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Tooth Loss and Metabolic Syndrome in South Korea: The 2012 Korean National Health and Nutrition Examination Survey

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Abstract: To evaluate the relationship between tooth loss and metabolic syndrome (MS) in South Korean adults.

Subjects and Methods: A total of 3589 adults (1511 men and 2078 women aged over 40 years) from the 2012 Korean National Health and Nutrition Examination Survey were included and divided into 3 groups according to the number of remaining teeth (0–19, 20–27, and 28). We recorded the number of remaining teeth and measured MS components such as waist circumference, systolic and diastolic blood pressure, fasting blood glucose, serum high-density lipoprotein-cholesterol, and triglyceride concentration. We also calculated the number of subjects who met the inclusion criteria of MS in each group. Multiple logistic regression analysis was performed to estimate the prevalence of MS components according to the number of remaining teeth after adjusting for covariates.

Women without MS had significantly more teeth than those with MS (24.5 ± 0.2 vs 21.0 ± 0.3). In men, the prevalence of high blood pressure and high fasting blood glucose levels were significantly different among the 3 groups ($P = 0.003$ and $P < 0.001$, respectively); however, the prevalence of MS and all MS components were significantly different in women ($P < 0.001$ for all comparisons). Men with 0 to 19 remaining teeth were most likely to have high blood pressure and high fasting blood glucose, while women with 0 to 19 remaining teeth had the highest prevalence of MS and each MS component. Multiple logistic regression analysis revealed that women with fewer remaining teeth had a higher prevalence of MS and MS components after adjusting for covariates.

Having only a few remaining teeth was associated with MS in women in South Korea.

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Abbreviations: BMI = body mass index, BP = blood pressure, CI = confidence interval, CRP = C-reactive protein, DBP = diastolic blood pressure, FBG = fasting blood glucose, HDL-C = high-density lipoprotein cholesterol, IL = interleukin, LDL-C = low-density lipoprotein-cholesterol, MS = metabolic syndrome, OR = odds ratio, SBP = systolic blood pressure, TG = triglyceride, TNF-α = tumor necrosis factor alpha, WC = waist circumference.

INTRODUCTION

Tooth loss is defined as the exfoliation of at least 1 tooth from the alveolar bone of the jaw,[1] and was considered to be a part of the aging process until the middle of the 20th century. However, as dental care procedures progressed and developed, teeth could be better preserved with the aid of restorative and prosthodontic treatment.[2–4] Nevertheless, tooth loss remains a problem, especially in the elderly. According to the National Health and Nutrition Examination Survey, 91% of adults aged 20 to 64 years had dental caries, and only 34% of adults aged 40 to 64 years had all of their teeth.[5] Tooth loss gives rise to nutritional deficiencies and general weakness that is involved in several medical problems such as subclinical atherosclerosis,[6] physical disability, and mental impairment.[7–9] Tooth loss is caused by many conditions such as periodontal problems, dental caries, and trauma,[10,11] and some recent studies found that metabolic syndrome (MS) was also associated with tooth loss.[12–14]

MS is defined as a cluster of metabolic abnormalities including abdominal obesity, high blood pressure (BP), high fasting blood glucose (FBG), elevated serum triglycerides (TG), and low high-density lipoprotein cholesterol (HDL-C) levels.[15–18] The main mechanism of MS is insulin resistance, which results in type 2 diabetes mellitus and subsequent cardiovascular diseases.[19–21] The prevalence of MS has been increasing and is now an important social problem in both Western and Asian countries. The prevalence of MS is about 20% to 25% in the adults of western countries[22–25] and 5% to 20% in Asian adults.[26–28] The risk factors for MS include aging, stress, a sugar-rich diet, limited physical activity, alcohol abuse, irregular sleep patterns,[29–33] and a postmenopausal state.[34–36] MS is also associated with dental problems such as poor oral health behavior[37,38] and periodontal diseases.[39–41]

For reducing these metabolic risk factors, routine monitoring of several cholesterol levels, FBG, BP, body weight, and waist circumference (WC) is needed. The general treatments of MS include remedies to alleviate metabolic risk factors by low caloric diet, enhancing physical activity, use of medication such as antihypertensive, antidyslipidemic, and antihyperglycemic

agents.[17] In some obese subjects with MS, weight-loss drugs or bariatric surgery is also recommended.[42] Another study reported that some people with MS were more likely to use complementary and alternative medicine such as herbal supplements, aromatherapy, or massage therapy compared to people without MS.[43]

Although associations between tooth loss and MS have been previously reported,[12–14] none of these studies involved a Korean population. Therefore, we examined the relationship between tooth loss and MS in a representative South Korean population. We hypothesized that tooth loss is associated with MS.

SUBJECTS AND METHODS

Survey Overview

Data from the 2012 Korean National Health and Nutrition Examination Survey were used in this study. This survey consisted of 3 main categories, which were a nutrition survey, health examination, and health interview. A total of 200 regions were selected and 10,000 individuals aged over 1 year old were selected. The health examination and interview were performed in specially equipped buses, and the nutrition survey was conducted at home 1 week after the health interview. Trained professionals including nurses, dietitians, and health scientists conducted face-to-face interviews with structured questionnaires.

SUBJECTS

A total of 8058 subjects were included in the 2012 Korean National Health and Nutrition Examination Survey. We only selected men and women aged ≥40 years old, and thus 3556 subjects were excluded. Among the 4502 participants, 381 subjects who did not fast for at least 8 hours before the blood test, 373 subjects who did not give sufficient dental data, and 159 participants who did not give sufficient information to extract data for MS were excluded. Finally, a total of 3589 adults (1511 men and 2078 women) were included in this study. The study was approved by the institutional review board of the Korean Center for Disease Control and Prevention (2012-01EXP-01-2C), and was conducted according to the Ethical Principles for Medical Research Involving Human Subjects as defined by the Helsinki Declaration.[44] All the subjects provided written informed consent.

Anthropometric and Blood Pressure Measurements

The WC was measured at the end of a normal expiration to within 0.1 cm on a horizontal plane at the midpoint between the iliac crest and the costal margin while the subject was wearing loose fitting clothing. The subject's height was measured to within 0.1 cm and their weight without shoes or heavy clothing was recorded using a digital scale to within 0.1 kg. Body mass index (BMI) was calculated by dividing weight (kg) by the square of height (m^2). Each subject was seated and rested for at least 5 minutes before their BP was taken. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using a mercury sphygmomanometer (Baumanometer; W. A. Baum Co., Inc., Copiague, NY). The final BP value was determined by averaging the 2nd and 3rd BP values.

Biochemical Measurements

Blood samples were taken from subjects after they had fasted for at least 8 hours. Total cholesterol, low-density lipoprotein-cholesterol, HDL-C, TG, and FBG were measured enzymatically using a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan) at the Central Testing Institute in Seoul, Korea.

Socio-Demographic and General Health Behaviors

Socio-demographic and general health characteristics were evaluated using self-administered questionnaires regarding age, sex, smoking, alcohol consumption, physical activity, level of education, and household income. Nonsmokers were defined as those who never smoked or had smoked less than 100 cigarettes in their whole life. Ex-smokers were defined as those who had smoked more than 100 cigarettes in their whole life, but had stopped smoking at the time of the study. Current smokers were those who were smokers at the time of the study. Mild to moderate drinkers were defined as those who drank less than 3 glasses per day (15–30 g/day) and heavy drinkers were defined as those who drank more than 3 glasses per day (≥30 g/day). Physical activity was assessed using the International Physical Activity Questionnaire.[45] Regular exercise was defined as exercise more than 5 times a week and for 30 min/session, or strenuous exercise more than 3 times a week and for 20 min/session. Education level was classified as either high school graduate (≥13 years) or not, and household income was divided into quartiles after adjusting for the number of family members.

Oral Health Behavior

We recorded the time of day when tooth-brushing occurred and whether secondary oral hygiene products including dental gargle, dental floss, interdental brush, and electric toothbrushes were used. The time of day was categorized as before or after breakfast, lunch, dinner, after snacks, and before bedtime. The frequency of daily tooth-brushing was calculated as the total number of times the subject cleaned their teeth in 1 day.

Measurement of Remaining Teeth

We categorized the number of remaining teeth into 3 groups; 0 to 19, 20 to 27, and 28 teeth. People with complete dentition have 28 teeth, excluding the 4 third molars. The subjects who had lost at least 1 of their natural teeth were classified to the other 2 groups.

Definition of MS

The American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement defined the criteria for MS in Asians.[17,18] Subjects with 3 or more of the following 5 medical conditions were defined as having MS: abdominal obesity or a WC more than 90 cm in men and more than 80 cm in women, BP more than 130/85 mm Hg or the use of an antihypertensive drug, FBG more than 100 mg/dL or the use of an antidiabetic drug, an HDL-C level less than 40 mg/dL in men and 50 mg/dL in women or the use of an antidyslipidemic drug, and a TG level more than 150 mg/dL or use of an antidyslipidemic drug.

Statistical Analysis

Data are given as the mean ± standard error for continuous variables or as a percentage (standard error) for categorical variables. The general characteristics of subjects were analyzed using an unpaired *t* test for continuous variables and the Chi-square test for categorical variables. The latter was used to

analyze the prevalence of MS and each component of MS among the 3 remaining teeth groups in men and women, and to analyze the proportion of each remaining teeth group according to the number of MS components in men and women. A multivariable logistic regression analysis was used to determine the odds ratio (OR) and 95% confidence interval (CI) of the 5 MS components among the 3 remaining teeth groups after adjusting for the following covariates: age, sex, and BMI in model 1; covariates of model 1 plus smoking, alcohol, regular exercise, education level, and household income in model 2; covariates of model 2 plus the use of secondary oral products and frequency of tooth brushing in model 3. The SAS software package version 9.2 (SAS institute, Cary, NC) was used for statistical analysis. All the statistical tests were 2-tailed and differences were considered to be statistically significant when the P value was less than 0.05.

RESULTS

The general characteristics of subjects with or without MS are summarized in Table 1. Both men and women with MS were older than those without MS ($P < 0.05$). However, BMI, WC, SBP, DBP, FBG, and TG were all higher and HDL-C was lower in subjects with MS compared to those without MS in both men and women (all $P < 0.001$). A significantly greater proportion of women with MS were in the lowest income quartile (Q1), but a significantly smaller proportion of these women had an education level ≥13 years ($P < 0.001$ for both). Periodontitis was more common in women with MS compared to those without MS (19.9% ± 1.6% vs 32.9% ± 2.3%), and women without MS also had a significantly greater number of remaining teeth compared to those with MS (24.5 ± 0.2 vs 21.0 ± 0.3, respectively) and the frequency of tooth brushing and the use of secondary oral products were also significantly different only among the female subjects ($P < 0.001$ for all).

The prevalence of MS and each MS component among the 3 remaining teeth groups is given in Table 2. Men showed significant differences in the prevalence of high BP and high FBG levels ($P = 0.003$ and $P < 0.001$, respectively), although the prevalence of MS and all MS components were significantly different in women ($P < 0.001$ for all). Men with 0 to 19 remaining teeth had the highest prevalence of high BP and high FBG levels, and women with 0 to 19 remaining teeth had the highest prevalence of MS and each MS component.

The relationship between the number of remaining teeth and the number of MS components is summarized in Figure 1. The proportion of subjects in each remaining teeth group was significantly different in men and women ($P = 0.017$ and $P < 0.001$, respectively), although the proportion of women in the 28 and the 0 to 19 remaining teeth groups increased and decreased, respectively, with an increasing number of MS components (P for trend < 0.001).

Compared to the 28 remaining teeth group, the OR for the prevalence of MS and each MS component in the 0 to 19 and 20 to 27 remaining teeth groups were not significantly different in men after adjusting for the covariates (Table 3). In women, the

TABLE 1. General Characteristics of Subjects With or Without Metabolic Syndrome in the KNHANES

	Men			Women		
	MS (−)	MS (+)	*P*	MS (−)	MS (+)	*P*
Unweighted (n)	989	522		1171	907	
Age, years	53.9 ± 0.4	55.5 ± 0.6	0.01	52.9 ± 0.4	60.7 ± 0.5	<0.001
BMI, kg/m^2	23.3 ± 0.1	25.7 ± 0.2	<0.001	22.9 ± 0.1	25.9 ± 0.2	<0.001
WC, cm	82.2 ± 0.3	89.6 ± 0.4	<0.001	76.6 ± 0.3	86.6 ± 0.5	<0.001
SBP, mm Hg	120.1 ± 0.7	127.7 ± 0.9	<0.001	115.8 ± 0.7	129.2 ± 0.8	<0.001
DBP, mm Hg	78 ± 0.5	83.4 ± 0.6	<0.001	74.5 ± 0.4	77.7 ± 0.5	<0.001
FBG, mg/dL	97.5 ± 0.7	112 ± 0.3	<0.001	92 ± 0.4	111 ± 1.6	<0.001
HDL-C, mg/dL	50.1 ± 0.4	42.7 ± 0.4	<0.001	57 ± 0.4	46.9 ± 0.5	<0.001
TG, mg/dL*	112.3 (107.9–116.9)	202.2 (191.2–213.8)	<0.001	90.5 (87.3–93.7)	154.5 (146.6–162.9)	<0.001
Current smoking (yes, %)	37.7 ± 1.9	35 ± 3	0.455	4 ± 0.7	5.7 ± 1.2	0.215
Heavy alcohol intake (yes, %)	14.9 ± 1.4	19 ± 2.2	0.123	1.7 ± 0.5	1.8 ± 0.6	0.919
Physical activity (yes, %)	20.1 ± 1.7	16.4 ± 2	0.221	13.4 ± 1.2	11.9 ± 1.5	0.461
Education (%, ≥13 years)	68.7 ± 2.2	63.2 ± 2.7	0.067	59.5 ± 2	31.6 ± 2.2	<0.001
Income (Q1) (yes, %)	14.5 ± 1.4	14.1 ± 2	0.891	14.3 ± 1.4	30.5 ± 2.3	<0.001
Periodontitis, %	39 ± 2.3	38.1 ± 3	0.807	19.9 ± 1.6	32.9 ± 2.3	<0.001
Remaining teeth (n)	24.1 ± 0.3	23.7 ± 0.3	0.273	24.5 ± 0.2	21 ± 0.3	<0.001
Tooth brushing (n/day)			0.09			<0.001
0/1	15.3 (1.5)	17.8 (2.1)		8.7 (1)	12.7 (1.4)	
2	44.2 (1.9)	36.3 (2.9)		38.2 (1.7)	48.7 (2.2)	
3	40.4 (2.2)	45.9 (3.1)		53.1 (1.7)	38.6 (2.2)	
Use of secondary oral product, %	41.9 (2)	45.9 (2.8)	0.184	53.8 (1.8)	37.9 (1.8)	<0.001

BMI = body mass index, DBP = diastolic blood pressure, FBG = fasting blood glucose, HDL-C = high density lipoprotein -cholesterol, KNHANES = Korean National Health and Nutrition Examination Survey, MS = metabolic syndrome, SBP = systolic blood pressure, TG = triglyceride, WC = waist circumference.

*Geometric mean (95% CI) data are presented as the mean ± SE. The P values were obtained using an unpaired t test or Chi-square test, and all were <0.001.

TABLE 2. Prevalence of MS and MS Components in the 3 Remaining Teeth Groups in Men and Women

	Men				Women			
Remaining Teeth (n)	**0–19**	**20–27**	**28**	***P***	**0–19**	**20–27**	**28**	***P***
MS	39.4 (3.7)	31.5 (2.1)	31.8 (2.8)	0.199	64 (2.7)	43.2 (2)	24.5 (2.2)	<0.001
High WC	22 (3.2)	24.9 (2.1)	24 (2.7)	0.778	64 (2.9)	54.7 (2.1)	36 (2.7)	<0.001
High BP	63.3 (3.4)	51.9 (2.5)	46.3 (3)	0.003	72.9 (2.4)	47.2 (2.1)	27.9 (2.5)	<0.001
High FBG	55.3 (3.5)	40.5 (2.2)	36.2 (2.9)	<0.001	44.7 (2.4)	34.3 (1.9)	24.9 (2.1)	<0.001
Low HDL-C	33.5 (3)	27.6 (2)	28.4 (2.7)	0.329	62.4 (2.4)	50.5 (1.8)	38.8 (2.7)	<0.001
High TG	41.7 (3.3)	45.5 (2)	45.7 (3.1)	0.668	48.7 (3.2)	40 (1.8)	25.3 (2)	<0.001

Data are presented as percentages (SE). *P* values were obtained by using the Chi-square test and all were <0.001. BP = blood pressure, FBG = fasting blood glucose, HDL-C = high density lipoprotein cholesterol, MS = metabolic syndrome, SE = standard error, TG = triglyceride, WC = waist circumference.

OR (95% CI) for the prevalence of MS was 1.784 (1.200–2.653) in the 0 to19 remaining teeth group and 1.480 (1.085–2.019) in the 20 to 27 remaining teeth group after adjusting for covariates. The prevalence of a high WC was high only in the 20 to27 remaining teeth group (OR [95% CI], 1.882 [1.060–3.343]). The prevalence of high BP was higher in both the 0 to 19 and 20 to 27 remaining teeth groups (OR [95% CI], 1.571 [1.067–2.313] and 1.410 [1.076–1.847], respectively) and the prevalence of high TG levels was also higher in both the 0 to 19 and 20 to 27 remaining teeth groups (OR [95% CI], 1.535 [1.029–2.292] and 1.476 [1.119–1.947], respectively) in women after adjusting for covariates.

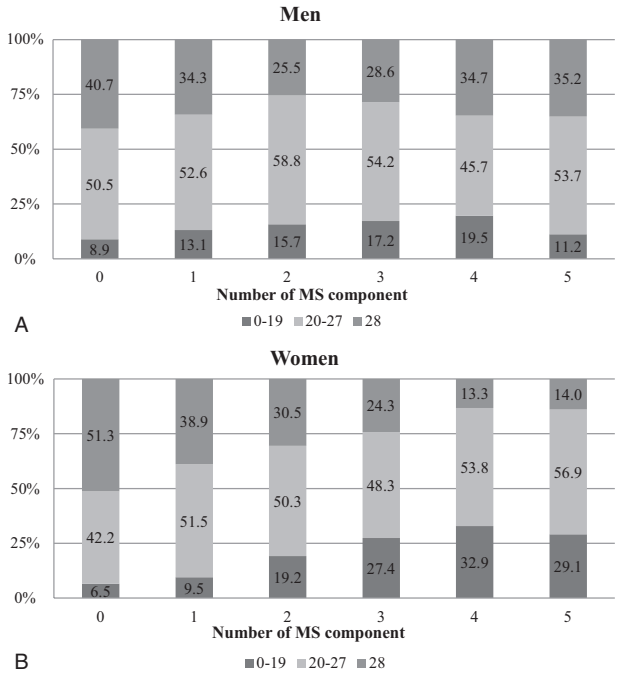

FIGURE 1. (A) Proportion of each remaining teeth group according to the number of metabolic syndrome (MS) components in men. ($P = 0.017$, P for trend <0.01). (B) Proportion of each remaining teeth group according to the number of MS components in women ($P < 0.001$, P for trend <0.001).

DISCUSSION

In this study, women with MS had significantly fewer remaining teeth than women without MS. The proportion of women with 28 and 0 to 19 remaining teeth decreased and increased, respectively, with an increasing number of MS components. The prevalence of MS and MS components was not associated with the number of remaining teeth in men. However, the prevalence of MS, high BP, and high TG levels was higher in women with 0 to 19 and 20 to 27 remaining teeth compared to those with 28 remaining teeth.

Several studies have shown an association between tooth loss and MS. A self-reported study of 947 Swedish subjects aged over 70 years old found that the number of remaining teeth was inversely related to the prevalence of MS.[12] Another study that involved a total of 1354 middle-aged Finnish men showed an increased prevalence of MS in subjects with more than 4 missing teeth, although the third molars were also included and there was no adjustment for covariates.[13] Similarly, a US population-based study of adults aged 20 years or older also showed an association between tooth loss and MS.[14]

A number of studies also found a relationship between tooth loss and MS components. An English study of 1958 adults aged 25 to 74 years old found that tooth loss was positively associated with serum TG levels in women,[46] and another study showed similar results in that subjects with more than 6 missing teeth had significantly higher serum TG levels than subjects with less than 6 missing teeth.[47] Two studies showed that SBP was associated with tooth loss[48,49] and another prospective clinical trial showed a negative association between DBP and tooth loss in postmenopausal women.[50] It was also reported that there was a negative association between the number of remaining teeth and SBP in men,[49] although we could not find any association between tooth loss and MS in men.

In this study, abdominal obesity was more frequent in the 20 to 27 remaining teeth group in women. One cross-sectional study of 1720 adults aged 20 to 59 years old in Brazil demonstrated that the prevalence of abdominal obesity increased when adults had less than 10 remaining teeth in at least 1 arch compared to those with 10 or more teeth in both arches including the maxilla and mandible, although this difference was not significant after adjusting for age.[51] Another Brazilian study of 471 elderly subjects aged between 60 and 89 years old also reported that subjects with fewer (1–8) remaining teeth had a significantly higher prevalence of abdominal obesity.[52] Similarly, Swedish subjects younger than 60 years old showed an

TABLE 3. Prevalence of MS and Each MS Component Among the 3 Remaining Teeth Groups in Men and Women

Remaining Teeth (n)	Men 0–19	Men 20–27	Men 28	Men *P*	Women 0–19	Women 20–27	Women 28	Women *P*
				Model 1				
MS	1.252 (0.758–0.069)	0.923 (0.638–1.336)	1	0.399	1.784 (1.204–2.643)	1.55 (1.137–2.114)	1	0.007
High WC	0.641 (0.311–1.32)	0.938 (0.547–1.606)	1	0.42	2.052 (0.981–4.292)	1.887 (1.105–3.222)	1	0.065
High BP	1.008 (0.594–1.709)	0.993 (0.707–1.395)	1	0.997	1.498 (1.005–2.231)	1.398 (1.057–1.848)	1	0.048
High TG	1.189 (0.792–1.785)	1.125 (0.826–1.533)	1	0.672	1.497 (1.007–2.225)	1.537 (1.172–2.016)	1	0.008
Low HDL-C	1.134 (0.746–1.723)	0.916 (0.653–1.285)	1	0.459	1.411 (0.976–2.039)	1.262 (0.973–1.638)	1	0.148
High FBG	1.341 (0.851–2.114)	1.01 (0.725–1.409)	1	0.309	0.883 (0.583–1.337)	1.055 (0.774–1.439)	1	0.468
				Model 2				
MS	1.204 (0.709–2.045)	0.899 (0.615–1.313)	1	0.446	1.795 (1.209–2.665)	1.511 (1.108–2.06)	1	0.008
High WC	0.645 (0.305–1.362)	0.968 (0.552–1.696)	1	0.424	2.131 (0.964–4.711)	1.855 (1.061–3.245)	1	0.091
High BP	1.046 (0.611–1.791)	0.962 (0.682–1.357)	1	0.909	1.584 (1.075–2.332)	1.412 (1.079–1.848)	1	0.024
High TG	1.117 (0.715–1.747)	1.076 (0.779–1.488)	1	0.873	1.538 (1.037–2.281)	1.508 (1.145–1.984)	1	0.012
Low HDL-C	1.134 (0.725–1.774)	0.911 (0.644–1.29)	1	0.462	1.465 (0.995–2.158)	1.254 (0.953–1.651)	1	0.147
High FBG	1.283 (0.795–2.071)	0.972 (0.689–1.371)	1	0.367	0.945 (0.606–1.474)	1.084 (0.782–1.501)	1	0.609
				Model 3				
MS	1.202 (0.709–2.039)	0.897 (0.613–1.311)	1	0.438	1.784 (1.2–2.653)	1.48 (1.085–2.019)	1	0.011
High WC	0.641 (0.3–1.368)	0.968 (0.552–1.699)	1	0.426	2.141 (0.966–4.746)	1.882 (1.06–3.343)	1	0.092
High BP	1.05 (0.614–1.795)	0.979 (0.695–1.38)	1	0.944	1.571 (1.067–2.313)	1.41 (1.076–1.847)	1	0.025
High TG	1.125 (0.72–1.756)	1.097 (0.795–1.516)	1	0.832	1.535 (1.029–2.292)	1.476 (1.119–1.947)	1	0.018
Low HDL-C	1.137 (0.727–1.776)	0.91 (0.643–1.288)	1	0.459	1.451 (0.976–2.158)	1.197 (0.906–1.582)	1	0.185
High FBG	1.268 (0.792–2.032)	0.945 (0.67–1.333)	1	0.317	0.949 (0.608–1.481)	1.071 (0.775–1.48)	1	0.682

Data are presented as the geometric mean (95% CI) Model 1 was adjusted for age, sex, and BMI. Model 2 was adjusted for age, sex, BMI, smoking, drinking, regular exercise, education level, and household income. Model 3 was adjusted for age, sex, BMI, smoking, drinking, regular exercise, education level, household income, frequency of tooth-brushing per day, and use of a secondary oral product. *P* values were obtained using multiple logistic regression analysis. BMI = body mass index, BP = blood pressure, CI = confidence interval, FBG = fasting blood glucose, HDL-C = high density lipoprotein cholesterol, MS = metabolic syndrome, TG = triglyceride, WC = waist circumference.

increased prevalence of abdominal obesity when they had less than 20 remaining teeth adjusting for age, sex, socioeconomic status, life-style, and comorbidities.[53]

A possible mechanism underlying the relationship between tooth loss and MS may involve elevated systemic inflammation. Several studies suggested that high sensitivity C-reactive protein and proinflammatory cytokines, such as tumor necrosis factor alpha (TNF-α), interleukin (IL)-1, and IL-6, were elevated in patients with MS.[54–56] These inflammatory proteins may cause local periodontal destruction and subsequent tooth loss.[57,58] TG is an another cause of inflammation,[59] and the increased lipolysis of TG can give rise to endothelial inflammation through TNF-α release and the stimulation of reactive oxygen species production within cells.[60] A prospective cohort study of 20,525 US middle-aged female adults found that increased C-reactive protein was associated with forthcoming hypertension,[61] and hypertension itself also causes an increase in inflammatory markers.[62–64]

Obese people generally prefer a diet that is abnormally high in sugar, which might be involved in tooth loss.[52] Conversely, subjects with few remaining teeth are likely to have a high calorie diet because of their compromised masticatory function.[65] Taken together, this indicates that cumulative high-sugar diets may also increase the risk of both obesity and tooth loss,[66] and abdominal obesity may accelerate tooth loss, or conversely, tooth loss may accelerate the development of abdominal obesity.

Poor oral health may affect all of these pathways. Regular tooth brushing is an effective means of removing plaque and maintaining healthy gingiva.[67] A previous study of an adult Japanese population indicated that a low frequency of tooth brushing was associated with a high prevalence of MS,[38] and a study of Korean adults also demonstrated that a low frequency of tooth brushing or no dental flossing may increase the likelihood of MS.[37] Furthermore, local periodontitis as well as systemic inflammation may be worse in individuals with a poor oral health status.[68] Consequently, poor oral health behavior may aggravate MS, giving rise to systemic and local inflammation, and ultimately tooth loss.

There was a sex-based difference in the relationship between tooth loss and MS in this study. This may be explained in part by the inclusion of women who were postmenopausal, defined as the cessation of menstruation for at least 1 year.[69] Among the Korean population, women on average undergo the menopause when they are 46.9 ± 4.9 years old (median, 48 years).[70] Menopause induces the ageing process and is associated with reduced estrogen synthesis. This hormonal change can evoke various unpleasant physical and psychological changes.[34,71] A number of studies have shown that postmenopausal women have higher total cholesterol and TG levels, and lower HDL-C levels compared to premenopausal women.[72,73] It has also been shown that systemic inflammation was accelerated in postmenopausal women with MS,[36,74] which might explain the increased tooth loss in women compared to men in this study.

This study had a number of limitations that need to be considered. First, this was a cross-sectional study, and hence it is not possible to demonstrate a causal relationship between tooth loss and MS. Second, although this study enrolled a large representative sample, it was conducted in only a single Asian country. A multinational study involving subjects of other ethnicities is therefore needed for more generalizable results. Third, we did not measure the hormonal status of subjects, nor did we record their postmenopausal history, especially in women. Fourth, there were no descriptions of other causal factors for tooth loss such as dental caries and trauma. This study also has a number of notable strengths though. We used a representative sample of the whole South Korean population, and to the best of our knowledge, this is the first study to examine the relationship between tooth loss and MS in such a population. We also adjusted for many covariates such as age, sex, BMI, smoking, drinking, regular exercise, education level, household income, frequency of tooth-brushing, and the use of secondary oral products.

In conclusion, we found that tooth loss was associated with an increased prevalence of MS in South Korean women. Physicians should be aware that women with fewer remaining teeth may have an increased risk of MS. Further prospective, well-designed studies are needed to reveal the causal relationship between tooth loss and MS.

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