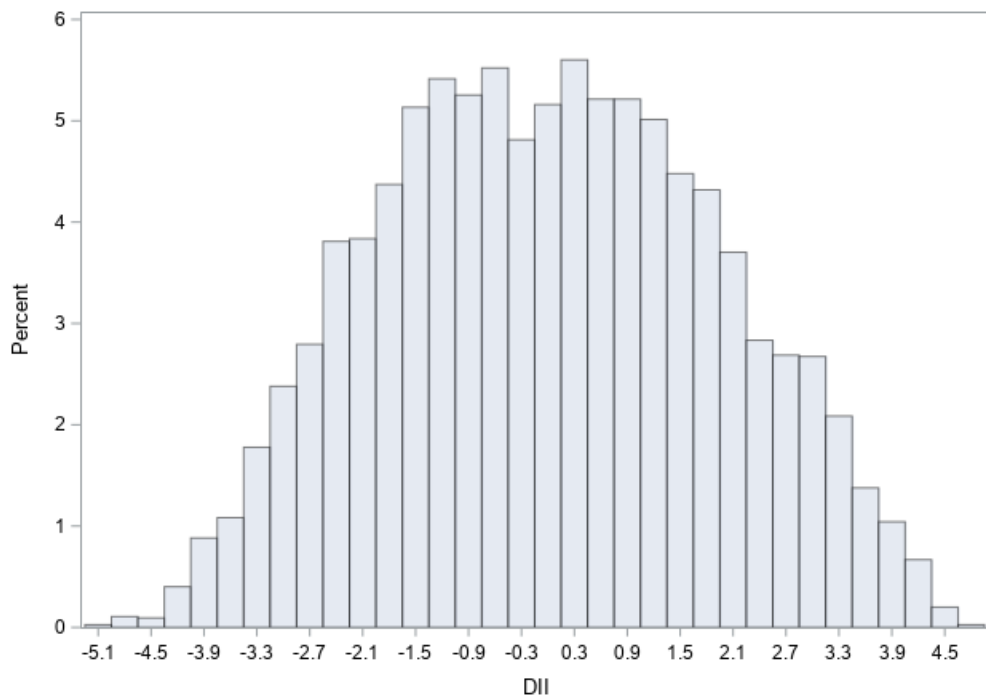
<b>3 Hours</b>	480 (10.7)	326 (10.9)
<b>4 Hours</b>	310 (6.9)	258 (8.6)
<b>5 Hours or more</b>	341 (7.6)	351 (11.7)
<b>Missing</b>	1573 (35.1)	1112 (37.1)

<sup>a</sup> There are 41 subjects with missing BMI.

<sup>b</sup> There are 162 subjects with missing WC.

<sup>c</sup> There are 3,925 subjects with missing fasting glucose.

Figure 2 below shows that the DII is normally distributed with a mean of 0.00 ( $\pm 1.91$ ) and a median of -0.019, with a minimum value of -5.16 and a maximum of 4.82. DII values  $\leq 0.54$  were categorized as low DII (anti-inflammatory) and DII values  $> 0.54$  were categorized as high DII (pro-inflammatory).



**Figure 2. Distribution of overall Dietary Inflammatory Index (DII) in the National Health and Nutrition Examination Survey cycles 2009-2014 (N=7480). Mean ( $\pm$  standard deviation): 0.00 ( $\pm 1.91$ ); median (min, max): -0.019 (-5.16, 4.82); 5<sup>th</sup>, 25<sup>th</sup>, 75<sup>th</sup>, and 95<sup>th</sup> percentiles: -3.07, -1.44, 1.43, and 3.21**

## **Total Periodontitis**

Of the total 7,480 men and women, 3,307 had periodontitis at the time of examination. As shown on Table 4, the prevalence of periodontitis was 42% in Low DII category and 47.5% in the High DII category. Among men, the prevalence of periodontitis was 49.8% in the Low DII category compared to 57.5% in the High DII category. Women had lower prevalence of periodontitis among both exposure groups compared with men. The prevalence of periodontitis among women in the Low DII category was 32.1% compared with 41.3% in the High DII diet group. According to unadjusted odds ratio, subjects in the High DII category had a 25% increased risk of having periodontitis compared with subjects in the Low DII category. In the final adjusted models, we retained those factors that led to a 5-10% change in the adjusted parameter estimates (compared with the unadjusted models). Here, we retained age, sex, alcohol consumption, and smoking as important confounders of the relation between the DII and periodontitis. We considered the inclusion of education in the model but decided that it was likely to be a strong determinant of the dietary exposure rather than true confounder. After adjusting for confounding, the final model suggests a 35% increased risk of periodontitis when exposed to pro-inflammatory diet compared to anti-inflammatory diet. Men with a more pro-inflammatory diet had 25% increased risk while women had 44% increased risk of periodontitis.

**Table 4. Prevalence (%) and unadjusted and adjusted odds ratios (OR (CI 95%)) for total periodontitis according to DII status**

	Yes	No	Prevalence %	OR (CI 95%) <sup>a</sup>	OR (CI 95%) <sup>b</sup>	OR (CI 95%) <sup>c</sup>
<b>Overall (n=7480)</b>						
<b>DII Status</b>						
<i>Low DII (n=4486)</i> <i>(Anti-inflammatory diet)</i>	1886	2600	42.04	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<i>High DII (n=2994)</i> <i>(Pro-inflammatory diet)</i>	1421	1573	47.46	1.25 (1.14-1.37)	1.41 (1.28-1.56)	1.35 (1.22-1.49)
<b>Men (n=3628)</b>						
<b>DII Status</b>						
<i>Low DII (n=2512)</i> <i>(Anti-inflammatory diet)</i>	1252	1260	49.84	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<i>High DII (n=1116)</i> <i>(Pro-inflammatory diet)</i>	644	472	57.71	1.37 (1.19-1.58)	1.33 (1.15-1.53)	1.25 (1.08-1.44)
<b>Women (n=3852)</b>						
<b>DII Status</b>						
<i>Low DII (n=1974)</i> <i>(Anti-inflammatory diet)</i>	634	1340	32.12	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<i>High DII (n=1878)</i> <i>(Pro-inflammatory diet)</i>	777	1101	41.37	1.49 (1.31-1.70)	1.49 (1.31-1.70)	1.44 (1.26-1.65)

<sup>a</sup> Unadjusted logistics models

<sup>b</sup> Sex and age adjusted OR for overall and age adjusted OR for women and men

<sup>c</sup> Fully adjusted for age, gender, alcohol, and smoking

## **Severity of Periodontitis**

After examining total periodontitis, we analyzed the severity of periodontitis. As shown on Table 5, the prevalence of mild periodontitis in the overall population was very slightly higher among participants adhering to anti-inflammatory diet (4.8%) compared with participants adhering to pro-inflammatory diet (4.8%). However, the prevalence of both moderate and severe periodontitis was substantially higher in the with a more pro-inflammatory diet. Moderate periodontitis was present in 29.1% of participants in the Low DII category and 31.8% of participants in the High DII category. Severe periodontitis was present in 8.2% of participants in the Low DII category and 10.9% of participants in the High DII category. The same prevalence trends were observed among men. Men with a more pro-inflammatory diet had higher prevalence of moderate and severe periodontitis compared with men having a more anti-inflammatory diet. In addition, prevalence of periodontitis at all levels of severity was lower in the anti-inflammatory diet group compared with the pro-inflammatory group.

**Table 5. Prevalence (n (%)) of periodontitis by subtype according to DII status**

	Subjects	Mild Cases	Moderate Cases	Severe Cases
<b>Overall (n=7480)</b>				
<b>DII Status</b>				
<i>Low DII (Anti-inflammatory diet)</i>	4486	217 (4.84%)	1303 (29.05%)	366 (8.16%)
<i>High DII (Pro-inflammatory diet)</i>	2994	143 (4.78%)	951 (31.76%)	327 (10.92%)
<b>Men (n=3628)</b>				
<i>Low DII (Anti-inflammatory diet)</i>	2512	145 (5.77%)	821 (32.68%)	286 (11.39%)
<i>High DII (Pro-inflammatory diet)</i>	1116	47 (4.21%)	406 (36.38%)	191 (17.11%)
<b>Women (n=3852)</b>				
<i>Low DII (Anti-inflammatory diet)</i>	1974	72 (3.65%)	482 (24.42%)	80 (4.05%)
<i>High DII (Pro-inflammatory diet)</i>	1878	96 (5.11%)	545 (29.02%)	136 (7.24%)

Table 6 shows the results of the chi-square test used to evaluate the overall association between the DII category and severity of periodontitis and the odds ratios among the subtypes of periodontitis. Overall, there was a statistically significant association between DII status and presence of periodontitis ( $p < 0.0001$ ). Subjects adhering to pro-inflammatory diet had non-statistically significant 9% increased risk of having mild periodontitis compared to subjects having an anti-inflammatory diet. Subjects with Low DII also had 21% statically significant increased risk of having

moderate periodontitis and 48% statistically significant increased risk of having severe periodontitis compared with subjects having a High DII.

**Table 6. Chi-square test and ORs for subtypes of periodontitis according to DII status**

	No Periodontitis	Mild Periodontitis	Moderate Periodontitis	Severe Periodontitis	Total
<b>DII Status</b>					
<i>Low DII</i> ( <i>Anti-inflammatory diet</i> )	2600	217	1303	366	4486
<i>High DII</i> ( <i>Pro-inflammatory diet</i> )	1573	143	951	327	2994
<b>Total</b>	4173	360	2254	693	7480
<b>OR (CI 95%)</b>	1 Ref	1.09 (0.87, 1.36)	1.21 (1.09, 1.33)	1.48 (1.26, 1.74)	
<b>Mantel-Haenszel chi-square</b>		0.579	12.41	22.49	27.37
<b>p-value</b>		0.4467	<0.001	<0.0001	<0.0001

## DISCUSSION

To the best of our knowledge, this is the first study examining the association between the DII developed by Shivappa et al.<sup>22</sup> and periodontal disease. We found that a pro-inflammatory diet (High DII) was associated with higher prevalence of periodontitis, particularly moderate and severe forms of the disease, in both men and women. The prevalence of mild periodontitis was higher among women having a High DII score, but not among men. In addition, the overall cohort had increased odds of having moderate, severe, and total periodontitis when consuming more pro-inflammatory foods and nutrients. Women were at higher risk, with 44% risk of those with a High DII having periodontitis, compared with 25% of men. When examining the odds ratios for the severity of periodontitis, subjects whose diet was more pro-inflammatory had statistically-significant increase in risk of moderate or severe periodontitis, but not mild.

The DII in this sample population was normally distributed, with scores ranging from -5.16 to 4.82. In the original DII, scores ranged from -8.87 to 7.98. That original score included forty-five food and nutrient-related factors while the current analyses included only the twenty-seven foods and nutrients that were available from the NHANES dietary records. The pro-inflammatory components that we measured were vitamin B<sub>12</sub>, carbohydrate, cholesterol, energy, total fat, iron, protein, and saturated fat. The anti-inflammatory components were alcohol, vitamin B<sub>6</sub>,  $\beta$ -carotene, fiber, folic acid, magnesium, monounsaturated fatty acids (MUFA), niacin, n-3 FA, n-6 FA,

polyunsaturated fatty acids (PUFA), riboflavin, selenium, thiamin, vitamin A, vitamin C, vitamin D, vitamin E, and zinc.

Prior research studies have shown associations of individual or multiple nutrients with periodontitis. One such study demonstrated that rats fed high cholesterol diet had alveolar bone resorption via tissue oxidative damage, and that the administration of vitamin C decreased the bone resorption and damage of the periodontal tissue<sup>38</sup>. Another study found that high-fat diet-induced obesity in mice triggered mandibular osteoporosis, but also spontaneous periodontal disease<sup>39</sup>. Current research indicates that substitution of saturated fats with MUFA and PUFA, in particular n-3 PUFA, may be a useful dietary measure for the prevention of periodontitis<sup>40</sup>. While there is extensive evidence about the roles of individual nutrients on oral health, our analysis of periodontal disease in the context of the Dietary Inflammatory Index shows a new perspective.

A data analysis from the PREDIMED trial has shown a direct association between the DII and indices of obesity, indicating that diet may have an effect on obesity through inflammatory mechanisms<sup>41</sup>. In addition, overweight and obesity have been recognized as risk factors for compromised oral health and specifically periodontitis<sup>42</sup>. In this analysis, subjects with Low DII also had lower BMI, waist circumference, and fasting glucose whether from overall healthier lifestyle or the potential benefits of the anti-inflammatory diet.

Smoking has been recognized to be a major risk factor for periodontitis. In this cohort, 27.8% of the participants with a pro-inflammatory diet reported the use of tobacco or nicotine products during the 5 days prior to the survey. The proportion of subjects who used tobacco or nicotine in the anti-inflammatory group was much lower, 16.6%. A systematic review published in 2020 has also shown an association between smoking and periapical periodontitis<sup>43</sup>. In addition to systemic inflammation potentially caused by pro-inflammatory foods and nutrients, smoking may have direct adverse effects on the periodontium, as well as on the overall immune system<sup>43</sup>. In addition, changes to the microbiome of the periodontal pocket may be linked with smoking<sup>44</sup>. Studies indicate that smokers are immunologically deficient in TNF- $\alpha$  and hBD-2 and have altered bone regeneration, decreased healing, poor circulation, and negatively altered host response<sup>45-47</sup>. Given the prevalence of tobacco and nicotine users in the cohort and the association between smoking and periodontitis, it was not surprising that smoking was a confounder in the current analyses.

Oral hygiene is another very important component that needs to be considered in our study. The presence of periopathogens in an oral biofilm, also known as dental plaque, is the primary factor in the exacerbation or formation of periodontal disease and even dental caries. Given that floss is able to remove interproximal plaque, it is often thought that regular flossing reduces the risk of periodontal disease<sup>48</sup>. A Cochrane systematic review confirms that flossing in addition to toothbrushing reduces gingivitis, which is the starting point for all periodontal disease<sup>48</sup>. In this cohort, subjects with High

DII used dental floss or flossing device less frequently than subjects with Low DII. However, when multivariate logistic regression analysis was done, we found out that flossing does not alter the association between the DII and periodontal disease.

Since the early 2000s, there has been evidence showing an inverse association between physical activity and periodontal disease. Multiple studies have shown that practicing recommended levels of physical exercises can decrease the risk of periodontal disease<sup>49-51</sup>. To explore this association, we used data on the number of hours of TV or video per day the participants watched in the 30 days prior to their interview. This provided an indication of how sedentary the participants' lifestyles were. We explored this factor as a potential confounder in our multivariable models. We found that people consuming more pro-inflammatory foods and nutrients, spent more hours watching TV or video compared with those who eat more anti-inflammatory foods. However, this did not significantly attenuate the association between the DII and periodontal disease and was thus not considered as a confounder in the analysis.

Another characteristic that we examined was education level. We found a larger proportion of individuals with the lowest levels of education (less than 9<sup>th</sup> grade) in the group with High DII, 9.9% versus 8.5% in the group with low DII. In contrast, the proportion of individuals with the highest level of education (college graduate or above) tended to have Lower DII scores. There was 16.6% and 34.3% of participants with

college degree or above in the pro-inflammatory and anti-inflammatory groups, respectively.

Controlling for education level in the logistic regression analysis attenuated the effects of diet. However, we hypothesized education was likely to be a determinant of the exposure rather than a true confounder. A separate study of the Healthy Eating Index (HEI) among Americans supported this hypothesis through the finding that education was associated with better nutrition knowledge and thus better dietary habits<sup>52</sup>. This relationship is reinstated by the effects of higher socioeconomic status and affluence on dietary choices<sup>52,53</sup>.

The strengths of this study include the large sample size for both men and women and the use of DII which incorporates micronutrients and macronutrients and their inflammatory potential as shown in the literature. The study had strong external validity as the participants were randomly selected from the general population. Therefore, the results apply to nationally representative samples and can be generalized to the US population. Data was collected by standardized protocols to minimize measurement errors. Another key strength of this study was the use of data collected from full-mouth periodontal examinations, which assessed six sites per tooth, allowing us to determine prevalence and severity based on updated case definitions for population-based surveillance of periodontitis.

The study possesses several limitations. First, the cross-sectional design restricts our ability to infer causality between DII levels and periodontitis. Similarly, we cannot determine whether the diet can work as a preventative or treatment method for periodontitis. Second, the DII is based on self-reported data, and is calculated using data collected by the 24-hour dietary reporting instrument, which may limit the ability to accurately describe individuals' habitual diet. Third, we were unable to distinguish whether the observed increased risk for periodontitis was due to an excess of pro-inflammatory nutrients or the concomitant shortage of anti-inflammatory, or to some combination of the two. More studies are needed to confirm the potential benefits of anti-inflammatory diets and provide further insights into possible mechanisms of action. Lastly, due to limitations in the NHANES data we were unable to include 18 food and nutrient parameters that are typically used in the calculation of the DII. However, previous studies have shown that this non-availability of some of the parameters is unlikely to have major impacts on the association of calculated DII scores and various health outcomes.<sup>14,16</sup>

## **CONCLUSION**

This is the first study to examine the inflammatory potential of diet, as measured by the DII, on periodontitis risk. In a large American cohort, subjects whose diet scored High DII had increased risk of moderate, severe, and total periodontitis compared to subjects whose diet scored Low DII, with women having greater risk of total periodontitis. The adherence to an anti-inflammatory diet may be an additional method for reducing systemic inflammation and for the prevention and management of periodontal disease.

## APPENDIX A

### NHANES Data Files Used to Create Dietary Dataset in the Cohort:

<b>Data file name</b>	<b>Description</b>	<b>Observations &amp; variables</b>
<b>DR1TOT_F</b>	Dietary Interview, Day 1, Total Nutrient Intake- 2009-2010	10253 observations and 166 variables
<b>DR1TOT_G</b>	Dietary Interview, Day 1, Total Nutrient Intake- 2011-2012	9338 observations and 166 variables
<b>DR1TOT_H</b>	Dietary Interview, Day 1, Total Nutrient Intake- 2013-2014	9813 observations and 168 variables
<b>DR2TOT_F</b>	Dietary Interview, Day 2, Total Nutrient Intake- 2009-2010	10253 observations and 83 variables
<b>DR2TOT_G</b>	Dietary Interview, Day 2, Total Nutrient Intake- 2011-2012	9338 observations and 83 variables
<b>DR2TOT_H</b>	Dietary Interview, Day 2, Total Nutrient Intake- 2013-2014	9813 observations and 85 variables

## APPENDIX B

### DII Food Parameters Used to Calculate Index Score and NHANES Equivalents

Used in the Analysis:

DII FOOD PARAMETER	UNIT	NHANES D1 VAR	NHANES D2 VAR	NHANES VARIABLE DESCRIPTION
Alcohol	g	DR1TALCO	DR2TALCO	Alcohol (g)
Vitamin B12	mcg	DR1TVB12	DR2TVB12	Vitamin B12 (mcg)
		DR1TB12A	DR2TB12A	Added vitamin B12 <sup>a</sup> (mcg)
Vitamin B6	mg	DR1TVB6	DR2RTVB6	Vitamin B6 (mg)
b-Carotene	mcg	DR1TBCAR	DR2TBCAR	Beta-carotene (mcg)
Caffeine	g	DR1TCAFF	DR2TCAFF	Caffeine (mg) <sup>b</sup>
Carbohydrate	g	DR1TCARB	DR2TCARB	Carbohydrate (g)
Cholesterol	mg	DR1TCHOL	DR2TCHOL	Cholesterol (mg)
Energy	kcal	DR1TKCAL	DR2TKCAL	Energy (kcal)
Eugenol	mg	missing in NHANES		
Total fat	g	DR1TTFAT	DR2TTFAT	Total fat (g)
Fiber	g	DR1TFIBE	DR2TFIBE	Dietary fiber (g)
Folic acid	mcg	DR1TFF	DR2TFF	Food folate (mcg)
		DR1TFA	DR2TFA	Folic acid (mcg)
		DR1TFOLA	DR2TFOLA	Total folate (mcg) <sup>c</sup>
		DR1TFDFE	DR2TFDFE	Folate as dietary folate equivalent (mcg)
Garlic	g	missing in NHANES		
Ginger	g	missing in NHANES		
Fe	mg	DR1TIRON	DR2TIRON	Iron (mg)
Mg	mg	DR1TMAGN	DR2TMAGN	Magnesium (mg)
MUFA	g	DR1TMFAT	DR2TMFAT	Total monounsaturated fatty acids (g)
Niacin	mg	DR1TNIAC	DR2TNIAC	Niacin (mg)
n-3 fatty acids	g	None	None	CREATED VAR TO SUM LISTED BELOW
		DR1TP183	DR2TP183	PFA 18:3 (Octadecatrienoic) (g)

		DR1TP184	DR2TP184	PFA 18:4 (Octadecatetraenoic) (g)
		DR1TP205	DR2TP205	PFA 20:5 (Eicosapentaenoic) (g)
		DR1TP225	DR2TP225	PFA 22:5 (Docosapentaenoic) (g)
		DR1TP226	DR2TP226	PFA 22:6 (Docosahexaenoic) (g)
n-6 fatty acids	g	None	None	CREATED VAR TO SUM LISTED
		DR1TP182	DR2TP182	PFA 18:2 (Octadecadienoic) (g)
		DR1TP204	DR2TP204	PFA 20:4 (Eicosatetraenoic) (g)
Onion	g	missing in NHANES		
Protein	g	DR1TPROT	DR2TPROT	Protein (g)
PUFA	g	DR1TPFAT	DR2TPFAT	Total polyunsaturated fatty acids (g)
Riboflavin	mg	DR1TVB2	DR2TVB2	Riboflavin (Vitamin B2) (mg)
Saffron	g	missing in NHANES		
Saturated fat	g	DR1TSFAT	DR2TSFAT	Total saturated fatty acids (g)
Se	mcg	DR1TSELE	DR2TSELE	Selenium (mcg)
Thiamin	mg	DR1TVB1	DR2TVB1	Thiamin (Vitamin B1) (mg)
Trans fat	g	missing in NHANES		
Turmeric	mg	missing in NHANES		
Vitamin A	RE*			New Var= DRTRET +(DRTBCAR/6)+(DRT ACAR/12)+(DRTCryp/ 12)
		DR1TRET	DR2TRET	Retinol (mcg)
		DR1TVARA	DR2TVARA	Vitamin A as Retinol activity equivalent (mcg)
		DR1TACAR	DR2TACAR	alpha-carotene (mcg)
		DR1TBCAR	DR2TBCAR	beta-carotene (mcg)
		DR1TCRYP	DR2TCRYP	beta-cryptoxanthin (mcg)
Vitamin C	mg	DR1TVC	DR2TVC	Vitamin C (mg)

Vitamin D	mg	DR1TVD	DR2TVD	Vitamin D (D2 + D3) (mcg)
Vitamin E	mg	DR1TATOC	DR2TATOC	Vitamin E as alpha- tocopherol (mg)
		DR1TATOA	DR2TATOA	Added alpha-tocopherol (Vitamin E) (mg) <sup>d</sup>
Zn	mg	DR1TZINC	DR2TZINC	Zinc (mg)
Green/black tea	g	missing in NHANES		
Flavan-3-ol	mg	missing in NHANES		
Flavones	mg	missing in NHANES		
Flavonols	mg	missing in NHANES		
Flavonones	mg	missing in NHANES		
Anthocyanidins	mg	missing in NHANES		
Isoflavones	mg	missing in NHANES		
Pepper	g	missing in NHANES		
Thyme/oregano	mg	missing in NHANES		
Rosemary	mg	missing in NHANES		

<sup>a</sup> Added Vitamin B12 was not used in the calculation of DII

<sup>b</sup> Caffeine units were converted for consistence with the index, but caffeine was ultimately not used in the analysis due to abnormal caffeine global mean and standard deviation as reported in DII

<sup>c</sup> The variable Total Folate was used to represent folic acid

<sup>d</sup> Added Vitamin E was not used in the calculation of DII

## APPENDIX C

### DII Distribution:

LEVEL	QUANTILE
100% Max	4.822056
99%	4.022894
95%	3.211123
90%	2.640727
75% Q3	1.428844
50% Median	-0.01877
25% Q1	-1.44385
10%	-2.5056
5%	-3.07432
1%	-3.89696
0% Min	-5.15772

DII MIN	-5.15772
DII MAX	4.82206

### SUBJECTS DISTRIBUTION

20%	-1.76502
40%	-0.60135
60%	0.54005
80%	1.75292
100%	4.82206

## APPENDIX D

### NHANES Files Used to Create Cohort:

<b>FILE NAME</b>	<b>DESCRIPTION</b>	<b>OBSERVATIONS</b>
<b>OHXREF_F</b>	Oral Health-Recommendation of Care 2009-2010	<b>8189</b>
<b>OHXREF_G</b>	Oral Health-Recommendation of Care 2011-2012	<b>8956</b>
<b>OHXREF_H</b>	Oral Health-Recommendation of Care 2013-2014	<b>9422</b>
	Appended to <b>REF_6YR</b>	<b>26567</b>
<b>OHXPER_F</b>	Oral Health-Periodontal 2009-2010	<b>5037</b>
<b>OHXPER_G</b>	Oral Health-Periodontal 2011-2012	<b>4365</b>
<b>OHXPER_H</b>	Oral Health-Periodontal 2013-2014	<b>4669</b>
	Appended to <b>PERIO_6YR</b>	<b>14071</b>
<b>OHXDEN_F</b>	Oral Health-Dentition 2009-2010	<b>8189</b>
<b>OHXDEN_G</b>	Oral Health-Dentition 2011-2012	<b>8956</b>
<b>OHXDEN_H</b>	Oral Health-Dentition 2013-2014	<b>9422</b>
	Appended to <b>DEN_6YR</b>	<b>26567</b>
<b>OHQ_F</b>	Oral Health 2009-2010	<b>5177</b>
<b>OHQ_G</b>	Oral Health 2010-2011	<b>9364</b>
<b>OHQ_H</b>	Oral Health 2012-2013	<b>9770</b>
	Appended to <b>OHQ_6YR</b>	<b>24311</b>
<b>DIQ_F</b>	Diabetes 2009-2010	<b>10109</b>
<b>DIQ_G</b>	Diabetes 2010-2011	<b>9364</b>
<b>DIQ_H</b>	Diabetes 2012-2013	<b>9770</b>
	Appended to <b>DIQ_6YR</b>	<b>29243</b>
<b>MCQ_F</b>	Medical Conditions 2009-2010	<b>10109</b>
<b>MCQ_G</b>	Medical Conditions 2010-2011	<b>9364</b>
<b>MCQ_H</b>	Medical Conditions 2012-2013	<b>9770</b>
	Appended to <b>MCQ_6YR</b>	<b>29243</b>
<b>RHQ_F</b>	Reproductive Health 2009-2010	<b>3745</b>
<b>RHQ_G</b>	Reproductive Health 2010-2011	<b>3298</b>
<b>RHQ_H</b>	Reproductive Health 2012-2013	<b>3618</b>

	Appended to <b>RHQ_6YR</b>	<b>10661</b>
<b>BMX_F</b>	Body measures 2009-2010	<b>10253</b>
<b>BMX_G</b>	Body measures 2011-2012	<b>9338</b>
<b>BMX_H</b>	Body measures 2013-2014	<b>9813</b>
	Appended to <b>BMX_6YR</b>	<b>29404</b>
<b>SMQ_F</b>	Smoking 2009-2010	<b>7528</b>
<b>SMQ_G</b>	Smoking 2010-2011	<b>6790</b>
<b>SMQ_H</b>	Smoking 2012-2013	<b>7168</b>
	Appended to <b>SMQ_6YR</b>	<b>21486</b>
<b>SMQRTU_F</b>	Smoking recent tobacco use 2009-2010	<b>7369</b>
<b>SMQRTU_G</b>	Smoking recent tobacco use 2011-2012	<b>6549</b>
<b>SMQRTU_H</b>	Smoking recent tobacco use 2013-2014	<b>6979</b>
	Appended to <b>SMQRTU_6YR</b>	<b>20897</b>
<b>DEMO_F</b>	Demographic Variables and Sample Weights 2009-2010	<b>10537</b>
<b>DEMO_G</b>	Demographic Variables and Sample Weights 2011-2012	<b>9756</b>
<b>DEMO_H</b>	Demographic Variables and Sample Weights 2013-2014	<b>10175</b>
	Appended to <b>DEMO_6YR</b>	<b>30468</b>
<b>PAQ_F</b>	Physical Activity 2009-2010	<b>9771</b>
<b>PAQ_G</b>	Physical Activity 2011-2012	<b>9107</b>
<b>PAQ_H</b>	Physical Activity 2013-2014	<b>9484</b>
	Appended to <b>PAQ_6YR</b>	<b>28362</b>
<b>GLU_F</b>	Plasma Fasting Glucose and Insulin 2009-2010	<b>3581</b>
<b>GLU_G</b>	Plasma Fasting Glucose and Insulin 2011-2012	<b>3239</b>
<b>GLU_H</b>	Plasma Fasting Glucose and Insulin 2013-2014	<b>3329</b>
	Appended to <b>GLU_6YR</b>	<b>10149</b>

## APPENDIX E

### Logistic Regression Models of Covariates:

	<b>DII</b>	<b>DII + Age</b>	<b>DII + Gender</b>	<b>DII + Race</b>
<b>OR</b>	1.245	1.221	1.436	1.254
<b>CI</b>	(1.135-1.367)	(1.112-1.342)	(1.303-1.581)	(1.142-1.376)
<b>Parameter Estimate</b>	0.2194	0.1999	0.3616	0.226

	<b>DII + Education</b>	<b>DII + BMI</b>	<b>DII + Glucose</b>	<b>DII + Waist circumference</b>
<b>OR</b>	1.076	1.235	1.259	1.223
<b>CI</b>	(0.977-1.184)	(1.124-1.356)	(1.098-1.443)	(1.121-1.355)
<b>Parameter Estimate</b>	0.0729	0.2108	0.2302	0.2091

	<b>DII + Flossing</b>	<b>DII + Alcohol</b>	<b>DII + Smoking</b>	<b>DII + Tv/video</b>
<b>OR</b>	1.228	1.264	1.201	1.211
<b>CI</b>	(1.119-1.348)	(1.151-1.388)	(1.094-1.319)	(1.103-1.330)
<b>Parameter Estimate</b>	0.2054	0.2342	0.1833	0.1918

## APPENDIX F

### Unadjusted and Adjusted Logistic Regression Models for the Overall Cohort:

	<b>DII</b>	<b>DII + Age</b>	<b>DII + Age + Sex</b>	<b>DII + Age + Sex + Alcohol</b>	<b>DII + Age + Sex + Alcohol + Smoking</b>
<b>OR</b>	1.245	1.221	1.412	1.418	1.346
<b>CI</b>	1.135-1.367	1.112-1.342	1.280-1.557	1.286-1.564	1.219-1.487

### Unadjusted and Adjusted Logistic Regression Models for Men Only:

	<b>DII</b>	<b>DII + Age</b>	<b>DII + Age + Alcohol</b>	<b>DII + Age + Alcohol + Smoking</b>
<b>OR</b>	1.373	1.328	1.334	1.246
<b>CI</b>	1.191-1.583	1.150-1.533	1.155-1.541	1.076-1.442

### Unadjusted and Adjusted Logistic Regression Models for Women Only:

	<b>DII</b>	<b>DII + Age</b>	<b>DII + Age + Alcohol</b>	<b>DII + Age + Alcohol + Smoking</b>
<b>OR</b>	1.492	1.492	1.498	1.439
<b>CI</b>	1.307-1.702	1.306-1.705	1.310-1.712	1.257-1.647

## LIST OF JOURNAL ABBREVIATIONS

Am J Clin Nutr	The American Journal of Clinical Nutrition
Adv Nutr	Advances in Nutrition
BMC Obes	BMC Obesity
Br J Nutr	British Journal of Nutrition
Cardiovasc Res	Cardiovascular Research
Clin Nutr	Clinical Nutrition
Clin Oral Investig	Clinical Oral Investigations
Diabetes Metab Syndr Clin Res Rev	Diabetes & Metabolic Syndrome: Clinical Research & Reviews
Eur J Nutr	European Journal of Nutrition
Iran J Immunol	Iranian Journal of Immunology
J Acad Nutr Diet	Journal of the Academy of Nutrition and Dietetics
J Appl Physiol	Journal of Applied Physiology
J Clin Periodontol	Journal of Clinical Periodontology
J Dent	Journal of Dentistry
J Dent Res	Journal of Dental Research
J Endod	Journal of Endodontics
J Nutr	The Journal of Nutrition
J Periodontol	Journal of Periodontology
Med	Medicina
Periodontol	Periodontology
Public Health Nutr	Public Health Nutrition
Respir Med	Respiratory Medicine

## REFERENCES

1. Muñoz Aguilera E, Suvan J, Buti J, et al. Periodontitis is associated with hypertension: a systematic review and meta-analysis. *Cardiovasc Res*. 2019. doi:10.1093/cvr/cvz201
2. Severin T. *Periodontal Health and Disease: A Practical Guide to Reduce the Global Burden of Periodontal Disease.*; 2018.
3. Eke PI, Borgnakke WS, Genco RJ. Recent epidemiologic trends in periodontitis in the USA. *Periodontol 2000*. 2020;82(1):257-267. doi:10.1111/prd.12323
4. Cochran DL. Inflammation and Bone Loss in Periodontal Disease. *J Periodontol*. 2008;79(August):1569-1576. doi:10.1902/jop.2008.080233
5. Caton JG, Armitage G, Berglundh T, et al. A new classification scheme for periodontal and peri-implant diseases and conditions - Introduction and key changes from the 1999 classification. *J Periodontol*. 2018;89:1-8. doi:10.1002/JPER.18-0157
6. Bartold PM, Van Dyke TE. An appraisal of the role of specific bacteria in the initial pathogenesis of periodontitis. *J Clin Periodontol*. 2019;46(1):6-11. doi:10.1111/jcpe.13046
7. Robati M, Ranjbari A, Boroujerdnia MG, Chinipardaz Z. Detection of IL-4, IL-6 and IL-12 serum levels in generalized aggressive periodontitis. *Iran J Immunol*. 2011;8(3):170-175.
8. Passoja A, Puijola I, Knuutila M, et al. Serum levels of interleukin-10 and tumour necrosis factor- $\alpha$  in chronic periodontitis. *J Clin Periodontol*. 2010;37(10):881-887. doi:10.1111/j.1600-051X.2010.01602.x
9. Demmer RT, Squillaro A, Papapanou PN, et al. Periodontal infection, systemic inflammation, and insulin resistance: Results from the continuous National Health and Nutrition Examination Survey (NHANES) 1999-2004. *Diabetes Care*. 2012;35(11):2235-2242. doi:10.2337/dc12-0072
10. Lerner UH, Loss INIB. Inflammation-induced Bone Remodeling in Periodontal Disease and the Influence of Post-menopausal Osteoporosis. *J Dent Res*. 2006;(85(7)):596-607.
11. Khumaedi AI, Purnamasari D, Wijaya IP, Soeroso Y. The relationship of diabetes, periodontitis and cardiovascular disease. *Diabetes Metab Syndr Clin Res Rev*.

2019;13(2):1675-1678. doi:10.1016/j.dsx.2019.03.023

12. Roberts CK, Barnard RJ. Effects of exercise and diet on chronic disease. *J Appl Physiol*. 2005;98(1):3-30. doi:10.1152/jappphysiol.00852.2004
13. Booth FW, Chakravarthy M V, Gordon SE, Spangenburg EE. Waging war on physical inactivity: using modern molecular ammunition against an ancient enemy. *J Appl Physiol*. 2002;93:3-30.
14. Mazidi M, Shivappa N, Wirth MD, et al. Dietary Inflammatory Index and Cardiometabolic Risk in US Adults. *Atherosclerosis*. 2018;276:23-27. doi:10.1016/j.atherosclerosis.2018.02.020
15. Protein C, Cavicchia PP, Steck SE, et al. A New Dietary Inflammatory Index Predicts Interval Changes in Serum High-Sensitivity. *J Nutr*. 2009;139(12):2365-2372. doi:10.3945/jn.109.114025.2365
16. Shivappa N, Steck SE, Hurley TG, et al. A population-based dietary inflammatory index predicts levels of C-reactive protein in the Seasonal Variation of Blood Cholesterol Study (SEASONS). *Public Health Nutr*. 2014;17(8):1825-1833. doi:10.1017/S1368980013002565
17. Shivappa N, Hébert JR, Rietzschel ER, et al. Associations between dietary inflammatory index and inflammatory markers in the Asklepios Study. *Br J Nutr*. 2015;113(4):665-671. doi:10.1017/S000711451400395X
18. Kytikova O, Novgorodtseva T, Denisenko Y, Antonyuk M, Gvozdenko T. Pro-resolving lipid mediators in the pathophysiology of asthma. *Med*. 2019;55(6):1-12. doi:10.3390/medicina55060284
19. Van Dyke TE, Sima C. Understanding resolution of inflammation in periodontal diseases: Is chronic inflammatory periodontitis a failure to resolve? *Periodontol 2000*. 2020;82(1):205-213. doi:10.1111/prd.12317
20. Dommisch H, Kuzmanova D, Jönsson D, Grant M, Chapple I. Effect of micronutrient malnutrition on periodontal disease and periodontal therapy. *Periodontol 2000*. 2018;78(1):129-153. doi:10.1111/prd.12233
21. Neiva RF, Al-Shammari K, Nociti FH, Soehren S, Wang H-L. Effects of Vitamin-B Complex Supplementation on Periodontal Wound Healing. *J Periodontol*. 2005;76(7):1084-1091. doi:10.1902/jop.2005.76.7.1084
22. Shivappa N, Steck SE, Hurley TG, Hussey JR, Hébert JR. Designing and developing a literature-derived, population-based dietary inflammatory index.

*Public Health Nutr.* 2014;17(8):1689-1696. doi:10.1017/S1368980013002115

23. Hébert JR, Shivappa N, Wirth MD, Hussey JR, Hurley TG. Perspective: The Dietary Inflammatory Index (DII) - Lessons Learned, Improvements Made, and Future Directions. *Adv Nutr.* 2019;10(2):185-195. doi:10.1093/advances/nmy071
24. Deng FE, Shivappa N, Tang YF, Mann JR, Hebert JR. Association between diet-related inflammation, all-cause, all-cancer, and cardiovascular disease mortality, with special focus on prediabetics: findings from NHANES III. *Eur J Nutr.* 2017;56(3):1085-1093. doi:10.1007/s00394-016-1158-4
25. Park YMM, Choi MK, Lee SS, et al. Dietary inflammatory potential and risk of mortality in metabolically healthy and unhealthy phenotypes among overweight and obese adults. *Clin Nutr.* 2019;38(2):682-688. doi:10.1016/j.clnu.2018.04.002
26. Dye BA, Li X, Thornton-Evans G. Oral health disparities as determined by selected healthy people 2020 oral health objectives for the United States, 2009-2010. *NCHS Data Brief.* 2012;(104):1-8.
27. Healthy People. <https://www.healthypeople.gov/2020/topics-objectives/topic/oral-health>. Accessed October 2, 2020.
28. Eke PI, Dye BA, Wei L, et al. Update on Prevalence of Periodontitis in Adults in the United States: NHANES 2009 to 2012. *J Periodontol.* 2015. doi:10.1902/jop.2015.140520
29. Centers for Disease Control and Prevention. [https://www.cdc.gov/nchs/nhanes/about\\_nhanes.htm](https://www.cdc.gov/nchs/nhanes/about_nhanes.htm). Accessed January 2, 2020.
30. About the National Health and Nutrition Examination Survey. [https://www.cdc.gov/nchs/nhanes/about\\_nhanes.htm](https://www.cdc.gov/nchs/nhanes/about_nhanes.htm). Accessed January 2, 2020.
31. National Institute on Alcohol Abuse and Alcoholism. What Is A Standard Drink? <https://www.niaaa.nih.gov/what-standard-drink>. Accessed November 2, 2020.
32. National Cancer Institute Dietary Assessment Primer. Learn More about Software for Dietary Analysis of 24 Hour Dietary Recalls (24HR) and Food Records. <https://dietassessmentprimer.cancer.gov/learn/software-24.html>. Accessed April 3, 2020.
33. National Health and Nutrition Examination Survey. [https://wwwn.cdc.gov/Nchs/Nhanes/2009-2010/DR1TOT\\_F.htm](https://wwwn.cdc.gov/Nchs/Nhanes/2009-2010/DR1TOT_F.htm).

34. National Center for Health Statistics. NHANES Oral Health Examiners Manual. 2013. [https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/manuals/Oral\\_Health\\_Examiners.pdf](https://wwwn.cdc.gov/nchs/data/nhanes/2013-2014/manuals/Oral_Health_Examiners.pdf).
35. National Center for Health Statistics. NHANES Oral Health Examiners Manual 2009. [https://wwwn.cdc.gov/nchs/data/nhanes/2009-2010/manuals/OralHealth\\_Examiners.pdf](https://wwwn.cdc.gov/nchs/data/nhanes/2009-2010/manuals/OralHealth_Examiners.pdf).
36. Eke PI, Dye BA, Wei L, et al. Update of the case definitions for population -based surveillance of periodonitits. *J Periodontol*. 2012;83(December):1449-1454. doi:10.1902/jop.2015.140520
37. National Health and Nutrition Examination Survey. 2013-2014 Data Documentation, Codebook, and Frequencies. [https://wwwn.cdc.gov/Nchs/Nhanes/2013-2014/PAQ\\_H.htm](https://wwwn.cdc.gov/Nchs/Nhanes/2013-2014/PAQ_H.htm).
38. Sanbe T, Tomofuji T, Ekuni D, Azuma T, Tamaki N, Yamamoto T. Oral Administration of Vitamin C Prevents Alveolar Bone Resorption Induced by High Dietary Cholesterol in Rats. *J Periodontol*. 2007;78(11):2165-2170. doi:10.1902/jop.2007.070181
39. Fujita Y, Maki K. High-fat diet-induced obesity triggers alveolar bone loss and spontaneous periodontal disease in growing mice. *BMC Obes*. 2016;3(1). doi:10.1186/s40608-016-0082-8
40. Varela-López A, Quiles J, Cordero M, Giampieri F, Bullón P. Oxidative Stress and Dietary Fat Type in Relation to Periodontal Disease. *Antioxidants*. 2015;4(2):322-344. doi:10.3390/antiox4020322
41. Ruiz-Canela M, Zazpe I, Shivappa N, et al. Dietary inflammatory index and anthropometric measures of obesity in a population sample at high cardiovascular risk from the PREDIMED (PREvención con DIeta MEDiterránea) trial. *Br J Nutr*. 2015;113(6):984-995. doi:10.1017/S0007114514004401
42. Pischon N, Heng N, Bernimoulin J-P, Kleber B-M, Willich SN, Pischon T. Obesity, Inflammation, and Periodontal Disease. *J Dent Res*. 2007;86(5):400-409. doi:10.1177/154405910708600403
43. Aminoshariae A, Kulild J, Gutmann J. The association between smoking and periapical periodontitis: a systematic review. *Clin Oral Investig*. 2020;24(2):533-545. doi:10.1007/s00784-019-03094-6
44. Haffajee AD, Socransky SS. Relationship of cigarette smoking to the subgingival microbiota. *J Clin Periodontol*. 2001;28(5):377-388. doi:10.1034/j.1600-

051x.2001.028005377.x

45. Ghattas Ayoub C, Aminoshariae A, Bakkar M, et al. Comparison of IL-1 $\beta$ , TNF- $\alpha$ , hBD-2, and hBD-3 Expression in the Dental Pulp of Smokers Versus Nonsmokers. *J Endod.* 2017. doi:10.1016/j.joen.2017.08.017
46. Ohta T, Yamashita N, Maruyama M, Sugiyama E, Kobayashi M. Cigarette smoking decreases interleukin-8 secretion by human alveolar macrophages. *Respir Med.* 1998. doi:10.1016/S0954-6111(98)90191-3
47. Palmer RM, Wilson RF, Hasan AS, Scott DA. Mechanisms of action of environmental factors - Tobacco smoking. In: *Journal of Clinical Periodontology.* ; 2005. doi:10.1111/j.1600-051X.2005.00786.x
48. Sambunjak D, Nickerson JW, Poklepovic T, et al. Flossing for the management of periodontal diseases and dental caries in adults. *Cochrane Database of Systematic Reviews* 2011. doi:10.1002/14651858.cd008829.pub2
49. Al-Zahrani MS, Borawski EA, Bissada NF. Increased physical activity reduces prevalence of periodontitis. *J Dent.* 2005;33(9):703-710. doi:10.1016/j.jdent.2005.01.004
50. Merchant AT, Pitiphat W, Rimm EB, Joshipura K. Increased physical activity decreases periodontitis risk in men. *European Journal of Epidemiology* 2003;18:891-898. doi:10.1023/A:1025622815579
51. Sanders AE, Slade GD, Fitzsimmons TR, Bartold PM. Physical activity, inflammatory biomarkers in gingival crevicular fluid and periodontitis. *J Clin Periodontol.* 2009;36(5):388-395. doi:10.1111/j.1600-051X.2009.01394.x
52. Hiza HAB, Casavale KO, Guenther PM, Davis CA. Diet Quality of Americans Differs by Age, Sex, Race/Ethnicity, Income, and Education Level. *J Acad Nutr Diet.* 2013;113(2):297-306. doi:10.1016/j.jand.2012.08.011
53. Darmon N, Drewnowski A. Does social class predict diet quality? *Am J Clin Nutr.* 2008;87(5):1107-1117. doi:10.1093/ajcn/87.5.1107

## CURRICULUM VITAE



