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Relationship between smoking status and periodontal conditions: findings from national databases in Japan

M. Ojima[1], T. Hanioka[2], K. Tanaka[3], E. Inoshita[4], H. Aoyama[5]

[1]Department of Preventive Dentistry, Graduate School of Dentistry, Osaka University, Osaka, Japan, [2]Department of Preventive and Public Health Dentistry, Fukuoka Dental College, Fukuoka, Japan, [3]Department of Public Health, Fukuoka University School of Medicine, Fukuoka, Japan, [4]Otsu Center for Health and Welfare of Shiga Prefecture, Shiga, Japan and [5]Tochigi Prefectural Medical and Social Welfare College, Utsunomiya, Tochigi, Japan

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Background and Objective: The association between cigarette smoking and periodontitis was examined employing two nationally representative samples of adults in Japan.

Material and Methods: Data were derived from the Survey of Dental Diseases (SDD) and the National Nutrition Survey (NNS) in 1999. In the SDD, periodontal conditions were evaluated by calibrated dentists utilizing the Community Periodontal Index (CPI), whereas in the NNS, participants were interviewed on the basis of smoking status by enumerators. Among 6805 records electronically linked via a household identification code, 4828 records of individuals aged 20 yr or older were analyzed.

Results: The prevalence of periodontal disease varied significantly by smoking status ($p < 0.0001$): 39.3%, 49.5% and 47.3% (CPI ≥ 3), and 7.9%, 11.7% and 12.4% (a more severe form of periodontitis, CPI = 4), for nonsmokers, former smokers and current smokers, respectively. In adults aged ≥40 yr ($n = 3493$), logistic regression models revealed greater probabilities (approximately 1.4 times higher) of periodontitis [CPI ≥ 3, odds ratio = 1.38 (1.12–1.71), $p = 0.0024$] and a more severe form of periodontitis [odds ratio = 1.40 (1.04–1.89), $p = 0.0288$] in current smokers compared with nonsmokers, following adjustment for possible confounding factors.

Conclusion: Based on the findings of this study and other numerous reports, cigarette smoking leads to deterioration of periodontal conditions in Japanese adults.

Takashi Hanioka, Department of Preventive and Public Health Dentistry, Fukuoka Dental College, 2-15-1 Tamura, Sawara-ku, Fukuoka 814–0193, Japan
Tel: +81 92 8010 616
Fax: +81 92 8010 616
e-mail: haniokat@college.fdcnet.ac.jp

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Smoking is currently accepted as a well-established risk factor for periodontal disease. Investigations regarding the association between smoking and periodontal disease have consistently demonstrated negative periodontal effects and greater probabilities of established periodontal disease among smokers in comparison with nonsmokers (1–4). In addition, smokers display poor prognosis following both surgical and nonsurgical periodontal therapy. A recent comprehensive review of 70 epidemiologic articles, including cross-sectional, case-control and cohort studies, concluded that evidence is sufficient to infer a causal relationship between smoking and periodontitis (5).

The association between cigarette smoking and periodontitis has been

examined in nationally representative samples in the USA (6,7) and in large randomized samples in Sweden (8). The study in the USA estimated that more than half of periodontitis cases involving adults may be attributable to cigarette smoking. Cigarette smoking prevalence varies with age, gender, education and race/ethnicity (9,10). Health consequences of smoking at the national level are strongly correlated to the trend in cigarette consumption. Smoking prevalence increased until the 1990s in western countries; furthermore, the smoking rates of men and women were nearly equivalent. In Asian countries, a difference in smoking rate is apparent with respect to gender (men 30–70%, women 3–10%). In Japan, cigarette consumption increased until recently; moreover, consumption in men has been found to be highest in industrialized countries, whereas the prevalence of smoking in women has remained relatively low (11). To the best of our knowledge, the effects of smoking on periodontal disease at the national level have not been documented in Asian countries.

Data on cigarette smoking and periodontal condition have been accumulated in two independent national surveys in Japan. Linkage of these databases could be beneficial; thus, the present study attempted to examine the association between smoking status and periodontal disease, employing these two national databases.

Material and methods

Data source

Databases of the National Nutrition Survey (NNS) and the Survey of Dental Diseases (SDD) in 1999 were obtained from the Ministry of Health, Labor and Welfare. The NNS has been conducted annually to obtain basic data pertaining to health conditions and dietary intake and to clarify the relationships between health outcomes and nutrition. The survey covers households and their members within those districts randomly selected from the districts of the Comprehensive Survey of the Living Condition of the People on Health and Welfare. Participants received physical examinations and were interviewed regarding health practices, including cigarette smoking and dietary intake, by enumerators in local public centers. Data were collected from 12,763 persons of approximately 5000 households in 300 districts.

The SDD has been conducted in conjunction with the NNS every 6 yr. The survey, which attempted to acquire basic data relating to tooth and periodontal conditions and to influence policy for oral health promotion in Japan, was conducted on a sample consisting of 6903 persons ≥ 1 yr in age. Participants were asked about frequencies of daily brushing; additionally, dental caries, periodontal pockets, restorations, and tooth conditions were evaluated.

Data regarding periodontal condition and tobacco use

According to the description in the report on the SDD, calibrated dentists examined periodontal conditions of the subjects, employing a modification method of the Community Periodontal Index (CPI), based on partial-mouth recordings: pocket probing was performed at buccal sites in the maxillary and at lingual sites in the mandible. The highest value of CPI scores among the six sections served as the subject's code.

Subjects were classified as current smokers (those who currently smoke cigarettes daily or occasionally), former smokers (those who have smoked cigarettes at some point in their lives, but who currently do not smoke), and nonsmokers (those who were experimental smokers or who have never smoked cigarettes). Current smokers were asked about cigarette consumption in terms of number of cigarettes per day and duration of smoking.

Possible confounding factors for periodontitis

Several variables were selected *a priori* as possible confounders prior to the application of national databases. Correlations between periodontal disease and obesity (12–14), alcohol consumption (15–17), diabetes (blood sugar level) (18–20), vitamin C (21,22) and vitamin E (23,24) intakes, and frequencies of tooth brushing (25,26), have been reported. Body mass index (BMI) was calculated as an indicator of obesity. BMI was divided into three groups: < 18.5; 18.5–25.0; and ≥ 25.0. Alcohol consumption was classified into three groups: current, former and never; additionally, blood sugar level was partitioned into two groups: normal (< 110 mg/dL) and high level (≥ 110 mg/dL). Based on the Recommended Dietary Allowances for Japanese (6th Revision), vitamin C and vitamin E intakes were categorized into two groups: deficiency and sufficiency. The reference values of vitamin C and vitamin E for men, and of vitamin E for women, were 100 mg/d, 10 mg/d, and 8 mg/d, respectively. Frequency of daily brushing was divided into two groups: < 2 times per day and ≥ 2 times per day.

Data analysis

Records in the SDD database were electronically linked to those in the NNS using the household identification number as the linking variable. All links were checked via comparison of the information on birth month and gender between the two electronic databases. In the event of a mismatch of these variables, such cases were evaluated by a manual search of records among the same household. Among records of 6903 subjects in the SDD and of 12,763 subjects in the NNS, 6805 records were linked successfully.

Two levels of periodontal condition were defined: periodontitis (CPI ≥ 3) and a more severe form of periodontitis (CPI $= 4$). The prevalence of periodontitis was compared among nonsmokers, former smokers and current smokers on the basis of gender, age group (20–39, 40–59 and 60+ yr) and study variables. Bivariate analyses were conducted to determine associations between smoking and prevalence of periodontitis using the chi-square test. Two models were constructed for multiple logistic regression, which included gender, age, frequency of

daily brushing, BMI, current smoking, vitamin E and vitamin C intakes, and alcohol consumption as confounding factors. Adjusted odds ratios (ORs) for periodontitis for each variable were calculated. Blood sugar level was excluded because of a large volume of missing data (332 records). Dr SPSS for Windows (SPSS Inc., Chicago, IL, USA) was utilized.

Results

Analyses were limited to those adults aged 20 yr or older with complete clinical periodontal data and information related to cigarette smoking. Records of 4828 subjects were used to compute smoking rate and prevalence of periodontitis. Percentage of records characterized by missing data for each covariate was less than 1%, with the exception of blood sugar level. Subject age ranged from 20 to 93 yr (mean age, 50.8 ± 15.7 yr).

Distribution of smokers by study variables

Table 1 exhibits the prevalence of current, former and nonsmokers by study variables among adults aged ≥ 20 yr. In 1999, the overall percentage of current smokers was 25.0% of the study population (47.9% men and 10.2% women). Comparisons with the percentage of current smokers in the NNS revealed differences between 0.1 and 1.3 points (47.9% vs. 49.2%, 10.2% vs. 10.3%, and 25.0% vs. 26.2% in men, women, and overall, respectively). Among both men and women, current smoking was higher in the younger age group. More than 50% of men in the 20–39- and 40–59-yr age groups were current smokers. In women, the 20–39-yr age group displayed the highest percentage of current smokers (15.5%). Smoking prevalence in men was greater than that in women in all age groups. The proportion of former smokers increased with age, up to ≈40% in men. Men demonstrated a 40-pack-yr history of cigarette smoking at around 50 yr of age.

Prevalence of periodontitis by smoking status

Table 2 presents the prevalence of periodontitis by smoking status. Overall, 42.5% of subjects exhibited

Table 1. Prevalence of cigarette smoking and pack-years among study population by study variables

	Smoking status				
				Current smoker	
Variables	Total *n*	Non-smoker % (*n*)	Former smoker % (*n*)	% (*n*)	Pack-years[b]
Men (yr)	1896	27.5 (521)	24.6 (467)	47.9 (908)	30.8 ± 21.2
20–39	472	36.7 (173)	8.1 (38)	55.3 (261)	13.3 ± 9.2
40–59	703	23.5 (165)	21.5 (151)	55.0 (387)	35.5 ± 19.1
60+	721	25.4 (183)	38.6 (278)	36.1 (260)	41.5 ± 22.0
Women (yr)	2932	86.2 (2528)	3.6 (105)	10.2 (299)	13.0 ± 13.6
20–39	863	79.8 (689)	4.6 (40)	15.5 (134)	6.4 ± 5.4
40–59	1150	86.0 (989)	3.4 (39)	10.6 (122)	16.2 ± 14.3
60+	919	92.5 (850)	2.8 (26)	4.7 (43)	24.5 ± 17.5
Frequency of daily brushing					
≥ 2 times	3385	70.1 (2372)	10.5 (355)	19.4 (658)	23.2 ± 20.7
< 2 times	1407	46.4 (653)	15.1 (212)	38.5 (542)	30.5 ± 20.8
BMI					
18.5–25.0	3296	63.8 (2102)	11.3 (373)	24.9 (821)	26.3 ± 17.9
< 18.5	283	65.4 (185)	8.1 (23)	26.5 (75)	18.8 ± 13.4
≥ 25	1241	60.8 (755)	14.1 (175)	25.1 (311)	28.5 ± 21.0
Alcohol consumption					
Never	3331	78.8 (2626)	6.3 (210)	14.9 (495)	19.8 ± 12.0
Former	199	25.6 (51)	37.7 (75)	36.7 (73)	33.3 ± 24.9
Current	1278	28.5 (364)	22.2 (284)	49.3 (630)	30.9 ± 24.2
Blood sugar level					
< 110 mg/dL	3514	63.1 (2219)	11.4 (400)	25.5 (895)	25.0 ± 17.4
≥ 110 mg/dL	982	62.2 (611)	13.4 (132)	24.3 (239)	32.0 ± 22.5
Vitamin C intake					
≥ 100 mg	2863	66.2 (1894)	12.8 (367)	21.0 (602)	28.0 ± 21.5
< 100 mg	1964	58.8 (1154)	10.4 (205)	30.8 (605)	24.8 ± 20.5
Vitamin E intake[a]					
≥ 10 or 8 mg	2498	67.9 (1695)	10.7 (267)	21.5 (536)	25.3 ± 20.3
< 10 or 8 mg	2330	58.1 (1354)	13.1 (305)	28.8 (671)	27.3 ± 21.6
All	4828	63.2 (3049)	11.8 (572)	25.0 (1207)	26.4 ± 21.0

[a] Men, 10 mg; women, 8 mg.

Number of missing data: frequency of daily brushing ($n = 36$), body mass index (BMI) ($n = 8$), alcohol consumption ($n = 20$), blood sugar level ($n = 332$), Vitamin C intake ($n = 1$).

[b] Assuming 20 cigarettes per pack, pack-years were estimated using the following formula [(cigarettes per day/20) × years smoked].

Table 2. Prevalence of periodontitis

	Total	Smoking status			Non vs. Current smoker *p*-value
		Non	Former	Current	
Periodontitis[a]					
Men	49.0	42.8	53.5	50.2	0.0069
Women	38.3	38.5	31.4	38.5	0.9821
All	42.5	39.3	49.5	47.3	< 0.0001
More severe form of periodontitis[b]					
Men	12.5	11.1	13.3	12.9	0.3306
Women	7.5	7.2	4.8	11.0	0.0179
All	9.5	7.9	11.7	12.4	< 0.0001

[a] Community Periodontal Index (CPI) ≥ 3 (i.e. the presence of at least one site displaying a pocket depth of > 4 mm).
[b] CPI = 4 (i.e. the presence of at least one site displaying a pocket depth of > 6 mm).

periodontitis (CPI ≥ 3). A larger percentage of men (49.0%) displayed periodontitis compared with women (38.3%). Periodontitis was evident in approximately half of current (47.3%) and former (49.5%) smokers; the prevalence in nonsmokers was 39.3%. A significant difference was observed between current and nonsmokers overall ($p < 0.0001$, simple comparison). A meaningful difference was detected between male nonsmokers and male current smokers ($p = 0.0069$); in contrast, this association was absent in women.

Prevalence of a more severe form of periodontitis (CPI = 4) was 9.5% overall. Current (12.4%) and former (11.7%) smokers were more likely to demonstrate a more severe form of periodontitis than were nonsmokers (7.9%). A significant difference was also detected in the prevalence of a more severe form of periodontitis between current smokers and nonsmokers overall ($p < 0.0001$, simple comparison). In women, a meaningful distinction was observed between current smokers and nonsmokers ($p = 0.0179$); in contrast, this association was absent in men.

The prevalence of periodontitis in each smoking status and age group are presented in Fig. 1. In both levels of periodontitis as a total (Fig. 1A,B), current smokers and former smokers exhibited a higher prevalence of periodontitis, compared with nonsmokers, in the ≥40 yr age groups. Significant differences were apparent in the prevalence of periodontitis between current smokers and nonsmokers ($p < 0.0001$, simple comparison). In the younger age group (20–39 yr), no significant difference was observed in the prevalence of periodontitis between current smokers and nonsmokers. In comparisons between current smokers and nonsmokers based on gender (Fig. 2), meaningful differences were evident in the ≥ 40 yr age groups in men ($p < 0.05$, Fig. 2A) and women ($p < 0.01$ and $p < 0.0001$, Fig. 2D), in the prevalence of periodontitis and more severe form of periodontitis, respectively.

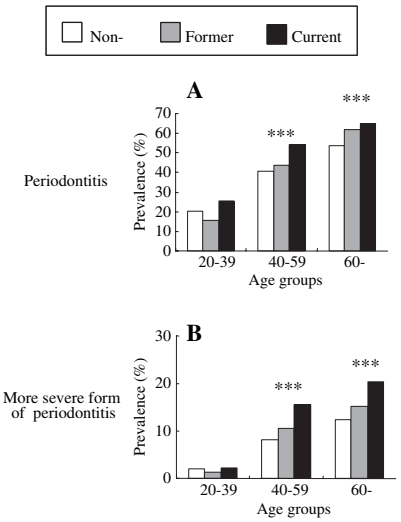

Fig. 1. Comparisons of prevalence of periodontitis among current smokers (black), former smokers (grey) and nonsmokers (white) on the basis of three age groups by levels of periodontitis. Periodontitis, CPI = 3 (presence of at least one site exhibiting pocket depth greater than 4 mm); a more severe form of periodontitis, CPI = 4 (presence of at least one site displaying pocket depth greater than 6 mm). ***significant between nonsmokers and current smokers ($P < 0.0001$).

Association between the prevalence of periodontitis and cigarette smoking

Based on the differences in the prevalence of periodontitis between current and nonsmokers clearly revealed in the ≥ 40 yr age groups, the following analyses were limited to subjects aged older than 40 yr ($n = 3493$). According to bivariate analyses, crude ORs of periodontitis and a more severe form of periodontitis were 1.58 [95% confidence interval (CI): 1.34–1.86] and 1.85 (95% CI: 1.47–2.33) times greater for current smokers than for nonsmokers, respectively (data not shown). Adjusted ORs for smoking and each covariate are presented in Table 3. Adjusted ORs of periodontitis and a more severe form of periodontitis were 1.38 (95% CI: 1.12–1.71, $p = 0.0024$) and 1.40 (95% CI: 1.04–1.89, $p = 0.0288$) times greater for current smokers than for nonsmokers, respectively. Age, current smoking and vitamin E intake were associated with prevalence of periodontitis. Age, frequency of daily brushing, current smoking and vitamin E intake were significantly correlated with the prevalence of a more severe form of periodontitis.

Discussion

Periodontal index in the SDD

Adjusted ORs of current smoking were 1.38 and 1.40 in terms of periodontitis and a more severe form of periodontitis, respectively. These figures are lower than those previously reported (5). Epidemiological studies involving local populations in Japan demonstrated that the OR of smokers was 2.1 following adjustment for possible confounders (26). Findings of the Third National Health and Nutrition Examination Survey (NHANES III) in the USA revealed that current smokers were approximately four times more likely to exhibit periodontitis than were persons who had never smoked (6). In

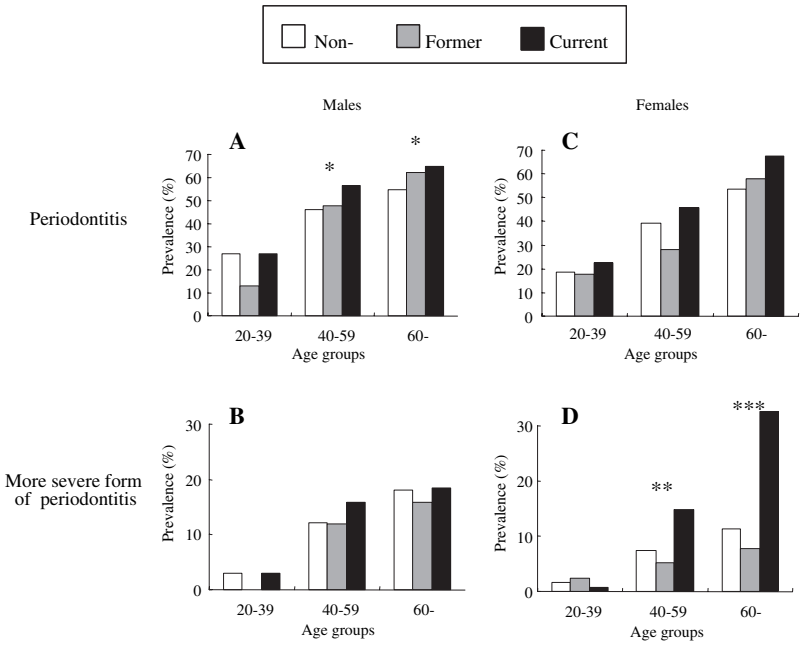

Fig. 2. Comparisons of prevalence of periodontitis among current smokers (black), former smokers (grey) and nonsmokers (white) on the basis of three age groups by levels of periodontitis and gender.
Periodontitis, CPI = 3 (presence of at least one site exhibiting pocket depth greater than 4 mm); a more severe form of periodontitis, CPI = 4 (presence of at least one site displaying pocket depth greater than 6 mm).
*significant between nonsmokers and current smokers ($P < 0.05$)
**significant between nonsmokers and current smokers ($P < 0.01$)
****significant between nonsmokers and current smokers ($P < 0.0001$)

the investigation, periodontitis was defined as the presence of clinical attachment level ≥4 mm and probing depth ≥4 mm. Estimates of relative risks depend on the prevalence, definition, and measurement methods of periodontal disease (27). A modification method of the CPI served as a surrogate marker of periodontal conditions in the SDD (i.e. probing of pocket depth was not utilized to evaluate the severity of periodontal disease). Moreover, assessments were limited to buccal sites of the maxillary jaw. Gingival recession, which decreases probing depth, was frequently observed at buccal sites and is more prevalent in smokers (28). Significant damage, including loss of attachment, was apparent at palatal sites of the maxillary jaw, which was suggestive of the local effect of cigarette smoking (29). Owing to the techniques applied to the evaluation of periodontitis in the survey, a partial recording system and underestimation of periodontal destruction attributable to the effect of smoking may occur in the analyses. The original objective of the SDD was acquisition of basic data relating to tooth and periodontal conditions.

Table 3. Prevalence odds ratios (OR) of periodontitis among adults ≥40 yr

		Periodontitis[a]			More severe form of periodontitis[b]		
Independent variables	Category	*n*	OR (95% CI)	*p*-value	*n*	OR (95% CI)	*p*-value
Smoking	Non	1021/2187	1.00 (Reference)		223/2187	1.00 (Reference)	
	Former	271/494	1.06 (0.83–1.36)	0.6168	66/494	0.96 (0.67–1.38)	0.8327
	Current	471/812	1.38 (1.12–1.71)	0.0024	141/812	1.40 (1.04–1.89)	0.0288
Gender	Female	956/2069	1.00 (Reference)		206/2069	1.00 (Reference)	
	Male	807/1424	1.12 (0.92–1.38)	0.2642	224/1424	1.30 (0.96–1.77)	0.0902
Age (yr)	40–59	824/1853	1.00 (Reference)		193/1853	1.00 (Reference)	
	60+	939/1640	1.66 (1.44 −1.91)	0.0000	237/1640	1.44 (1.16–1.78)	0.0009
Frequency of daily brushing	≥ 2 times	1127/2350	1.00 (Reference)		247/2350	1.00 (Reference)	
	< 2 times	623/1119	1.12 (0.96–1.31)	0.1470	179/1119	1.30 (1.05–1.63)	0.0189
BMI	18.5–25.0	1167/2351	1.00 (Reference)		285/2351	1.00 (Reference)	
	< 18.5	70/146	0.90 (0.64–1.27)	0.5522	24/146	1.35 (0.84–2.16)	0.2153
	≥ 25	522/992	1.15 (0.99–1.35)	0.0643	120/992	1.00 (0.79–1.26)	0.9950
Alcohol consumption	Never	1103/2316	1.00 (Reference)		251/2.316	1.00 (Reference)	
	Former	99/165	1.16 (0.82–1.64)	0.4158	29/165	1.20 (0.76–1.91)	0.4320
	Current	554/987	1.13 (0.93–1.37)	0.2086	147/987	1.00 (0.76–1.33)	0.9570
Vitamin C intake	≥ 100 mg	1127/2257	1.00 (Reference)		259/2257	1.00 (Reference)	
	< 100 mg	636/1236	0.95 (0.82–1.11)	0.5344	171/1236	1.09 (0.87–1.37)	0.4346
Vitamin E intake	≥ 10 or 8 mg	836/1816	1.00 (Reference)		183/1816	1.00 (Reference)	
	< 10 or 8 mg	927/1677	1.34 (1.16–1.56)	0.0001	247/1677	1.32 (1.06–1.65)	0.0117

[a] Community Periodontal Index (CPI) ≥ 3 (i.e. the presence of at least one site displaying a pocket depth of ≥4 mm).
[b] CPI = 4 (i.e. the presence of at least one site displaying a pocket depth of ≥6 mm).
BMI, body mass index; CI, confidence interval.

The prevalence of periodontitis is decreasing in the USA where tobacco consumption has declined (30). Although smoking prevalence among Japanese males decreased after 1970, following a peak in the mid-1960s, reduction in cigarette consumption per capita has appeared only recently (11). The data in the present study were derived from a cross-sectional survey in 1999; the number of years since quitting smoking was not provided. Furthermore, various criteria of periodontal measurements were used in the past SDD. Therefore, we could not evaluate the relationship between the trend of prevalence of periodontitis and reduction of cigarette consumption.

Comparison of study population with the NNS population

The 4828 records utilized for analyses consisted of 98% and 48% of those in the SDD and the NNS, respectively. Consequently, differences in distribution between the current study and the NNS should be considered carefully. In terms of smoking status, the differences were 0.1–1.3 points. Therefore, this sample may be similar to the NNS sample, and ascertainment bias, owing to use of linkage data, was estimated to be negligible with respect to smoking status. Differences in distribution by age and gender were also small (data not shown).

Smoking and other factors as risk factors of periodontitis

Differences in the prevalence of periodontitis between current smokers and nonsmokers were remarkable in subjects of the ≥ 40 yr age groups. Influence of smoking on periodontal tissue may be cumulative and may appear after the age of 40 yr. Following adjustment for confounding factors, current smoking was independently correlated with prevalence of periodontitis among persons aged 40 yr or older.

Increasing age and dietary deficiency of vitamin E were associated with the prevalence of periodontitis. The relationship between vitamin C intake and the prevalence of periodontitis was not apparent in this study despite the NHANES III data, which demonstrated a positive association between low dietary vitamin C intake and periodontal disease (21). Vitamin E is the most powerful aerobic lipid-soluble antioxidant (31). The effect of dietary vitamin E intake was shown to accelerate gingival wound healing and to prevent alveolar bone loss in experimental animals (23,24). Frequency of tooth brushing was also correlated with a more severe form of periodontitis.

Gender difference in smoking effect on periodontal tissue

Effects of smoking on periodontal tissue differed by gender: a meaningful effect on the prevalence of periodontitis (CPI ≥ 3) was detected in men, whereas the effect was not observed in women. However, the effect on prevalence of a more severe form (CPI = 4) was significant in women. The appearance of the association in men indicated that much of the Japanese population may be influenced by tobacco smoking as many men still smoke in Japan. A more severe form of periodontal disease resulted in tooth loss; consequently, male smokers may exhibit greater numbers of lost teeth, which were affected by smoking, via periodontitis; as a result, the effect of smoking on a severe form of periodontitis was masked.

In women, differences in the prevalence of periodontitis (CPI ≥ 3) between current smokers and nonsmokers were not evident. The association may be underestimated owing to low smoking prevalence and environmental tobacco smoke exposure (32). Smoking rate was low in women, although the effect of smoking could be detected in a more severe form (CPI = 4). Alternatively, gender difference, in terms of susceptibility to tobacco smoking, may exist [e.g. effects of smoking on adult pulmonary function (33), and interaction of estrogen deficiency and smoking in postmenopausal women (34,35)]. Recently, young woman and girls have become a special target of the tobacco industry; moreover, smoking prevalence in younger women has been on the rise in Asian countries, including Japan (11).

Smoking cessation and prevention in patients with periodontitis

The risks of smoking, with respect to periodontitis, have been shown to decline with the number of years since cessation among former smokers in the US population (6). Recent evidence suggests that smoking cessation possesses an additional beneficial effect in terms of reduction of probing following nonsurgical treatment over a 12-mo period (36). Dental professionals should continue smoking cessation efforts as an important part of periodontal treatment in dental settings.

On the basis of findings of this and numerous other studies, we conclude that cigarette smoking leads to deterioration of periodontal conditions in Japanese adults, especially in persons aged older than 40 yr. The World Health Organization recommends integrated preventive strategies for periodontal disease, based on the common risk factors approach for public health practices (37). Incorporation of prevention and cigarette smoking cessation regimes into national and community programmes for adult periodontitis in Japan is essential.

Acknowledgements

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