The association between dietary habits and periodontal disease in young adult women

Short title: Dietary habits and periodontal disease

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Abstract

Background

Among middle-aged and elderly individuals, dietary habits have previously been reported to differ between patients with and without periodontal disease. However, in young adults, there are only a few reports that show a correlation between nutrient/food intake and periodontal disease. Moreover, no report has assessed the correlation between dietary habits measured by a self-administered diet history questionnaire (DHQ) and periodontal disease. Therefore, we assessed the correlation between dietary habits, determined using a DHQ, and periodontal disease in young adult women who are likely to develop a periodontal disease.

Methods

The participants were 120 healthy, non-smoking, female college students (mean age, 20.4 ± 1.1 years) from two universities who did not have any systemic disease. The participants were assessed for periodontal disease according to community periodontal index (CPI) and were divided into two groups. Subjects with a CPI code of 0, 1, or 2 were assigned to non-periodontal disease group (non-PD), and subjects with a CPI code of 3 or 4 were assigned to periodontal

disease group (PD). Dietary habits were assessed using a DHQ. In addition, physical status, level of difficulty in chewing food (dietary hardness), masticatory performance, and quality of life (QoL) were assessed.

Results

The PD group had a significantly lower nutrient intake of minerals, fat, water-soluble vitamins, and dietary fiber than the non-PD group. In terms of food groups, the PD group consumed significantly lesser amounts of green and yellow vegetables than the non-PD group. In addition, the PD group consumed significantly lesser amounts of hard foods than the non-PD group.

Conclusion

Young adult women with a periodontal disease had a significantly lower nutrient/food intake than young adult women without a periodontal disease.

1. Introduction

Periodontal disease is a chronic inflammatory disease that begins in the gingiva and spreads throughout the periodontal tissues, culminating to its destruction [1]. Periodontal disease occurs in young adulthood and progresses with age [2]. According to the results of the Survey of Dental Diseases 2016, the percentage of persons in Japan with periodontal pockets of ≥4 mm increased with age [3]. Moreover, since 17.6% individuals aged 15-24 years and 32.4% individuals aged 25-34 years have periodontal pockets of ≥4 mm, periodontal disease is now known to be common among the elderly and the young adults. Among middle-aged individuals, the prevalence of periodontal disease is higher in women than in men. The decrease in estrogen levels after menopause leads to a decrease in bone density, which causes the progression of alveolar bone resorption, a symptom of periodontal disease [4]. Therefore, with age, women are at a greater risk of developing periodontal disease than men [4].

It is important to prevent periodontal disease because it is known to affect systemic diseases such as cardiovascular disease [5], diabetes mellitus [6, 7], and metabolic syndrome [8] and premature/low-birth-weight delivery [9, 10]. Previous studies assessing the causes and etiology of periodontal disease

65 mainly focused on oral microbes and surrounding host environment [11, 12].
66 Previously reported environmental factors predisposing the host to periodontal
67 disease include smoking habits, drinking habits [13], and dental hygiene [14].

68 In addition, the nutrients and food consumed have also been reported to
69 be correlated with periodontal disease. Shariq Najeeb *et al.* suggested that
70 decreased consumption of vitamins and minerals, particularly vitamin C, which
71 has antioxidant activity, was highly associated with periodontal disease;
72 however, vitamin C supplementation was not effective in treating periodontal
73 disease [15]. Varun Kulkami *et al.* showed a similar intake of particular nutrients
74 in patients with and without periodontal disease. However, they pointed to a
75 possible correlation between consumed nutrients and periodontal disease status
76 [16]. In addition, Yoshihara *et al.* showed a negative correlation between the
77 intake of green and yellow vegetables and periodontal disease prevalence.
78 However, it has also been reported that a high intake of cereals, nuts, sugar,
79 sweets, and candy is positively correlated with the presence of periodontal
80 disease [17]. As described above, most of the previous studies on the effect of
81 diet/nutrient targeted elderly patients, with very few studies targeting the young
82 adults.

Our foods are divided into relatively hard foods and soft foods based on physical properties. The hardness of food is regarded as the difficulty involved in chewing, hereafter referred to as dietary hardness. Dietary hardness has been assessed as an estimate of masticatory muscle activity for the habitual diet [28]. A positive correlation between dietary hardness and chewing muscle activity has also been reported in a previous study [18].

Therefore, we aimed at assessing the correlation between dietary habits and periodontal disease in young adult women. In addition, we assessed the correlation between the intake of hard foods and periodontal disease.

2. Materials and Methods

2.1. Participants

One hundred and twenty-seven female college students from the Tokyo Medical and Dental University and the Tokyo Healthcare University were recruited for the study between February 2014 to March 2015.

The inclusion criteria were not having caries teeth and missing teeth excluding third molars. On the other hand, the exclusion criteria were in the following; a

101 smoker, taking gastrointestinal disease drugs, dry mouth, impaired oral
102 movement and psychiatric illness.
103 After 6 smokers and 1 person taking gastrointestinal disease drugs were
104 excluded, 120 subjects (mean age, 20.4 years) were finally enrolled in the study.
105 One dentist with ≥5 years of experience in clinical trials assessed the subjects
106 for periodontal disease. Two other evaluators practiced the chewing gum and
107 gummy jelly tests in advance so that their results matched. The Ethical
108 Committee of the Tokyo Medical and Dental University (#1002) and Tokyo
109 Healthcare University (#25-8) approved the study protocols. All participants
110 provided written informed consent before enrolment in the study, and
111 experiments were performed following the guidelines in the Helsinki Declaration
112 on the use of human subjects for research.
113
114 **2.2. Dietary assessment**
115 Nutrient/food intake was measured using the self-administered diet history
116 questionnaire (DHQ). The validity and reliability of the DHQ have previously
117 been confirmed [19, 20]. The DHQ includes questions concerning the frequency
118 of consumption, the semi-quantitative portions of 151 food and beverage items

consumed, general eating habits including skipping meals and eating irregularly, use of dietary supplements, and major cooking methods. An *ad hoc* of food composition in Japan was used to calculate the estimated dietary intake of energy, food group items, and nutrients [21]. The nutrient/food intake was converted to intake per 1,000 kcal of consumed energy. Since the total intake was expected to vary with body size, physical activity, and energy intake the nutrient/food intake was adjusted for total energy by using energy density (per 1,000 kcal) [22].

2.3. Estimation of dietary hardness

Dietary hardness was calculated using a previously described method [23]. Each food intake was multiplied by each masticatory muscle's activity for the habitual diet. Subsequently, dietary hardness was obtained by dividing the total sum of the above value by the energy intake.

2.4. Periodontal disease variables

Each participant underwent assessments for periodontics according to the Community Periodontal Index (CPI) from code 0 to code 4 (code 0: health

137 periodontal conditions; code 1: gingival bleeding on probing; code 2: calculus
138 and bleeding; code 3: periodontal pocket 4–5 mm; and code 4: periodontal
139 pocket ≥6 mm) [24, 25]. Then, the participants were assigned to two groups,
140 namely, non-periodontal disease (non-PD) group for CPI codes 0-2 and
141 periodontal disease (PD) group for CPI codes 3-4.
142
143 **2.5. Anthropometry**
144 Age and self-reported body heights were obtained from the DHQ. The weight
145 and percentage of body fat were measured using a body composition meter
146 (Inner scan 50, TANITA corporation, Japan). Body mass index (BMI) was
147 calculated as body weight (kilograms) divided by the square of body height
148 (meters).
149
150 **2.6. Measuring masticatory performance by using color-changeable**
151 **chewing gum and gummy jelly test**
152 Mixing ability was measured using a color-changeable chewing gum
153 (Masticatory Performance Evaluating Gum XYLITOL, Lotte Co., Ltd, Tokyo
154 Japan). After mouth-rinsing with water for 15 seconds, the participants were then

155 allowed to chew the provided gum by free chewing at a rate of one stroke per
156 second with an electric metronome. The participants chewed the gum for 60
157 strokes. Changes in color were assessed using a colorimeter (CR-13,
158 Konica-Minolta sensing, Tokyo, Japan), and then the mean values of L*, a*, and
159 b* in the CIELAB color system were measured. Thereafter, the ΔE values were
160 obtained using following the equation [26, 27].

161 $$\Delta E = \sqrt{(L^* - 72.3)^2 + (a^* + 14.9)^2 + (b^* - 33.0)^2}$$

162 Comminution test was measured using a test gummy jelly (UHA Mikakuto Co.,
163 Ltd, Japan) and a reported scoring method [28]. The participants chewed the
164 test jelly on their preferred chewing side for a total of 30 strokes. Subsequently,
165 the chewed test jellies were evaluated on a scale of one to ten by using a visual
166 scoring method [29]. Higher scores represented better comminution.

167

168 **2.7. Health-related QoL**

169 The general health-related QoL of the participants was evaluated by using the
170 Health-related quality of life scale, Short Form-8 (SF-8) [30, 31, 32].

171

172 **2.8. Statistical analyses**

Age, height, weight, BMI, body fat percentage, nutrient/food intake, dietary hardness, masticatory performance, and health-related QoL were compared between the two groups by using Student's *t*-test or Mann-Whitney U test. JMP Pro 11.0.0 (SAS) software was used for analyses. $P < 0.05$ was considered statistically significant. Except for physical status, dietary hardness, and QoL, all the other variables were log-transformed to achieve a normal distribution.

3. Results

3.1. Characteristics of participants

The mean age, body fat percentage, weight, height, and BMI of each group are shown in Table 1. The average age of the participants was 20.4 ± 1.1 years. Seventy-one subjects were assigned to the non-PD group, and 49 subjects were assigned to the PD group. There was no significant difference in age, height, weight, percentage body fat, and BMI between the two groups.

189

Table 1. The character of participants.

		Total		non-PD		PD		*p*
		Mean	SD	Mean	SD	Mean	SD	
Age[2)]	yrs	20.4	1.1	20.4	1.1	20.3	1.1	0.10
Body height[2)]	cm	158.9	5.8	158.4	5.3	159.0	6.3	0.91
Body weight[1)]	kg	51.2	6.9	51.2	7.4	51.1	6.2	0.89
BMI[2)]	kg/m^2	20.3	2.4	20.4	2.6	20.2	2.0	0.78
Body fat[1)]	%	27.0	5.2	27.0	5.8	27.0	4.1	0.97

Total n=120; non-PD n=71; PD n=49

1) Student's t-test

2) Mann-Whitney U test

190

191 **3.2. Intake of nutrients**

192 Table 2 shows the results of the intake of nutrients. A comparison of energy
193 intake and protein, fat, and carbohydrate energy ratio did not show a significant
194 difference between the two groups. The intake of minerals such as potassium,
195 calcium, magnesium, and iron was significantly lower in the PD group. Moreover,
196 the intake of fat-soluble vitamins, including vitamin A, beta-carotene
197 equivalence, vitamin E, and vitamin K, was significantly lower in the PD group.
198 The intake of water-soluble vitamins, including pantothenic acid (vitamin B5),
199 vitamin B6, and folic acid (vitamin B9), were also significantly lower in the PD
200 group.

201

202

Table 2. Nutrient intake in the PD and non-PD groups.

		Total		non-PD		PD		*p*
		Mean	SD	Mean	SD	Mean	SD	
Energy[1)]	kcal/day	1769	403	1806	431	1715	356	0.27
Protein[1)]	% energy	14.1	1.9	14.3	1.9	13.8	1.8	0.16
Fat[2)]	% energy	30.6	5.3	31.1	5.1	29.8	5.6	0.30
Carbohydrate[1)]	% energy	53.1	5.8	52.6	5.5	54.0	6.3	0.21
Sodium[2)]	mg/1000kcal	2198	582	2223	644	2161	484	0.86
Potassium[2)]	mg/1000kcal	1142	248	1185	244	1080	242	0.04*
Calcium[1)]	mg/1000kcal	273	90	285	81	256	101	0.02*
Magnesium[1)]	mg/1000kcal	124	27	128	28	117	25	0.02*
Phosphorus[1)]	mg/1000kcal	527	93.0	539	91	509	94	0.06
Iron[1)]	mg/1000kcal	3.9	0.8	4.0	0.1	3.6	0.1	0.01*
Zinc[1)]	mg/1000kcal	4.1	0.5	4.2	0.5	4.0	0.5	0.11
Copper[2)]	mg/1000kcal	0.57	0.10	0.59	0.11	0.55	0.09	0.09
Manganese[2)]	mg/1000kcal	1.98	0.7	1.96	0.74	2.02	0.57	0.22
Vitamin A[1)]	μg/1000kcal	297	155	325	167	256	128	0.007**
Retinol[2)]	μg/1000kcal	141	120	151	132	128	102	0.55
b-Carotene equivalents[1)]	μg/1000kcal	1841	1004	2068	1041	1515	855	0.001**
Vitamin D[1)]	μg/1000kcal	3.5	1.9	3.4	1.8	3.5	2.2	0.97
Vitamin E[1)]	mg/1000kcal	4.5	1.1	4.7	1.2	4.1	1.0	0.002**
Vitamin K[1)]	μg/1000kcal	147	74	162	83	125	53	0.004**
Thiamin[1)]	mg/1000kcal	0.46	0.10	0.47	0.10	0.44	0.12	0.13
Riboflavin[2)]	mg/1000kcal	0.72	0.16	0.73	0.16	0.72	0.18	0.36
Naiacin[1)]	mg/1000kcal	8.0	1.9	8.1	1.7	7.9	2.1	0.66
Vitamin B_6[1)]	mg/1000kcal	0.58	0.15	0.60	0.15	0.55	0.15	0.03*
Vitamin B_{12}[1)]	μg/1000kcal	3.0	1.2	3.0	1.2	3.0	1.3	0.75
Folic acid[1)]	μg/1000kcal	158	44	167	47	144	35	0.006**
Pantothenic acid[2)]	mg/1000kcal	3.19	0.55	3.28	0.55	3.05	0.53	0.01*
Vitamin C[1)]	mg/1000kcal	50	22	52	22	48	22	0.25
Fatty acid[2)]	g/1000kcal	29.63	5.40	30.16	5.29	28.85	5.52	0.39
Saturated[1)]	g/1000kcal	9.87	2.12	9.96	2.15	9.74	2.08	0.33
Monounsaturated[2)]	g/1000kcal	12.02	2.63	12.21	2.52	11.73	2.79	0.38
Polyunsatutated[2)]	g/1000kcal	7.45	1.60	7.67	1.55	7.12	1.63	0.12

n-3 Polyunsaturated[2)]	g/1000kcal	1.28	0.36	1.30	0.35	1.25	0.38	0.50
n-6 Polyunsaturated[2)]	g/1000kcal	6.27	1.31	6.48	1.26	5.95	1.31	0.06
Choresterol[2)]	mg/1000kcal	173	61	177	69	167	49	0.67
Total dietary fiber[1)]	g/1000kcal	6.7	1.8	7.1	1.7	6.1	1.8	< 0.001***
Solubule dietary fiber[1)]	g/1000kcal	1.7	0.5	1.8	0.4	1.6	0.6	0.003**
Insoluble dietary fiber[1)]	g/1000kcal	4.7	1.3	5.0	1.3	4.3	1.2	< 0.001***

Total n=120; non-PD n=71; PD n=49

1) Student's t-test

2) Mann-Whitney U test

*P＜0.05, **P＜0.01, ***P＜0.001

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204

205 **3.3. Intake of different food groups**

206 The results of food intake per 1000 kcal of energy for each group are shown in
207 Table 3. The intake of green and yellow vegetables and other vegetables was
208 significantly lower in the PD group than in the non-PD group. Although there was
209 no significant difference in the intake of seeds, nuts, and beans, their intake was
210 lower in the PD group. In addition, the intake of sugar, animal fats, and
211 beverages was higher in the PD group. When green and yellow vegetables and
212 other vegetables were analyzed (Table 4), the intake of carrots (among green
213 and yellow vegetables) and the intake of cabbage (among other vegetables)
214 were significantly lower in the PD group than in the non-PD group. Furthermore,
215 although there was no significant difference, the intake of broccoli, as a green

and yellow vegetable, and that of cucumber, eggplant, and lotus root, as a part of the other vegetables, were lower in the PD group.

219

Table 3. Food intake per 1000 kcal in the PD and non-PD groups.

g/1,000kcal

	Total		non-PD		PD		*p*
	Mean	SD	Mean	SD	Mean	SD	
Cereals[2)]	204.3	58.2	197.9	59.2	213.5	56.2	0.19
Nuts and seeds[2)]	1.1	2.5	1.2	2.6	0.9	2.2	0.09
Potatoes[2)]	13.9	8.4	14.8	8.4	12.7	8.4	0.06
Sugars[2)]	6.2	3.0	6.1	2.6	6.3	3.6	0.86
Confectioneries[2)]	51.4	25.1	51.3	25.3	51.6	25.1	0.89
Animal fat[2)]	0.5	0.7	0.4	0.5	0.6	0.8	0.20
Vegetable fats and oil[2)]	12.4	8.5	12.4	8.3	12.4	9.0	0.59
Pulses[1)]	38.2	41.1	42.9	48.4	31.5	26.2	0.17
Fruits[2)]	45.6	38.1	46.7	41.6	43.9	32.6	0.93
Green and yellow vegetables[1)]	61.4	35.9	68.5	38.5	51.2	29.4	0.01*
Other vegetables[1)]	61.6	34.4	67.3	37.7	53.3	27.5	0.02*
Mushrooms[2)]	7.3	7	7.3	6.5	7.4	8.7	0.21
Seaweeds[2)]	7.4	7.3	7.6	6.7	7.0	8.2	0.57
Seasonings[2)]	8.5	6.0	8.2	4.9	8.8	7.3	0.91
Alcholic beverages[2)]	25.3	50.8	25.9	52.7	25.6	48.5	0.58
Beverages[2)]	383.7	241.4	357.5	244.0	421.7	234.8	0.09
Fish[1)]	28.9	15.2	28.4	15.3	29.5	15.2	0.84
Meat[1)]	43.3	18.9	44.4	17.1	41.7	21.3	0.17
Eggs[2)]	19.3	13.5	20.2	15.1	18.1	10.9	0.76
Milk produces[2)]	69.3	61.6	71.4	54.9	66.2	70.8	0.28

Total n=120; non-PD n=71; PD n=49

1) Student's t-test

2) Mann-Whitney U test

*P＜0.05

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221

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Table 4. Intake of green/yellow and other vegetables in the PD and non-PD groups.

g/1,000kcal

	Total		non-PD		PD		*p*
	Mean	SD	Mean	SD	Mean	SD	
Green and yellow vegetables							
Carrots[2)]	8.1	5.9	9.1	5.9	6.7	5.8	0.02*
Pumpkins[2)]	3.8	5.1	4.1	5.8	3.5	4.0	0.94
Tomatoes[1)]	13.0	12.5	14.5	13.6	10.9	10.3	0.13
Sweet peppers[2)]	2.9	3.3	3.1	3.6	2.6	2.8	0.36
Broccoli[2)]	6.6	9.3	7.7	10.2	5.1	7.8	0.06
Green leafy vegetables[2)]	17.7	18.5	20.8	22.3	13.3	9.5	0.15
Other vegetables							
Cabbage[1)]	14.7	14.9	17.1	16.6	11.2	11.3	0.01*
Cucumbers[1)]	4.8	5.7	5.5	5.5	3.8	4.3	0.05
Lettuce[2)]	6.3	5.8	7.3	6.5	5.0	4.2	0.13
Chinese cabbage[2)]	4.4	7.4	4.4	7.5	4.4	7.2	0.73
Bean sprouts[2)]	5.4	7.1	5.7	7.0	5.0	7.2	0.60
Radishes[2)]	6.4	6.0	7.0	6.5	5.6	5.2	0.43
Onions[1)]	10.9	9.5	11.3	10.2	10.3	8.6	0.59
Cauliflower[2)]	0.3	0.9	0.4	1.1	0.2	0.6	0.25
Eggplants[2)]	3.4	5.4	3.6	4.0	3.1	7.1	0.06
Burdock[2)]	1.7	2.3	2.0	2.8	1.2	1.1	0.12
Lotus root[2)]	0.8	1.1	0.9	1.3	0.7	0.9	0.06

Total n=120; non-PD n=71; PD n=49

1) Student's t-test

2) Mann-Whitney U test

*P＜0.05

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224 ## 3.4. Dietary hardness

225 Masticatory muscle activity was analyzed as a measurement of dietary hardness

226 (Table 5). The results showed that the intake of hard foods was significantly
227 lower in the PD group when compared with the non-PD.

228

Table 5. Hard food intake in the PD and non-PD groups.

m･V/1000kcal

	Total		non-PD		PD		*p*
	Mean	SD	Mean	SD	Mean	SD	
Intake of hard foods[1)]	204	30.4	208	31	197	30	0.046*

Total n=120; non-PD n=71; PD n=49

1）Student's t-test

*P＜0.05

229

230 **3.5. Masticatory performance and health-related QoL**

231 Masticatory performance and QoL are shown in Table 6. There was no
232 significant difference in mixing ability, comminution ability, and QoL between the
233 two groups.

234

235

Table 6. Masticatory performance and health related QoL.

	Total		non-PD		PD		*p*
	Mean	SD	Mean	SD	Mean	SD	
Masticatory Perfomance							
Color-changeable chewing gum[1)]	22.5	5.0	22.2	5.3	22.9	0.7	0.42
Gummy jelly test[2)]	6.2	0.9	6.1	0.1	6.3	0.1	0.45
SF-8 score							
Physical component summary[2)]	53.4	4.4	53.2	0.5	53.8	0.6	0.52
Mental component summary[2)]	44.4	7.0	44.5	7.1	44.3	6.9	0.82

Total n=120; non-PD n=71; PD n=49

1) Student's t-test

2) Mann-Whitney U test

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237

238 **4. Discussion**

239 In this study, the two groups showed significant differences in the intake of

240 several nutrients.

241 In previous studies, subjects with periodontal disease significantly

242 consumed less potassium and iron. In the present study, the intake of potassium

243 and iron in the PD group was significantly lower than that in the non-PD group,

244 which was consistent with that reported in previous studies. Magnesium is

245 known to be involved in bone and tooth formation. It was reported that in

246 40-year-old individuals, serum magnesium concentration is associated with the

247 risk of periodontal disease [33]. The intake of magnesium was significantly lower
248 in the PD group in the present study. We, therefore, think that there is a
249 significant positive correlation between the presence of periodontal disease and
250 low intake of magnesium in not only the elderly but also in young adults. Both
251 animal and human studies have reported that a lack of calcium intake leads to
252 alveolar bone resorption [34, 35] and a decrease in bone density [36], indicating
253 that insufficient calcium intake might cause the progression of periodontal
254 disease. In addition, it was shown that the risk of periodontal disease associated
255 with calcium intake was observed in both men and women aged between 20 and
256 39 years (odds ratio; 1.99 and 1.84), only in men aged between 40 and 59 years,
257 and in neither men nor women aged ≥60 years [37]. In the present study, the
258 intake of calcium was significantly lower in the PD group. Therefore, we think
259 that low calcium intake is more strongly correlated with the presence of
260 periodontal disease in younger adults than in older adults.

261 In the present study, the intake of vitamin C was lower, although not
262 significantly, in the PD group, while the intake of vitamins A, K, and E and
263 beta-carotene were significantly lower. Among the elderly and smokers, the
264 prevalence of periodontal disease was reported to be associated with vitamin C

265 intake. There was a weak but significant dose-response increase in the risk of
266 periodontal disease in subjects who had lower vitamin C intake [38]. Vitamin C is
267 known to suppress oxidative stress through its antioxidant activity [39]. In
268 addition, vitamins A and K [40] and vitamin E and beta-carotene [41] have
269 antioxidant activity. In previous studies, oxidative stress caused by reactive
270 oxygen species in the tissues surrounding the gingiva affects the onset of
271 periodontal disease [42]. Therefore, it was suggested that the antioxidant effect
272 of several vitamins contributed to the absence of periodontal disease in the
273 non-PD group. Low intake of folic acid is known to be related to increased
274 bleeding during probing [43, 44], which supports our findings that the intake of
275 folic acid was significantly lower in the PD group. In the present study, the intake
276 of pantothenic acid and vitamin B6, which are not known to have any correlation
277 with periodontal disease, was significantly lower in the PD group. Previous
278 reports have shown that decreased vitamin B complex intake reduced the
279 efficiency of access flap surgery for periodontal disease treatment [45].
280 However, the effect of each specific vitamin B in the complex on periodontal
281 disease treatment has not been shown yet. Based on our findings, it was
282 suggested that there is a positive correlation between the intake of pantothenic

283 acid and vitamin B6, among the vitamin B complex, and the absence of
284 periodontal disease.

285 In a previous study, there was a significant positive correlation between the
286 intake of whole grains and the absence of periodontal disease because whole
287 grains contain dietary fiber [46]. Green and yellow vegetables and other
288 vegetables like whole grains contain soluble and insoluble dietary fibers.
289 Therefore, in this study, since the consumption of green/yellow vegetables and
290 other vegetables was higher in the non-PD group than in the PD group, we think
291 that dietary fibers play a protective role against the development of periodontal
292 disease.

293 It was reported that the risk for periodontal disease among elderly persons
294 with low intake of docosahexaenoic acid is approximately 1.5 times that among
295 those with high intake [47]. However, in the present study, there was no
296 significant difference in the intake of fatty acids between the two groups. N-3
297 polyunsaturated fatty acids such as docosahexaenoic acid and
298 eicosapentaenoic acid exert anti-inflammatory effects by blocking intracellular
299 signaling systems required for producing inflammatory cytokines such as IL-1,
300 IL-6, and TNF-α [47]. Therefore, the immunological differences between younger

301 adults and the elderly might have caused the difference in the findings between
302 the present study and previous studies.

303 This study showed that the PD group significantly consumed foods with
304 lower dietary hardness when compared with the non-PD group. Yanagisawa, *et*
305 *al*. classified foods into 10 ranks according to chewing muscle activity [18]. In the
306 study, carrots and cabbage were ranked 8^{th} out of 10 (>1400 μV・sec) and
307 carrots, cabbage, and lotus root were ranked 6^{th} out of 10 (>1000 μV・sec). We
308 found that the non-PD group routinely consumed hard dietary foods when
309 compared with the PD group. The quantity of saliva secreted has been reported
310 to increase proportionally with an increase in chew number, chewing time, or
311 chewing muscle activity [48]. Saliva washes away residual food particles and
312 bacteria in the mouth. Saliva also contains lysozyme, amylase, peroxidase, and
313 the proteins lactoferrin and IgA which possess antibacterial activity [49, 50].
314 Therefore, we think that eating foods with high dietary hardness (as seen in the
315 non-PD group) protects against periodontal disease through oral washing and
316 antibacterial activity resulting from increased saliva secretion.

317 In the present study, the participants in the PD group accounted for 40.8%
318 of the total participants. The 2016 Survey of Dental Diseases reported that

319 women aged 20 to 24 with periodontal disease accounted for 16.7% of the total
320 population [3]. Thus, the high prevalence of periodontal disease observed in our
321 study population is likely because we did not comprehensively diagnose
322 periodontal disease by using multiple diagnostic methods. Our diagnoses were
323 based only on the CPI, which might have resulted in the observed high
324 prevalence.

325 Presently, dietary or nutritional studies assessing how diet/nutrition can be
326 helpful in the prevention or treatment of periodontal disease are lacking.
327 Therefore, more studies are required to elucidate the connection between
328 periodontal disease and diet/nutrition. In addition, longitudinal studies on dietary
329 habits that effectively prevented or suppressed the progression of periodontal
330 disease are warranted.

331

332

333 **5. Conclusion**

334 Under the limited conditions of the present study, the intake of minerals
335 (potassium, calcium, magnesium, and iron), fat-soluble vitamins (vitamin A,
336 beta-carotene, vitamin E, and vitamin K), water-soluble vitamins (pantothenic

337 acid, vitamin B6, and folic acid), and dietary fibers was significantly lower in
338 young adult women with periodontal disease than in young adult women without
339 periodontal disease.
340
341
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345
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