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Association between dietary quality and the prevalence of periodontitis in older Korean adults aged 60 or over

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

ABSTRACT

Purpose: This study investigated the association between dietary quality and the prevalence of periodontitis in older Korean adults (≥60 years of age) using data from the seventh Korea National Health and Nutrition Examination Survey (KNHANES VII, 2016–2018).
Methods: Among the 16,489 KNHANES participants from 2016–2018, those aged ≥60 years were selected as the eligible population. After applying our exclusion criteria, 3,527 participants were included in the final study population. Periodontal status was measured using the Community Periodontal Index (CPI). To determine the association between dietary quality and the prevalence of periodontitis, analysis of variance, the chi-square (χ^2) test, and logistic regression analysis were performed.
Results: The population was divided into quartile groups and stratified by sex. The percentage of men and women with periodontitis was 54.34% and 42.74%, respectively. The quartile with higher Korean Healthy Eating Index scores had a lower percentage of people with periodontitis in both sexes. For men, only vegetable intake showed a significant difference between sub-groups with or without periodontitis, whereas, for women, the intake of fruits, milk, sweets, carbohydrates, and fats showed significant differences. There was a strong positive association between vegetable intake and periodontitis in men in the 3 models used in this study; model 3 had an adjusted odds ratio (aOR) of 1.367 (95% confidence interval [CI], 1.091–1.712). In women, a strong positive association with periodontitis was shown for sweets in all 3 models, with an aOR of 1.477 in model 3 (95% CI, 1.125–1.939).
Conclusions: Dietary quality was inversely associated with the prevalence of periodontitis in Korean adults aged ≥60 years. Further comprehensive studies are needed to help establish nutrition and health policies for older adults in Korea.

Keywords: Aged; Cross-sectional study; Healthy diet; Periodontitis

INTRODUCTION

Periodontitis is a complex chronic disease that causes progressive destruction of teeth-supporting structures such as periodontal ligaments and alveolar bones. The disease involves

Author Contributions

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complex dynamic interactions among active herpesviruses, certain bacterial pathogens, and destructive immune responses. Severe periodontitis can lead to a complete loss of teeth and reduced quality of life [1,2].

The global prevalence of periodontitis is well known. Approximately 11% of the world's population may have severe periodontitis, affecting 743 million individuals [3,4]. When compared with other chronic diseases, the prevalence of severe periodontitis is lower than that of hypertension (1,130 million), but higher than those of diabetes (463 million), depression (264 million), and asthma (235 million) [2]. Periodontitis is a common disease among adults, affecting 34.5% of Koreans above the age of 30 years according to the seventh Korean National Health and Nutrition Examination Survey (KNHANES VII, 2016–2018) [5]. According to the KNHANES VII, the prevalence of periodontitis was 46.3% among people aged 60–69 years and 47.9% among people over 70 years old.

The Healthy Eating Index (HEI) evaluates the overall quality of consumers' diets based on the dietary guidelines of the Department of Health and Human Services in the United States [6]. The HEI defines dietary quality as an individual's degree of adherence to dietary guidelines. The index consists of multiple component scores for the dietary quality of specific elements, and a total score for overall dietary quality. The components and scoring system of the Korean Healthy Eating Index (KHEI) is based on the HEI of the United States [7]. The index was modified to reflect the eating habits of Koreans based on the Dietary Guidelines for Koreans, and the Dietary Reference Intake for Koreans by the Korea Center for Disease Control and Prevention (KCDC; now the Korea Disease Control and Prevention Agency [KDCA]) [8,9].

Several epidemiological studies have reported on the association between dietary quality (using the KHEI) and other chronic or mental diseases, such as metabolic syndrome, cardiovascular diseases, and depression [10-12]. However, reports on the association between dietary quality and oral-related diseases have been limited to specific foods like nutritional supplemental drinks and yogurt that were associated with better periodontal health [13,14]. This study evaluated the association between the overall dietary quality of older Korean adults and the prevalence of periodontitis using the recently developed KHEI.

MATERIALS AND METHODS

Data source and study population

This was a cross-sectional study based on data from the nationwide KNHANES VII (2016–2018). The KNHANES VII is a population-based survey examining the general health and nutritional status of Koreans, conducted by the KCDC from 2016 to 2018 [5]. Our survey protocols were approved by the Institutional Review Board (IRB) of the KCDC (approval number: 2018-01-03-P-A).

Of the 16,489 participants in the KNHANES VII, 4,623 (1,996 men and 2,627 women) were aged ≥60 years. Since periodontitis was more prevalent and severe in the KNHANES VII participants ≥60 years, they became the eligible population for our study. Among this population, those with non-responses or missing values were excluded. Of the possible confounders, most non-responses or missing values were for the Community Periodontal Index (CPI) (n=482), HEI-related variables (n=447), education level (n=267), and economic

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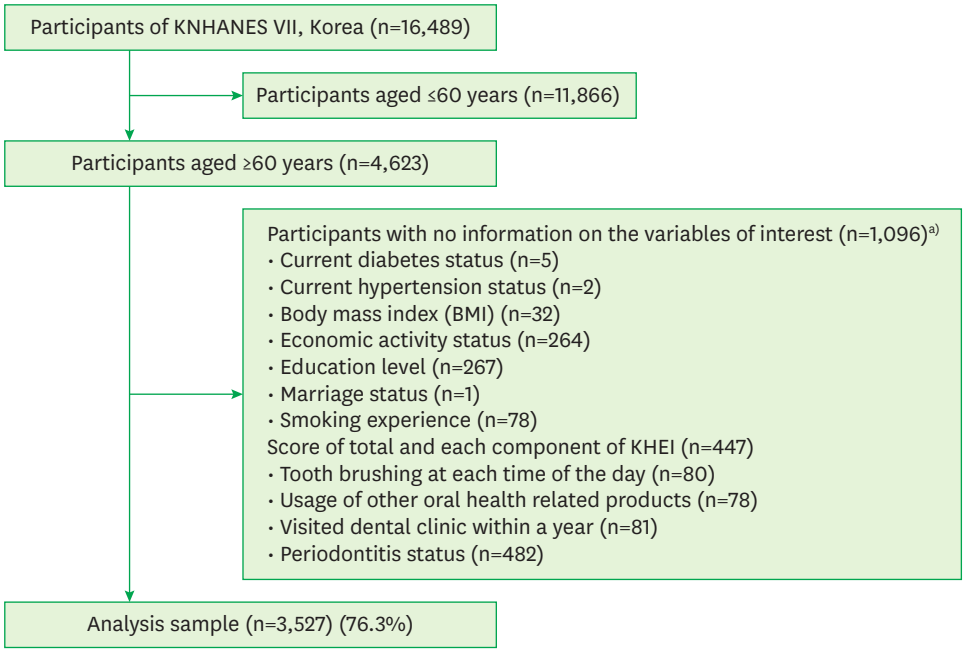

Figure 1. Flowchart of the participants included in this study of dietary quality and the prevalence of periodontitis in older Korean adults.
KNHANES VII: seventh Korea National Health and Nutrition Examination Survey.
a)Some participants were without several variables.

status (n=264). A final total of 3,527 older adult participants (1,496 men and 2,031 women) were included in this study (**Figure 1**).

The sample size required for this study was calculated using the single population proportion formula:

$$\text{Sample size} = \frac{(\text{Z} - \text{score})^2 \times \text{Prevalence} \times (1 - \text{Prevalence})}{(\text{Precision})^2}$$

The Z-score equaled 1.96 at a 5% level of significance, and the precision or confidence interval (CI) was set at 95. The prevalence of periodontitis in the Korean population has been reported to be 23.4% [15]; thus, a sample size of 276 was required for this study.

Periodontal examinations

The periodontal status of each participant was evaluated using the CPI developed by the World Health Organization (WHO) [16]. The maxillary arch and the mandibular arch were each divided into 3 sections; canine to canine, left premolar and molar, and right premolar and molar. The periodontal status of 10 index teeth, 2 molars in each posterior sextant, and the upper right and lower left central incisors, were measured to evaluate whether there was periodontitis in each sextant [17]. The evaluation was done following the WHO guideline using a CPI probe at 6 sites (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual) for each index tooth. If there was a missing index tooth in the sextant, only the existing ones were evaluated. If there were <2 remaining teeth in the sextant, the data for the remaining tooth was included in another sextant of the same jaw [18]. The CPI score for each sextant was recorded in 5 levels (0 to 4) and a score of 3 or 4 indicated a section with periodontitis. For this study, we considered everyone with periodontitis in any section of the sextant as a participant with periodontitis.

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Dietary assessment and the KHEI

The KHEI is an index developed by the KCDC to evaluate the quality of Korean diets. There are 14 components in the KHEI, and each component is scored either 0–5 or 0–10 by assessing adherence to national dietary guidelines. Eight out of 14 components (breakfast, whole grains, fruits, vegetables, meat/fish/eggs and beans, and milk and dairy) are evaluated to determine the adequacy of the recommended food and nutrient intake. Three components (saturated fatty acids, sodium, and sweets and beverages) are based on the moderation of food or nutrition intake. The last 3 components (carbohydrates, total fat, and energy) are based on the balance of energy intake. A maximum overall KHEI score is 100 points, and the minimum score is 0; a higher score means that the participant adheres to a healthier diet [7].

Assessment of covariates

Information on covariates was obtained using self-reporting questionnaires. The sociodemographic factors and risk factors included in the analysis were age, sex, education level, region, occupation status, marriage status, body mass index (BMI), hypertension, diabetes, smoking status, and tooth brushing frequency. Education level was defined as the highest diploma the participant had received: college or higher, high school, middle school, and elementary school or lower. Region was divided into city and rural regions. For BMI, participants were classified as obese (BMI >25 kg/m^2) and not obese (BMI ≤25 kg/m^2) [19]. Hypertension was defined as an average systolic blood pressure of ≥140 mmHg or an average diastolic blood pressure of ≥90 mmHg. Diabetes was determined by a fasting blood sugar ≥126 mg/dL. For smoking status, participants were divided into 2 groups, smokers and nonsmokers. Tooth brushing frequency was defined by whether participants brushed their teeth less than twice a day, or twice or more a day.

Statistical analysis

The KHEI score was divided into quartiles, and then stratified by sex to analyze the association with periodontitis. Three models are used in this analysis. In model 1, only socioeconomic covariates were adjusted. A dental covariate (tooth brushing frequency) was added for model 2. In model 3, additional medical covariates (hypertension and smoking experience) were included. For analysis of the KHEI components, each component was divided into 2 or 3 sub-groups depending on the distribution of scores. The distribution of scores for some components was heavily skewed, with most of the population scoring either 0 or the maximum score. For those components, the population was dichotomized. For "breakfast," "total vegetables, including kimchi and pickles," "vegetables, excluding kimchi and pickles," "meat, fish, eggs, and beans," "saturated fatty acid," "sodium," and "sweets and beverages," the sub-groups were divided into those with a maximum score and those without a maximum score. For these categories, sub-groups with maximum scores were used as the reference for logistic analysis. For "milk and dairy" and "carbohydrates," the sub-groups were divided into scores of zero and not zero. For these categories, the zero score sub-group was used as the reference for logistic analysis. For the components that did not have a skewed score distribution ("whole grain," "total fruit, including juice," "fruit, excluding juice," "fat," and "total energy") the population was divided into 3 groups, where group 1 included the population with a score of 0, group 3 included the population with a maximum score, and group 2 included the population with scores in-between (**Supplementary Table 1**).

To test for significance in the differences between quartiles for each category, an analysis of variance for continuous variables and a chi-square (χ^2) test for noncontinuous variables were used, with significance set at P<0.05. Logistic regression analyses were performed to

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examine the association between the KHEI and periodontitis by calculating odds ratios (ORs) with 95% CIs. The analyses were adjusted for covariates that showed significance. Post hoc analysis using the Dunn test with alpha=0.05 was performed to analyze whether significant differences were present between pairs of quartile groups. As a sensitivity test, categories that showed a statistically significant OR were reconverted into continuous variables and reanalyzed with multivariate logistic regression. All statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA).

RESULTS

General characteristics of the participants

A total of 3,527 participants (1,496 men and 2,031 women) were included in this study. The mean age of the study population was 69.47±6.32 years for men and 69.59±6.44 years for women. The mean KHEI score was 66.74±12.12 for men and 68.55±12.97 for women. The general characteristics and oral-related variables of the study population according to the KHEI score quartiles are shown in **Table 1**. The number of participants in each quartile is also presented in **Table 1**. Both men and women in the quartile with the highest KHEI score (Q4) were more likely to have received a higher education, live in an urban region, be married, and currently live together than the quartile with the lowest KHEI score (Q1). In addition, they were less likely to have hypertension, never smoked, brushed their teeth twice or more a day, and used other oral-care supplies like dental floss or an interdental brush. However, there were no significant differences in occupation status, BMI, and diabetes among the KHEI score quartiles.

Relationship of periodontitis to dietary quality

The periodontitis status and number of participants in each quartile are shown in **Table 2**. Participants with at least 1 index tooth and a CPI score of 3 or 4 were considered to have periodontitis. Since a pocket depth of ≥4 mm is required for a CPI score of 3 or 4, it is highly likely that those participants had progressive periodontitis and needed periodontal treatment like deep scaling. The percentage of subjects with periodontitis was 54.34% in men and 42.74% in women. There were more women in Q4 than in Q1, while Q1 contained more men than women. The Q4 participants had a lower rate of periodontitis in both sexes. The proportion of subjects with periodontitis was 58.82% in Q1 versus 50.00% in Q4 in men (P=0.0483), and the corresponding proportions in women were 48.41% and 37.23%, respectively (P=0.0039). These findings show a lower prevalence of periodontitis in people with higher KHEI scores. The only significant difference in the post-hoc analysis was between Q1 and Q4 in women.

Comparison of KHEI component scores according to the presence of periodontitis

Statistically significant differences in the 14 components of the KHEI scores according to sex and periodontitis status were analyzed (**Table 3**). For men, only vegetables excluding kimchi and pickles (P=0.0055) showed a significant difference according to the presence of periodontitis. For women, more KHEI components showed a significant difference between those with periodontitis and those without periodontitis: total fruit including juice (P=0.0077), milk and dairy (P=0.0025), sweets and beverages (P=0.0026), carbohydrates (P=0.004) and fats (P=0.0197).

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Table 1. General characteristics of study population according to the quartiles of KHEI score (n=3,527)

Variables	Categories	Men						Women					
		Total	Q1 (total=408)	Q2 (n=400)	Q3 (n=370)	Q4 (n=318)	*P* value	Total	Q1 (n=473)	Q2 (n=482)	Q3 (n=512)	Q4 (n=564)	*P* value
Age		69.47±6.32	69.89±6.70	68.87±6.23	69.66±6.18	69.45±6.07	<0.0001	69.59±6.44	71.34±6.94	69.99±6.57	68.95±6.10	68.35±5.80	<0.0001
Education level	College or higher	298	38	66	82	112	<0.0001	150	9	26	46	69	<0.0001
	High school	404	98	99	111	96		295	36	58	87	114	
	Middle school	268	89	69	64	46		333	55	74	83	121	
	Elementary school or lower	526	183	166	113	64		1,253	373	324	296	260	
Region	Urban	1,132	285	277	300	270	<0.0001	1,551	318	350	411	472	<0.0001
	Rural	364	123	123	70	48		480	155	132	101	92	
Occupational status	Yes	739	196	211	184	148	0.3685	707	155	172	195	185	0.2164
	No	757	212	189	186	170		1,324	318	310	317	379	
Marriage status	Married	1,307	326	346	344	291	<0.0001	1,199	223	264	338	374	<0.0001
	Not married	21	13	4	1	3		15	2	4	1	8	
	Married, other	168	69	50	25	24		817	248	214	173	182	
BMI	Obese	517	135	129	137	116	0.4157	813	199	213	201	200	0.0252
	Not Obese	979	273	271	233	202		1,218	274	269	311	364	
Hypertension	Yes	726	215	203	179	129	0.0085	1,006	256	256	249	245	0.0018
	No	770	193	197	191	189		1,025	217	226	263	319	
Diabetes	Yes	327	99	76	81	71	0.3424	390	96	104	99	91	0.1361
	No	1,169	309	324	289	247		1,641	377	378	413	473	
Ever smoker	Yes	1,179	339	317	287	236	0.0309	116	53	27	24	12	<0.0001
	No	317	69	83	83	82		1,915	420	455	488	552	
Tooth brushing frequency	2 or more times a day	1,158	277	314	290	277	<0.0001	1,791	381	417	468	525	<0.0001
	less than 2 times a day	338	131	86	80	41		240	92	65	44	39	

Values are presented as mean ± standard deviation or number (%). KHEI score for men, Q1: 20.88–59.23 Q2: 59.32–68.01 Q3: 68.06–76.73 Q4: 76.77–95.85; KHEI score for women, Q1: 24.98–59.27 Q2: 59.28–68.04 Q3: 68.05–76.71 Q4: 76.73–99.47.
KHEI: Korean Healthy Eating Index, BMI: body mass index.

Table 2. Periodontitis prevalence of the study population

Dependent variables	Categories	Men						Women					
		Q1 (n=408)	Q2 (n=400)	Q3 (n=370)	Q4 (n=318)	*P* value	Post hoc	Q1 (n=473)	Q2 (n=482)	Q3 (n=512)	Q4 (n=563)	*P* value	Post hoc
Periodontitis	Yes	240 (58.82)	225 (56.25)	189 (51.08)	159 (50.00)	**0.0483**	-	229 (48.41)	210 (43.57)	219 (42.77)	210 (37.30)	**0.0039**	Q1>Q4
	No	168 (41.18)	175 (43.75)	181 (48.92)	159 (50.00)			244 (51.59)	272 (56.43)	293 (57.23)	354 (62.88)		

Bold style *P* values indicate statistical significance.

Table 3. Differences in KHEI component by periodontitis prevalence

Dependent variables	Periodontitis	Men				Women			
		Group 1	Group 2	Group 3	*P* value	Group 1	Group 2	Group 3	*P* value
Breakfast (0–10)	Yes	64	749		0.7696	93	775		0.4224
	No	51	632			112	1,051		
Whole grains (0–5)	Yes	286	224	303	0.7189	260	328	280	0.9772
	No	227	191	265		348	435	380	
Total fruit, including juice (0–5)	Yes	288	277	248	0.0651	266	201	401	**0.0077**
	No	218	218	247		291	262	610	
Fruit, excluding juice (0–5)	Yes	369	98	346	0.2495	316	64	488	0.1967
	No	286	77	320		383	80	700	
Total vegetable, including kimchi and pickles (0–5)	Yes	500	313		0.134	564	304		0.7279
	No	394	289			747	416		
Vegetable, excluding kimchi and pickles (0–5)	Yes	575	238		**0.0055**	538	330		0.3104
	No	437	246			695	468		
Meat, fish, eggs, and beans (0–10)	Yes	548	265		0.3905	569	299		0.8203
	No	446	237			768	395		
Milk and dairy (0–10)	Yes	571	242		0.6808	567	301		**0.0025**
	No	473	210			683	480		
Saturated fatty acid (0–10)	Yes	141	672		0.8544	143	725		0.8611
	No	116	567			195	969		
Sodium (0–10)	Yes	633	180		0.9882	481	387		0.3271
	No	532	151			619	544		
Sweets and beverage (0–10)	Yes	99	714		0.2055	128	740		**0.0026**
	No	69	614			120	1,043		
Carbohydrate (0–5)	Yes	315	498		0.2525	444	424		**0.004**
	No	245	438			520	643		
Fat (0–5)	Yes	256	237	320	0.2653	342	229	297	**0.0197**
	No	192	197	294		389	327	447	
Total energy (0–5)	Yes	210	169	434	0.1648	260	202	406	0.078
	No	156	167	360		296	284	583	

Bold style *P* values indicate statistical significance.
KHEI: Korean Healthy Eating Index.

Odds ratios for periodontitis according to KHEI score

The adjusted ORs (aORs) with 95% CIs for periodontitis derived from logistic analysis according to KHEI scores are presented in **Table 4**. Interestingly, in men, the aOR for periodontitis and the total KHEI scores showed a negative association up to model 2 in Q3 (OR, 0.734; 95% CI, 0.548–0.982) and Q4 (OR, 0.710; 95% CI, 0.521–0.969), but not in model 3. In women, the adjusted OR for periodontitis and total KHEI scores showed a negative association up to model 2 in Q4 (OR, 0.763; 95% CI, 0.587-0.990), but not in model 3.

When we analyzed the adjusted OR for periodontitis in association with each component of the KHEI (**Table 4**), men showed a strong positive association with vegetable intake, excluding kimchi and pickles in all 3 models (e.g., model 3: aOR, 1.367; 95% CI, 1.091–1.712). There was a strong positive association between periodontitis and the intake of sweets and beverages in women in all 3 models (e.g., model 3: aOR, 1.477; 95% CI, 1.125–1.939). For women, milk and dairy intake only showed a negative association with periodontitis in model 1 (aOR, 0.823; 95% CI, 0.683–0.993).

For vegetables, excluding kimchi and pickles, and for sweets and beverages, which showed statistical significance in all 3 models, an additional sensitivity test of multivariate logistic regression was done after converting these categorical variables into continuous variables (**Table 5**). When considering the KHEI category level as a continuous variable, the aOR for the intake of vegetables, excluding kimchi and pickles, in men was 0.922 (95% CI, 0.864–0.984), and the aOR for sweets and beverage intake in women was 0.941 (95% CI, 0.898–0.986).

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Table 4. Adjusted ORs with 95% CIs for participants with periodontitis

Independent Variable	Men				Women			
	Crude OR (95% CI)[a]	Model 1 (95% CI)[b]	Model 2 (95% CI)[c]	Model 3 (95% CI)[d]	Crude OR (95% CI)[a]	Model 1 (95% CI)[b]	Model 2 (95% CI)[c]	Model 3 (95% CI)[d]
Total KHEI								
Q1	reference	reference	reference	reference	reference	reference	reference	reference
Q2	0.900 (0.681–1.190)	0.895 (0.675–1.186)	0.885 (0.667–1.174)	0.900 (0.677–1.197)	0.823 (0.638–1.061)	0.874 (0.676–1.131)	0.883 (0.682–1.143)	0.887 (0.684–1.150)
Q3	**0.731 (0.550–0.971)**	**0.740 (0.553–0.990)**	**0.734 (0.548–0.982)**	0.758 (0.565–1.016)	0.796 (0.619–1.024)	0.898 (0.693–1.163)	0.914 (0.705–1.185)	0.921 (0.709–1.195)
Q4	**0.700 (0.521–0.940)**	**0.722 (0.530–0.983)**	**0.710 (0.521–0.969)**	0.758 (0.553–1.037)	**0.632 (0.493–0.810)**	**0.748 (0.577–0.970)**	**0.763 (0.587–0.990)**	0.775 (0.595–1.008)
Total fruit, including juice								
S1	reference	reference	reference	reference	reference	reference	reference	reference
S2	0.962 (0.749–1.235)	0.973 (0.756–1.253)	0.968 (0.752–1.247)	1.000 (0.775–1.291)	0.839 (0.655–1.075)	0.921 (0.714–1.187)	0.930 (0.721–1.199)	0.929 (0.720–1.199)
S3	0.760 (0.592–0.975)	0.781 (0.603–1.010)	0.772 (0.596–1.000)	0.827 (0.636–1.074)	**0.719 (0.584–0.886)**	0.816 (0.657–1.013)	0.828 (0.666–1.029)	0.835 (0.671–1.039)
Vegetable, excluding kimchi and pickles								
S1	**1.360 (1.094–1.690)**	**1.358 (1.087–1.697)**	**1.372 (1.097–1.716)**	**1.367 (1.091–1.712)**	1.098 (0.917–1.315)	1.012 (0.841–1.217)	1.010 (0.840–1.216)	1.007 (0.837–1.212)
S2	reference	reference	reference	reference	reference	reference	reference	reference
Milk and dairy								
S1	reference	reference	reference	reference	reference	reference	reference	reference
S2	0.955 (0.765–1.191)	0.982 (0.783–1.230)	0.980 (0.782–1.228)	0.997 (0.794–1.252)	**0.755 (0.630–0.906)**	**0.823 (0.683–0.993)**	0.831 (0.689–1.002)	0.837 (0.694–1.010)
Sweets and beverage								
S1	1.234 (0.891–1.709)	1.210 (0.872–1.678)	1.214 (0.875–1.684)	1.177 (0.846–1.637)	**1.503 (1.152–1.962)**	**1.499 (1.145–1.962)**	**1.490 (1.138–1.952)**	**1.477 (1.125–1.939)**
S2	reference	reference	reference	reference	reference	reference	reference	reference
Carbohydrate								
S1	reference	reference	reference	reference	reference	reference	reference	reference
S2	0.884 (0.716–1.092)	0.896 (0.721–1.113)	0.895 (0.721–1.112)	0.907 (0.729–1.129)	**0.772 (0.647–0.921)**	0.878 (0.730–1.056)	0.880 (0.731–1.059)	0.879 (0.730–1.058)
Fat								
S1	reference	reference	reference	reference	reference	reference	reference	reference
S2	0.902 (0.692–1.177)	0.894 (0.682–1.172)	0.890 (0.679–1.167)	0.883 (0.672–1.160)	**0.797 (0.637–0.995)**	0.881 (0.701–1.107)	0.887 (0.706–1.115)	0.890 (0.708–1.120)
S3	0.816 (0.639–1.043)	0.832 (0.645–1.072)	0.828 (0.642–1.068)	0.827 (0.640–1.069)	**0.756 (0.615–0.929)**	0.886 (0.713–1.101)	0.892 (0.718–1.109)	0.894 (0.719–1.111)

Bold style values indicate statistical significance.
OR: odds ratio, CI: confidence interval, KHEI: Korean Healthy Eating Index.
[a]Crude shows odd ratio with CI of 95% without any adjustment; [b]Model 1: adjusted by age, education level, region, marriage status; [c]Model 2: adjusted by age, education level, region, marriage status, brushing frequency; [d]Model 3: adjusted by age, education level, region, marriage status, brushing frequency, hypertension, smoking experience.

Table 5. Multivariate logistic analysis for dietary categories

Independent variable	Men	Women
	Model 3[a] (95% CI)	Model 3[a] (95% CI)
Vegetable, excluding, kimchi and pickles	**0.922 (0.864–0.984)**	0.974 (0.923–1.025)
Sweets and beverage	0.956 (0.895–1.020)	**0.941 (0.898–0.986)**

[a]Model 3: adjusted by age, education level, region, marriage status, brushing frequency, hypertension, smoking experience.

DISCUSSION

This study used statistical analysis methods to investigate the relationship between dietary quality and the periodontal health of adults aged ≥60 years according to sex. Subjects with poor periodontal health tended to have lower KHEI scores. Thus, this negative correlation affirmed an association between dietary quality and the prevalence of periodontitis. Studies on the influence of nutrition on oral health have emphasized that malnutrition or inadequate

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nutrition can exacerbate periodontal and oral infectious diseases [20,21]. In addition, it has been suggested that periodontal disease is a sensitive predictor of abnormal macro- and micro-nutrient intake [22].

The components of the KHEI showed statistically significant differences between men and women. Among men, 1 serving of vegetables per day decreased the odds of having periodontitis by 8% compared to men who did not consume vegetables at all. Among women, a 1% decrease in total energy intake from sugar lowered the likelihood of periodontitis by 6% compared to women who gained 20% of their total energy intake from sugar.

Factors other than the KHEI components may help explain the heterogeneous influence of vegetable and sugar intake among men and women. Differences in the influence of vegetable intake on the prevalence of periodontitis in each sex may be explained by the fact that the recommended daily vegetable amounts are different for men and women [7]. For men over 65 years old, the maximum score for vegetable intake excluding kimchi and pickles can only be achieved if one eats ≥5 servings per day. For women over 65 years old, the maximum score can be achieved if one eats ≥3 servings per day [7]. It is possible that the scoring system caused differences in our results for the relationship between vegetable intake and the prevalence of periodontitis.

Reactive oxygen species (ROS) can damage cells and tissues, and thus play an important role in the pathogenesis of chronic inflammation including periodontitis [23,24]. It has been shown that patients with periodontitis have elevated levels of ROS in gingival crevicular fluid, saliva, and serum [25,26]. Vegetables commonly contain antioxidant and anti-inflammatory phytochemicals including flavonoids and their metabolites, which contain a direct free radical scavenging capacity and impair the production of ROS [26-28]. Moreover, men tend to experience higher oxidative stress than women, which suggests that the antioxidant and anti-inflammatory effects of vegetables may have a greater impact on men than women [29]. The association between lower vegetable intake and periodontitis in men may be explained by the higher ROS scavenging capacity of the phytochemicals in culinary vegetables.

The sugar contained in foods or beverages with added sugar is used in the production of polysaccharide polymers by oral microorganisms and contributes to the increase in plaque volume. There is a strong correlation between plaque volume and periodontitis [20,30]. Other studies have reported that sugar intake results in a hyperglycemic state, and a prolonged hyperglycemic state leads to systemic inflammation and an increased risk of periodontal disease [31-33]. Similar associations between sugar intake and periodontitis have been found in Western and Asian countries [20,32]. Since women tend to have a higher health burden after a diabetes diagnosis, it is likely that the increased risk of diabetes from a higher intake of free sugar may also have a greater impact on women than men for periodontitis [34]. These reports support the results obtained in this study that a high sugar intake is associated with an increase in the prevalence of periodontitis.

A cross-sectional study with a small study sample reported an association between lower milk and dairy intake and an increased prevalence of periodontitis [35]. In another study, a negative correlation between milk and dairy intake and the prevalence of periodontitis was found only according to the aOR [36]. These study findings are inconsistent, and the correlation of milk and dairy intake with the prevalence of periodontitis remains unresolved. To further analyze the correlation, larger study populations are needed.

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The KHEI components associated with periodontitis differed according to gender. Gender differences in food choice have been an important research topic, and it has been shown that the differences are based on various biological and socioeconomic factors [37-39]. Nutritional behaviors may change as people grow older due to changes in their chemosensory perception system and in their socioeconomic status [37,39].

Among the limitations of this study, the causal relationship between periodontitis and dietary quality could not be assessed because the study was based on a cross-sectional survey. In addition, the temporal relationship between dietary quality and periodontitis could not be assessed. It is possible that poor oral health caused by periodontitis may influence a person's choice of diet. A follow-up study with a more comprehensive design may be needed. Lastly, to evaluate periodontal status, the CPI uses representative teeth in each sextant instead of evaluating all remaining teeth; thus, there is always room for error in the test. Pseudo-pockets can also lead to misdiagnosis because the CPI only considers pocket depth when evaluating for scores of 3 and 4 [40]. The CPI does not include people who have lost all their teeth due to periodontitis, since the diagnosis can only be done with remaining teeth.

A strength of this study is that the KNHANES is a nationwide survey conducted by systemically trained interviewers; therefore, participants in this study are representative of the entire Korean population. In addition, periodontitis was diagnosed by trained dentists and the measurements were reliable. The KNHANES has been widely used in various studies; thus, the validity and accuracy of the participants' dietary quality were less likely to be biased.

In conclusion, this study showed that the KHEI was inversely associated with the prevalence of periodontitis in both Korean men and women aged 60 years and over. Vegetable intake had a negative correlation with the prevalence of periodontitis in men, and the intake of sweets had a positive correlation with the prevalence of periodontitis in women. Milk and dairy intake showed a negative correlation with periodontitis in women in model 1 only. More attention should be paid to the dietary habits of elderly Korean men and women, and more comprehensive studies are needed to offer customized guidelines for improving their oral health. The results of this study may be used to establish nutrition and health policies for the elderly in Korea.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Criteria for KHEI component sub-groups

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