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Original Article

Inadequate anti-inflammatory diets are associated with an increased risk of tooth loss

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ABSTRACT

Objectives: Anti-inflammatory dietary patterns and their association with tooth loss remain underexplored, despite extensive research on diet and chronic disease. This study aimed to investigate the association between dietary inflammatory potential and tooth loss due to dental disease. **Methods:** Data from the 2015-2016 and 2017-March 2020 waves of the United States National Health and Nutrition Examination Survey were analyzed. A total of 3,828 adults aged ≥20 years who underwent oral examinations and provided two days of dietary recall data for the calculation of the Dietary Inflammatory Index (DII), which is a measure of dietary inflammatory potential, were included. Lower DII scores indicate adherence to an anti-inflammatory dietary pattern. Multivariable linear and negative binomial regression models were used for the analyses. **Results:** Compared with individuals in the lowest DII quintile (indicative of an anti-inflammatory diet), those in the highest quintile (pro-inflammatory diet) exhibited a significantly higher mean ratio (MR) of teeth lost: 1.387 (95% CI: 1.128-1.705). This trend was consistently observed in both the 40–59 and ≥60 years age groups. **Conclusions:** This study found a significant inverse association between anti-inflammatory dietary intake and tooth loss. Targeted dietary counseling and preventive education are essential for reducing the risk of tooth loss in individuals with high consumption of pro-inflammatory nutrients.

Key Words: Cross-sectional studies, Cytokines, C-reactive protein, Diet, Dietary Inflammatory Index, National Health and Nutrition Examination Survey, Tooth loss

Introductions

As contemporary society undergoes swift transformation, the determinants of health are increasingly encompassing not only individual lifestyle and environmental factors but also biological influences, health literacy, and the structure of the healthcare system within a community. This has led to an increased focus on oral health, daily nutritional practices, and general systemic well-being. Specifically, socio-economic development and progress in medical technology have led to an enhancement in life expectancy, thereby resulting in a growing elderly population. This demographic transition has subsequently generated considerable apprehensions regarding the quality of life for older individuals [1,2]. Oral health is a critical determinant of quality of life, given its strong correlation with dietary habits. It plays an essential role in overall well-being and is linked to cognitive functioning and the capacity to engage in daily activities [2].

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Adequate nutrition derived from dietary consumption is crucial for sustaining life; nevertheless, the prevalence of Westernized dietary patterns—characterized by the intake of processed foods, fast food, convenience items, snacks, and sugary beverages—impedes the consumption of essential fiber, vitamins, and minerals. This may result in increased body weight, disturbances in lipid and energy metabolism, immune system dysfunction, and a range of chronic inflammatory conditions [3]. The Dietary Inflammatory Index (DII), created by Shivappa et al. [4], is a quantitative tool designed to assess the relationship between dietary intake and systemic inflammation. It provides a standardized method to numerically evaluate the inflammatory potential of an individual's diet. The index operates under the premise that the correlation between six inflammatory blood markers (IL-1β, IL-4, IL-6, IL-10, TNF-α, and C-reactive protein) and particular dietary factors is stable. The DII has been employed to examine correlations with a range of systemic diseases, such as cardiovascular disease [5], metabolic syndrome [6], type 2 diabetes [7], and chronic obstructive pulmonary disease [8]. In the domain of oral health, Kotsakis et al. [9] conducted an analysis utilizing data from the United States National Health and Nutrition Examination Survey (U.S. NHANES) for the years 2009-2010 and 2011-2012. Their findings indicated a correlation between anti-inflammatory dietary intake and a decrease in tooth loss. This evidence implies that adopting an anti-inflammatory dietary approach could be a viable public health intervention aimed at preventing oral health issues as well as other systemic inflammatory conditions. In a research study that analyzed data from the 2009-2014 U.S. NHANES, Feng et al. [10] found a significant correlation between dietary patterns characterized by elevated DII scores and the incidence of periodontitis, tooth loss, and indicators of systemic inflammation.

Inadequate oral health, stemming from various oral diseases, ultimately culminates in the loss of teeth. Tooth decay and periodontal disease are primary reasons for tooth loss globally. These are prevalent chronic conditions that can impact people of any age. Periodontal disease, especially, tends to increase with age and can lead to tooth loss caused by gingival recession, bleeding, and the destruction of the alveolar bone. Loss of teeth affects chewing ability and can also result in difficulties with speech and problems with the facial and chewing muscles. This issue can complicate eating and may increase the risk of overall malnutrition [11]. Moreover, losing teeth is a major health concern that creates a financial strain not just for individuals, but also for the public health system of a country as a whole. In addition to hindering chewing, losing teeth can negatively impact the grinding, absorption, and digestion of food, which may result in malnutrition. Tooth loss is particularly linked to aging, and its occurrence is on the rise. It has also been noted to have a strong connection with socio-demographic factors [12]. To avoid and lessen tooth loss, it is crucial to implement a dietary approach that reduces chronic inflammation, particularly one that helps ease inflammatory reactions. This method can be seen as an effective way to encourage the adoption of an anti-inflammatory diet in terms of both food choices and nutrition, ultimately improving overall systemic health, including oral health.

To date, few studies have used the DII to evaluate eating habits and their relationship with tooth loss, which is an important aspect of oral health. The U.S. NHANES features a wide variety of ethnic groups and dietary habits, which improves the applicability of the findings regarding the impact of dietary inflammation on the likelihood of tooth loss. This study aimed to determine the association between dietary inflammatory potential and tooth loss due to dental disease, using data from the U.S. NHANES.

Methods

1. Data source and participants

This study utilized data from the U.S. NHANES conducted during 2015–2016 and 2017 through March 2020. Adults aged 20 years or older who underwent an oral examination and completed two days of 24-hour dietary recall interviews were eligible for inclusion. Participants were excluded if they provided only one day of dietary recall data (n=2,804), were on unusual diets for health reasons (n=1,780), reported changes in their usual dietary habits (n=3,392), were pregnant or breastfeeding (n=66), or had incomplete data on confounding variables (n=1,489). A total of 3,828 participants were included in the final analysis <Supplementary Fig. S1>. The Institutional Review Board of Kyungpook National University has granted approval for this study (KNU-2025-0209).

2. Calculate the Dietary Inflammatory Index (DII)

The DII was used to evaluate the inflammatory potential of participants' diets. To construct the DII, Shivappa et al. [4] derived global average intakes and standard deviations for 45 food items from dietary intake data across 11 countries. Furthermore, based on a comprehensive literature review, they assigned each dietary component an Inflammatory Effect score-classified as +1 (pro-inflammatory), 0 (neutral), or -1 (anti-inflammatory)-according to its association with inflammatory markers.

In this study, the DII was calculated using 28 dietary components, as only these were available from the 24-hour dietary recall data provided by the U.S. NHANES. The DII score can theoretically vary from -5.5 to 5.5 when using 25 to 30 dietary factors. Energy consumption is quantified in kilocalories per day (kcal/day), whereas macronutrients encompass protein (g/day), carbohydrates (g/day), total fat (g/day), saturated fatty acids (g/day), monounsaturated fatty acids (MUFA; g/day), polyunsaturated fatty acids (PUFA; g/day), cholesterol (mg/day), and dietary fiber (g/day). Micronutrients encompass a variety of essential vitamins and minerals, including vitamin E (mg/day), vitamin C (mg/day), vitamin A (RE/day), beta-carotene (mcg/day), folate (mcg/day), iron (mg/day), magnesium (mg/day), selenium (mcg/day), niacin (mg/day), riboflavin (mg/day), thiamin (mg/day), vitamin B6 (mg/day), vitamin B12 (mcg/day), and zinc (mg/day). Additional nutrients encompass alcohol (g/day), vitamin D (mcg/day), caffeine (mg/day), omega-3 fatty acids (n-3 fatty acids; g/day), and omega-6 fatty acids (n-6 fatty acids; g/day).

The individualized DII was computed in accordance with the methodology established by Shivappa et al. [4]. Initially, we determined the average daily intake by examining two days of dietary data obtained from each participant through the 24-hour dietary recall methodology. Subsequently, we computed the Z-score by subtracting the global average intake from the individual intake of each food parameter and dividing the resultant value by the global standard deviation. Third, we standardized the Z-score to a range between -1 and +1. Fourth, the normalized Z-score was multiplied by the inflammatory effect score associated with each food parameter in order to compute the DII for each individual food item. Ultimately, a personalized DII was developed by aggregating the DII for each of the 28 food parameters. A higher dietary inflammatory index (positive value) signifies a dietary pattern that may facilitate inflammatory responses within the body or affect the biological pathways associated with such responses [4]. Conversely, a low or negative DII signifies a dietary pattern that is characterized by a comparatively elevated consumption of food components linked to anti-inflammatory effects. The DII was classified into quintiles according to the distribution of scores within the study population. The definitions for each quintile are as follows: 1st quintile (Q1; scores less than -0.110), 2nd quintile (Q2; scores ranging from -0.110 to 1.021), 3rd quintile (Q3; scores from 1.022 to 1.948), 4th quintile (Q4; scores from 1.949 to 2.889), and 5th quintile (Q5; scores equal to or greater than 2.890) <Supplementary Fig. S2>.

3. Definition of tooth loss (number of missing teeth)

Oral examinations for the U.S. NHANES were administered by dentists who are licensed to practice in the United States. These professionals have undergone formal education, clinical training, and have successfully completed standardized examination protocols. Oral examinations were conducted in a mobile examination center that included an oral examination room and utilized indirect lighting, a dental mirror, and a periodontal probe. To exclude unintentional tooth loss due to trauma, only cases attributed to dental disease were included in the count of missing teeth.

4. Confounding variables

In order to address potential confounding variables, we incorporated sociodemographic characteristics, body mass index (BMI), health-related behaviors, and chronic disease indicators into our analysis. Demographic characteristics included age categories (20–39, 40–59, ≥60 years), sex, race/ethnicity (non-Hispanic White, non-Hispanic Black, Asian, other non-Hispanic, Mexican American, other Hispanic), education level (middle school or below, high school, some college or above), income level (low, moderate, or high, based on household poverty thresholds), and marital status (never married, married or living with partner, divorced, separated, or widowed). BMI was categorized as normal or underweight (≤24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30.0 kg/m²) [13]. Health-related behaviors included smoking status (never smoker, former smoker consuming <10 or ≥10 cigarettes per day, occasional smoker, and daily smoker) and physical activity level (inactive, inadequately active, active, and highly active). Hypertension was defined as having a mean systolic/diastolic blood pressure of ≥130/80 mmHg or the use of antihypertensive medications [14]. Diabetes was identified based on at least one of the following: a previous diagnosis, fasting glucose ≥126 mg/dL, glycated hemoglobin (HbA1c) ≥6.5%, or the use of antidiabetic medications [15].

5. Statistical analysis

A multivariable linear regression analysis was performed to investigate the association between the DII and tooth loss. The unstandardized coefficient (β) along with the 95% confidence interval (CI) were computed to assess statistical significance. A negative binomial regression model was employed to assess the risk of tooth loss across the quintiles of the DII. The mean ratio (MR) and the 95% CI for the average number of teeth lost were computed. Weights were assigned to participants in the two-day 24-hour dietary recall interview (WTDR2D) and were subsequently adjusted through post-stratification based on sex, age, and race/ethnicity, in accordance with population estimates provided by the U.S. Census Bureau. Integrated weights from multiple survey cycles were then calculated and applied to the analysis. All statistical analyses were performed using R version 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria), with a significance level of 0.05.

Results

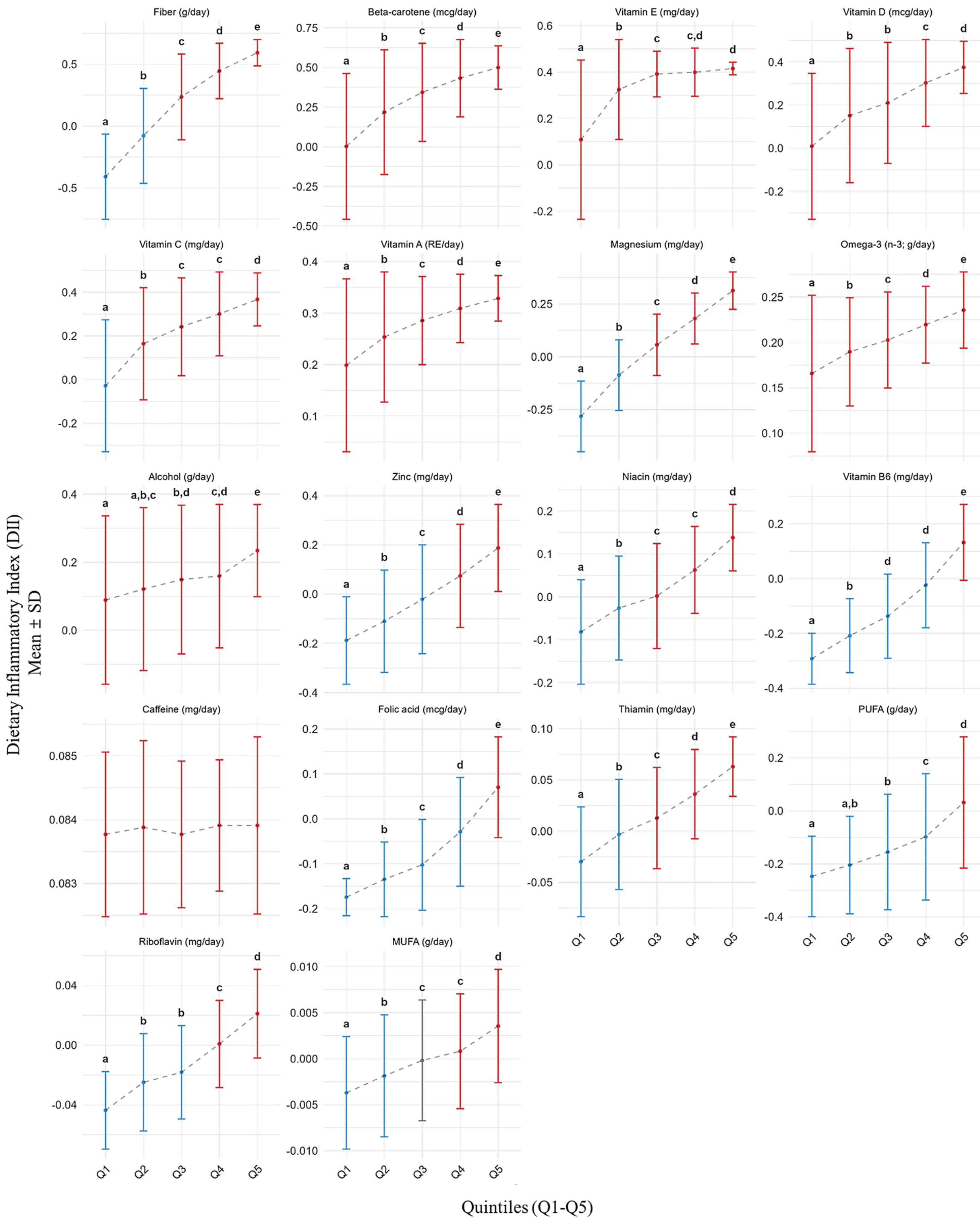
1. General characteristics of the study participants

Among 3,828 participants, 1,166 individuals (36.1%) were within the age range of 20 to 39 years, 1,253 individuals (34.8%) were aged between 40 and 59 years, and 1,409 individuals (29.1%) were aged 60 years or older. The sex distribution consisted of 2,111 males, representing 48.1% of the total, and 1,717 females, accounting for 51.9%. In terms of race and ethnicity, non-Hispanic whites represented the highest proportion, accounting for 64.2%. Regarding educational level, 67.2% of individuals possessed a college degree or a higher qualification. Additionally, 47.7% indicated a high income, while 63.6% were either married or living in a cohabiting arrangement. According to classifications based on BMI, 38.8% of the population was identified as obese, 32.4% as overweight, and 28.8% as either of normal weight or underweight. Regarding health behaviors, the engagement in regular physical activity was the most frequently reported, with 59.6% of participants indicating participation. Conversely, the most commonly reported smoking status was noted at 56.4%. The prevalence rates were 46.0% for hypertension and 11.3% for diabetes. The mean total of natural teeth present was 23.84, whereas the mean number of teeth lost due to dental disease was 3.76 <Table 1>. In the highest quintile of the DII (the upper 20%), the principal nutrients associated with pro-inflammatory effects included dietary fiber (+0.594), beta-carotene (+0.500), vitamin E (+0.415), vitamin D (+0.376), and vitamin C (+0.367) <Fig. 1>.

Table 1. General characteristics of the study participants

Characteristics	Division	N	%
Total		3,828	100.0
Age (yr)	20-39	1,166	36.1
	40-59	1,253	34.8
	60 and older	1,409	29.1
Sex	Male	2,111	48.1
	Female	1,717	51.9
Race/ethnicity	Non-Hispanic white	1,696	64.2
	Non-Hispanic black	780	11.7
	Asian	328	5.8
	Other Non-Hispanic	156	2.6
	Mexican American	480	7.5
	Other Hispanic	388	8.2
Education level	Middle school or below	201	2.4
	High school	1,273	30.4
	Some college or above	2,354	67.2
Income level	Low	948	17.3
	Moderate	1,538	35.0
	High	1,342	47.7
Marital status	Never married	669	18.0
	Married/living with partner	2,340	63.6
	Widowed/divorced/separated/other	819	18.4
Body mass index (kg/m^2)	Mean±SD	29.18±6.90	
	Normal/underweight (≤24.9)	1,057	28.8
	Overweight (25.0-29.9)	1,249	32.4
	Obesity (≥30.0)	1,522	38.8
Smoking status	Never smoked	2,048	56.4
	Former smoker (≤10 cig/day)	562	13.9
	Former smoker (>10 cig/day)	470	12.3
	Occasional smoker	172	4.1
	Daily smoker	576	13.3
Physical activity level	Inactive	876	18.7
	Insufficiently active	504	12.2
	Active	341	9.5
	Highly active	2,107	59.6
Hypertension		2,037	46.0
Diabetes		604	11.3
Number of natural teeth	Mean±SD	23.84±6.98	
Number of tooth loss	Mean±SD	3.76±6.95	
Dietary Inflammatory Index	Mean±SD	1.35±1.68	
	Q1 (<-0.110)	759	20.0
	Q2 (-0.110, 1.021)	734	20.0
	Q3 (1.022, 1.948)	721	20.1
	Q4 (1.949, 2.889)	767	20.0
	Q5 (≥2.890)	847	20.0

N: unweighted frequency; %: weighted percentage; Mean: weighted mean; SD: standard deviation



Notes: One-way ANOVA accounting for the complex survey design was conducted ($P < 0.05$). Post-hoc comparisons using Tukey's HSD were performed for statistically significant variables. No significant differences were observed for caffeine (P=0.184). Red indicates a pro-inflammatory net effect on the DII score, blue indicates an anti-inflammatory effect, and gray indicates no significant contribution to inflammatory potential.
Abbreviations: PUFA, polyunsaturated fatty acid; MUFA, monounsaturated fatty acid.

Fig. 1. Distribution of nutrients with the positive impact on Dietary Inflammatory Index in the highest quintile group (Q5)

2. Association between Dietary Inflammatory Index and tooth loss

Multivariable linear regression analysis demonstrated that an increased DII score was significantly associated with greater tooth loss due to dental disease, even after adjusting for confounders (β=0.275; 95% CI: 0.131–0.418; *p*=0.001) <Table 2>.

Table 2. Linear regression analysis of the association between Dietary Inflammatory Index and tooth loss

Variables	Model 1*			Model 2†		
	β	95% CI	*p*	β	95% CI	*p*
Dietary Inflammatory Index	0.410	0.254-0.566	<0.001	0.275	0.131-0.418	0.001

Multivariable linear regression was conducted accounting for the complex survey design (*p*<0.05).
*adjusted for age, sex, race/ethnicity, education level, income level, marital status, body mass index
†adjusted for age, sex, race/ethnicity, education level, income level, marital status, body mass index, smoking status, physical activity level, hypertension, and diabetes
β: unstandardized coefficient; CI: confidence interval

3. Association between Dietary Inflammatory Index quintiles (Q1–Q5) and tooth loss

Negative binomial regression analysis indicated that the mean number of teeth lost increased progressively across higher quintiles of the DII, even after adjusting for confounders. Specifically, the adjusted MRs of tooth loss due to dental disease were 1.149 (95% CI: 0.923–1.429; *p*=0.191) for the third quintile, 1.224 (95% CI: 0.928–1.614; *p*=0.136) for the fourth quintile, and 1.387 (95% CI: 1.128–1.705; *p*=0.005) for the fifth quintile <Table 3>. In the age-stratified subgroup analysis, no significant differences were observed across DII quintiles among participants aged 20–39 years. However, significant differences were observed among participants aged 40–59 years and those aged ≥60 years. Compared to participants in the first DII quintile, those in the fifth quintile had adjusted MRs of tooth loss of 1.646 (95% CI: 1.025–2.643; *p*=0.041) for the 40–59 age group and 1.322 (95% CI: 1.010–1.731; *p*=0.043) for the ≥60 age group, respectively <Table 4>.

Table 3. Mean ratios for tooth loss according to Dietary Inflammatory Index quintiles (Q1–Q5)

Variables	MR	95% CI	*p*
Model 1*			
Dietary Inflammatory Index (Reference: Q1)			
Q2 (-0.110, 1.021)	1.222	0.991-1.506	0.059
Q3 (1.022, 1.948)	1.258	1.015-1.559	0.037
Q4 (1.949, 2.889)	1.384	1.089-1.758	0.010
Q5 (≥2.890)	1.605	1.303-1.977	<0.001
Model 2†			
Dietary Inflammatory Index (Reference: Q1)			
Q2 (-0.110, 1.021)	1.198	0.972-1.477	0.084
Q3 (1.022, 1.948)	1.149	0.923-1.429	0.191
Q4 (1.949, 2.889)	1.224	0.928-1.614	0.136
Q5 (≥2.890)	1.387	1.128-1.705	0.005

Negative binomial regression was conducted accounting for the complex survey design (*p*<0.05).
*adjusted for age, sex, race/ethnicity, education level, income level, marital status, body mass index
†adjusted for age, sex, race/ethnicity, education level, income level, marital status, body mass index, smoking status, physical activity level, hypertension, and diabetes
MR: mean ratio; CI: confidence interval

Table 4. Mean ratios for tooth loss according to Dietary Inflammatory Index quintiles (Q1–Q5) by age group

Variables	20-39			40-59			≥60		
	MR	95% CI	*p*	MR	95% CI	*p*	MR	95% CI	*p*
Model 1*									
Dietary Inflammatory Index (Reference: Q1)									
Q2 (-0.110, 1.021)	1.050	0.569-1.938	0.871	1.281	0.807-2.034	0.279	1.298	0.989-1.702	0.059
Q3 (1.022, 1.948)	0.900	0.410-1.977	0.784	1.249	0.794-1.964	0.321	1.363	1.049-1.771	0.023
Q4 (1.949, 2.889)	1.192	0.586-2.425	0.613	1.414	0.812-2.461	0.209	1.422	1.070-1.891	0.018
Q5 (≥2.890)	1.394	0.648-2.997	0.378	2.036	1.265-3.277	0.005	1.437	1.079-1.914	0.015
Model 2†									
Dietary Inflammatory Index (Reference: Q1)									
Q2 (-0.110, 1.021)	1.015	0.569-1.810	0.956	1.327	0.842-2.091	0.203	1.234	0.955-1.596	0.100
Q3 (1.022, 1.948)	0.899	0.445-1.813	0.747	1.171	0.719-1.907	0.496	1.242	0.979-1.576	0.071
Q4 (1.949, 2.889)	1.110	0.565-2.182	0.743	1.289	0.724-2.296	0.360	1.262	0.942-1.691	0.109
Q5 (≥2.890)	1.414	0.690-2.896	0.315	1.646	1.025-2.643	0.041	1.322	1.010-1.731	0.043

Negative binomial regression was conducted accounting for the complex survey design ($p<0.05$).
*adjusted for age, sex, race/ethnicity, education level, income level, marital status, body mass index
†adjusted for age, sex, race/ethnicity, education level, income level, marital status, body mass index, smoking status, physical activity level, hypertension, and diabetes
MR : mean ratio; CI : confidence interval

Discussion

This study aimed to explore the association between dietary inflammatory potential and tooth loss due to dental disease. The results showed that participants in the most pro-inflammatory diet group (DII quintile 5) had a significantly greater mean number of teeth lost compared to those in the most anti-inflammatory diet group (DII quintile 1). This trend was consistently observed in both the 40–59 and ≥60 age groups. These findings suggest that a higher dietary inflammatory potential is associated with an increased risk of tooth loss in middle-aged and older adults.

Beta-carotene, vitamin E, and vitamin D-all known for their anti-inflammatory properties-were consistently consumed at inadequate levels across all DII quintiles (Q1-Q5), which contributed to elevated DII scores <Fig. 1>. Beta-carotene, a carotenoid and natural pigment found in numerous fruits and vegetables, is recognized for its ability to modulate systemic inflammatory responses, which can be ascribed to its antioxidant and anti-inflammatory properties. A significant decrease in serum C-reactive protein levels has been observed in individuals following a diet rich in beta-carotene [16]. Vitamin E is found in a variety of plant-based foods, including cooking oils, almonds, spinach, and broccoli. It is acknowledged as one of the most essential fat-soluble antioxidants that contribute to the maintenance of homeostasis within the body [17]. A meta-analysis suggests that α-tocopherol is the most bioactive form of vitamin E. Additionally, a daily supplementation of 500 mg or more has been statistically associated with an average reduction in C-reactive protein levels of 0.52 mg/L [18]. Although the exact mechanism by which vitamin D operates is not fully understood, current research suggests that it has a variety of regulatory effects on both the innate and adaptive immune systems [19]. Research has demonstrated that elevated inflammation associated with insufficient magnesium intake has been observed across various tertiles. A retrospective cohort study conducted among U.S. adults identified a relationship between low magnesium consumption and elevated levels of inflammatory markers, including high-sensitivity C-reactive protein, which is implicated in the development of systemic inflammation and metabolic disorders [20]. Moreover, heightened inflammation levels linked to insufficient zinc intake were observed across various quintiles <Fig. 1>. Zinc is essential for the regulation of cellular proliferation and differentiation, and the immune system, which relies heavily on effective cellular proliferation, is particularly susceptible to zinc deficiencies [21]. The DII is predicated on the hypothesis that six inflammatory biomarkers present in the bloodstream-specifically IL-1β, IL-4, IL-6, IL-10, TNF-α, and C-reactive protein-exhibit interconnections [4]. This interrelationship suggests that chronic systemic inflammation, which may result from a diet deficient in anti-inflammatory components, could contribute to the incidence of tooth loss.

By categorizing the DII into quintiles and analyzing the contribution of individual dietary components, we found that the increase in DII was primarily attributable to the inadequate intake of anti-inflammatory nutrients <Fig. 1>. Inadequate management of systemic inflammation via a suitable anti-inflammatory diet may compromise immune responses to periodontopathogenic bacteria, thereby increasing the likelihood of tooth loss. Middle-aged Americans, particularly those aged 45 to 64 years, demonstrate the highest prevalence of severe periodontitis and are at a heightened risk for tooth loss [22]. Periodontitis has the potential to induce systemic inflammation via various mechanisms. Instances encompass the hematogenous dissemination of periodontal pathogens and inflammatory mediators, in addition to the systemic migration of activated lymphocytes [23]. This form of persistent low-grade inflammation is acknowledged as a significant contributor to the onset of several metabolic disorders. Type 2 diabetes mellitus, which is characterized by the development of insulin resistance, adversely affects the cellular repair mechanisms that respond to damage inflicted by subgingival bacteria. This dysfunction is linked to increased concentrations of inflammatory cytokines, such as interleukin-1β and interleukin-6, in addition to elevated levels of C-reactive protein, a marker indicative of acute-phase inflammation. Consequently, the persistent accumulation of low-grade chronic inflammation may ultimately result in the loss of teeth [24]. Furthermore, visceral fat, which plays a crucial role in the development of abdominal obesity, secretes inflammatory adipokines such as tumor necrosis factor-α and interleukin-6 [25]. These molecules are recognized for their ability to disturb metabolic equilibrium and intensify low-grade chronic inflammation. Tooth loss is commonly noted among individuals exhibiting abdominal obesity [26], indicating that chronic inflammation associated with metabolic dysregulation may intensify periodontal inflammation, thereby contributing to the loss of teeth. The mitigation and management of systemic inflammation are essential for the prevention of metabolic disorders and the reduction of the likelihood of tooth loss. Consequently, adhering to an anti-inflammatory diet is crucial for reducing systemic inflammation and preserving metabolic equilibrium.

Research indicates that around 21% of American adults between the ages of 20 and 64 have untreated dental caries [27], whereas a significant 96% of individuals aged 65 and older have encountered dental caries at some point in their lives [28]. Tooth loss attributable to dental disease, as delineated in this research, encompasses loss resulting from dental caries, which may possess limited efficacy as a mediator of systemic inflammation. By analyzing the diverse characteristics of anti-inflammatory foods, it is possible to ascertain their potential advantages. The dietary component exhibiting the lowest consumption within the quintile of the DII was dietary fiber <Fig. 1>. Dietary fiberis present in whole grains, vegetables, and fruits, promotes the self-cleaning effect in the oral cavity and provides various micronutrients essential for maintaining oral health. Research conducted on adults in the United States has identified a relationship between insufficient dietary fiber consumption and a heightened risk of dental caries [29]. Consequently, it is imperative to prioritize sufficient fiber consumption as a means of enhancing dietary practices aimed at preventing tooth loss.

This study's strengths include the use of nationally representative data, which ensures external validity through post-stratification adjustments and survey weighting. Moreover, subgroup analyses considering age-related differences in tooth loss were conducted, enabling more detailed and robust findings through complex statistical approaches. Despite these strengths, this study has certain limitations. First, the DII assesses the inflammatory potential of nutrients but does not fully capture dietary patterns, including food types and processing levels. Further analysis considering these factors is needed. Second, this research employed only 28 out of the 45 available items to compute the DII, thereby constraining the interpretation of the findings. Third, a two-day period of 24-hour dietary recall may not provide a comprehensive representation of an individual's overall dietary consumption. Nevertheless, by omitting participants whose dietary consumption may have been affected and implementing a weighting adjustment that accounted for the day of the week and non-response (WTDR2D), we improved the robustness of our results. Fourth, tooth loss due to other causes was not considered in this study. Subsequent research should incorporate a more comprehensive array of factors that influence tooth loss. Fifth, this research is grounded in data from the U.S., its findings may have limited generalizability to the dietary patterns and cultural characteristics specific to Korea. Nonetheless, the principal benefit of employing U.S. data lies in its representation of a wide range of ethnicities, dietary practices, and cultural contexts. This diversity facilitates a more comprehensive assessment of the hypothesis concerning the association between dietary inflammation and tooth loss. Future research endeavors should include data from Korea. Furthermore, by conducting comparative analyses of the findings from this study alongside data from both the United States and Korea, researchers will be able to evaluate the influence of ethnic and cultural variables on the association between anti-inflammatory dietary consumption and tooth loss attributable to dental disease.

Conclusions

This study aimed to examine the association between dietary inflammatory potential and tooth loss due to dental disease, using data from the U.S. NHANES.

1. A progressive increase in the mean number of teeth lost was observed across DII quintiles. Participants in the most pro-inflammatory diet group (DII quintile 5) exhibited a mean tooth loss that was 1.387 times as high as those in the most anti-inflammatory diet group (DII quintile 1).

2. Age-stratified subgroup analysis revealed that within the 40–59 and ≥60 age groups, participants in the most pro-inflammatory diet group (DII quintile 5) had mean tooth losses 1.646 and 1.322 times as high, respectively, as those in the most anti-inflammatory diet group (DII quintile 1).

In middle-aged and older adults, inadequate consumption of anti-inflammatory dietary components has been associated with an increased risk of tooth loss due to dental disease. This underscores the importance of dietary recommendations and preventive education for individuals who consume a high quantity of pro-inflammatory foods, as these measures may contribute to a decreased risk of tooth loss.

Notes

Author Contributions

Conceptualization: YJ Lee, YE Lee; Data collection: YJ Lee, HJ Go; Formal analysis: YJ Lee, HJ Go; Writing-original draft: YJ Lee, HJ Go, YE Lee; Writing-review&editing: YJ Lee, HJ Go, JM Kang, YE Lee

Conflicts of Interest

YE Lee is a member of the Editorial Committee of the Journal of the Korean Society of Dental Hygiene, but was not involved in the review process of this manuscript. The authors declare no other conflicts of interest.

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None.

Ethical Statement

The study was approved as exempt by the Kyungpook National University Institutional Review Board (KNU-2025-0209) for secondary analysis of de-identified U.S. NHANES data.

Data Availability

The U.S. NHANES data files used in this study are publicly available on the official website, provided by the Centers for Disease Control and Prevention.

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항염증 식이 섭취 부족과 치아상실 위험 연관성 분석

초록

연구목적: 만성질환과 식이에 대한 활발한 연구에도 불구하고, 항염증 식이 패턴과 치아 상실 간의 연관성은 상대적으로 충분히 규명되지 않았다. 본 연구는 항염증 식이와 치아 상실과의 연관성을 확인하는 것을 목적으로 하였다. **연구방법:** 본 연구는 미국 국민건강영양조사(NHANES) 2015–2016년 및 2017-2020년 3월까지의 자료를 활용하였다. 총 3,828명의 20세 이상 성인이 구강검진을 완료하고 최소 2일 이상의 식이조사 자료를 제공하여 분석에 포함되었다. 식이 염증지수(Dietary Inflammatory Index, DII)는 28개 식이 지표를 이용해 산출하였으며, 다중 선형 회귀분석을 적용하여 DII 수준과 치아 상실 간의 연관성을 평가하였다. **연구결과:** 식이염증지수가 가장 낮은 1분위(항염증 식이 그룹)와 비교하였을 때, 가장 높은 5분위(염증성 식이 그룹)의 경우 평균 상실치아 수가 유의하게 많았다($p<0.05$). 이러한 경향은 40–59세와 60세 이상 연령군 모두에서 일관되게 나타났으며, 특히, 5분위 그룹은 1분위 대비 평균 상실치아 수의 비가 1.387배 높았으며, 연령 하위분석에서도 유의하게 증가하였다($p<0.05$). **결론:** 항염증 식이 섭취 부족은 치과질환으로 인한 치아상실 위험 증가와 유의한 연관성을 보였다. 중장년층 및 노인을 중심으로 한 예방적 식이지도와 교육은 치아상실 위험을 낮추는 데 효과적인 전략이 될 수 있다.

색인: 단면 연구, 사이토카인, C-반응성 단백질, 식이, 식이염증지수, 국민건강영양조사, 치아상실

Supplementary Materials

Table S1. Global standards for nutrients with mean intake, standard deviation, and corresponding inflammatory effect scores

Variables	Mean	SD	Inflammatory effect score
Energy (kcal)	2,056	338	0.180
Macronutrients			
Protein (g/day)	79.40	13.90	0.021
Carbohydrate (g/day)	272.20	40.00	0.097
Total fat (g/day)	71.40	19.40	0.298
Saturated fat (g/day)	28.60	8.00	0.373
MUFA (g/day)	27.00	6.10	-0.009
PUFA (g/day)	13.88	3.76	-0.337
Cholesterol (mg/day)	279.40	51.20	0.110
Fiber (g/day)	18.80	4.90	-0.663
Micronutrients			
Vitamin E (mg/day)	8.73	1.49	-0.419
Vitamin C (mg/day)	118.20	43.46	-0.424
Vitamin A (RE/day)	983.90	518.60	-0.401
Beta-carotene (mcg/day)	3,718	1,720	-0.584
Folic acid (mcg/day)	273.00	70.70	-0.190
Iron (mg/day)	13.35	3.71	0.032
Magnesium (mg/day)	310.10	139.40	-0.484
Selenium (mcg/day)	67.00	25.10	-0.191
Niacin (mg/day)	25.90	11.77	-0.246
Riboflavin (mg/day)	1.70	0.79	-0.068
Thiamin (mg/day)	1.70	0.66	-0.098
Vitamin B6 (mg/day)	1.47	0.74	-0.365
Vitamin B12 (mcg/day)	5.15	2.70	0.106
Zinc (mg/day)	9.84	2.19	-0.313
Other nutrients			
Alcohol (g/day)	13.98	3.72	-0.278
Vitamin D (mcg/day)	6.26	2.21	-0.446
Caffeine (mg/day)	8.05	6.67	-0.110
n-3 fatty acids (g/day)	1.06	1.06	-0.436
n-6 fatty acids (g/day)	10.80	7.50	-0.159

Notes: Dietary Inflammatory Index scores were derived from 11 international dietary surveys by scoring 45 food parameters based on their pro- or anti-inflammatory effects (+1, 0, −1) on six biomarkers: IL-1β, IL-4, IL-6, IL-10, TNF-α, and CRP. Adopted from Public Health Nutrition 2013;17(8):1689–96. https://doi.org/10.1017/S1368980013002115
PUFA: polyunsaturated fatty acid; MUFA: monounsaturated fatty acid

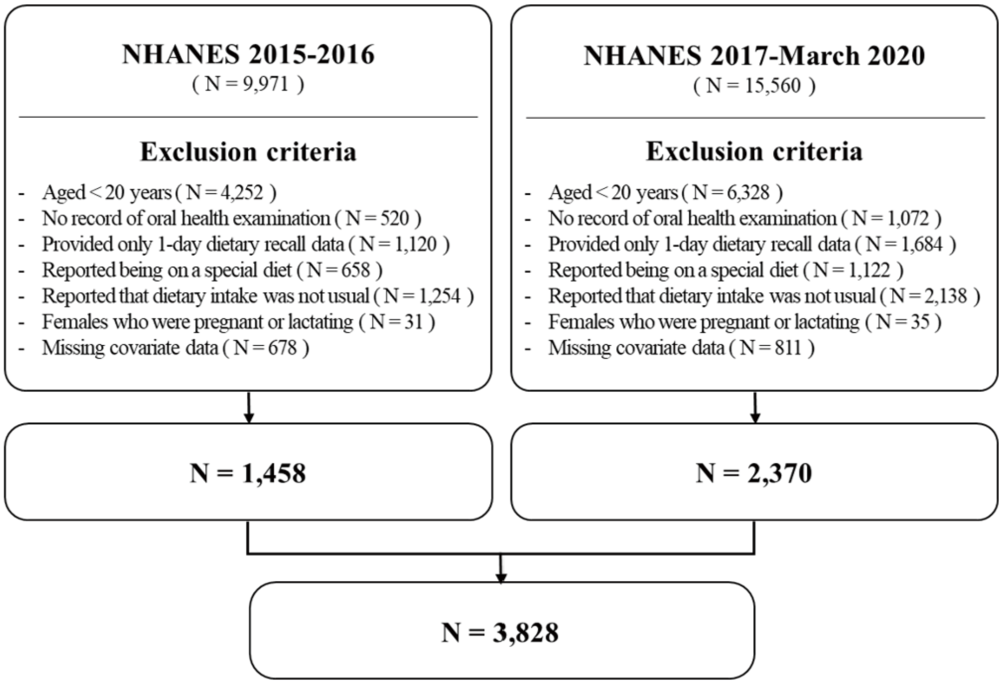

Fig. S1. Flow diagram of participant selection
Abbreviation: NHANES, National Health and Nutrition Examination Survey

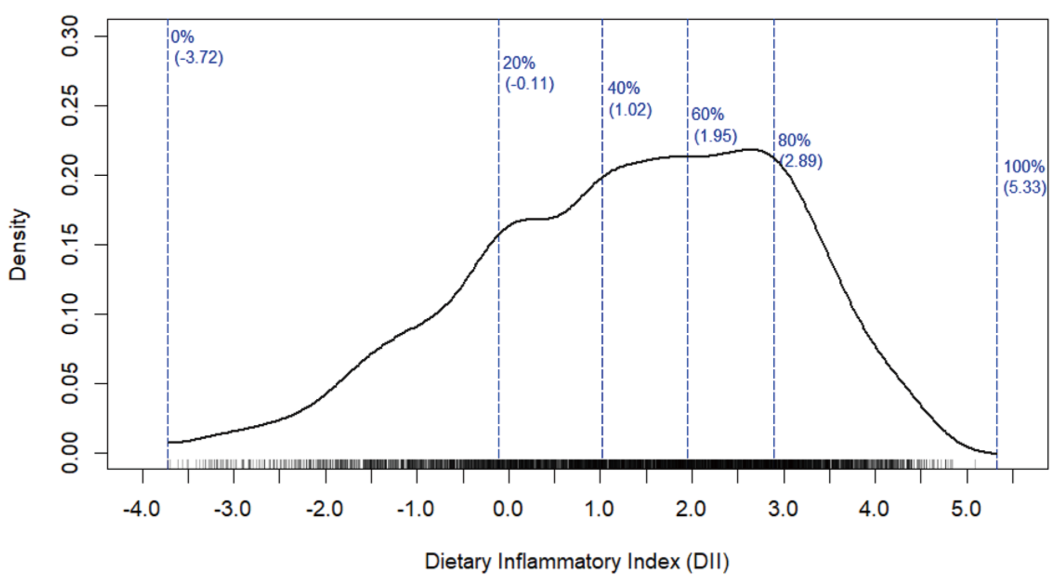

Fig. S2. Distribution of Dietary Inflammatory Index