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The association of metabolic syndrome with periodontal disease is confounded by age and smoking in a Korean population: the Shiwha–Banwol Environmental Health Study

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Abstract

Aim: Because metabolic syndrome (MS) is pro-inflammatory and periodontitis is inflammatory, we issued the hypothesis that MS (the explanatory variable) is associated with periodontitis (the outcome variable). This study aimed to examine the link between MS and periodontitis among Koreans.

Materials and Methods: From the Shiwha–Banwol Environmental Health Study, 1046 subjects aged 18 years or older were cross-sectionally surveyed. All participants underwent comprehensive dental and medical health examinations. The community periodontal index was used to assess periodontitis. Age, gender, monthly family income, smoking, drinking, frequency of daily teeth brushing, and physical activity were evaluated as confounders.

Results: MS was strongly associated with periodontitis [odds ratio (OR): 1.7, 95% confidence interval (CI): 1.22–2.37], and MS with more components had a higher association. The association was higher for elders aged 65 years or more, males, and smokers. MS including both high glucose and hypertension had a higher association with the OR of 2.19 (95% CI: 1.23–3.90) comparing with other types of MS.

Conclusions: Our results suggested that MS might be associated with periodontitis and the association was confounded by age, gender, and smoking. MS with high glucose and hypertension showed the higher impact on this link.

Key words: epidemiology; Korean; metabolic syndrome; periodontitis

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Conflict of interest and source of funding statement

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The metabolic syndrome (MS), a clustering within individuals of several cardiovascular risk factors, has been focused for several years in the United States and the world (Bray & Bellanger 2006). A diagnosis of MS is associated with a doubling in risk for future cardiovascular diseases and type-2 diabetes mellitus (Lorenzo et al. 2007). According to Adult Treatment Panel III and recent consensus workshops, MS is defined as the presence of three or more of five components: hypertension, hypertriglyceridaemia, low high-density lipoprotein (HDL) cholesterol, obesity, and insulin resistance (Grundy et al. 2005, Alberti et al. 2006). It is estimated that around a quarter of the world's adult population is affected by MS (Cameron et al. 2004).

Although MS was once considered a health problem in developed countries similar to obesity, the prevalence of MS has also increased in developing countries (Gu et al. 2005, Eapen et al. 2009). The age-adjusted prevalence of MS was

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increased from 23.6% in the 1998 Korean National Health and Nutrition Examination Survey (KNHANES) to 28.0% in 2001 KNHANES, which addressed an increase in prevalence by 18.6% over 3 years (Lim et al. 2005). In the United States, the age-adjusted prevalence of MS was increased from 24.1% in the National Health and Nutrition Examination Survey (NHANES) III (1988–1994) to 27.0% in NHANES 1999–2000 (Ford et al. 2004). MS is the emerging health problem in both developed and developing countries.

Periodontitis is a common chronic infection of the adult population and is closely related with diabetes (Grossi & Genco 1998) and stroke (Sim et al. 2008). A growing body of evidence also indicates that periodontitis is associated with obesity (Al-Zahrani et al. 2003, Saito et al. 2005).

Because both periodontitis and MS are associated with systemic inflammation and insulin resistance, and these two diseases may be linked through a common pathophysiological pathway. A few information, however, is available on the possible association between MS and periodontitis (Shimazaki et al. 2007, D'Aiuto et al. 2008, Li et al. 2009). Therefore, the hypothesis of this study is that MS (the explanatory variable) is associated with periodontitis (the outcome variable) and can deteriorate the periodontal health status.

In this cross-sectional study, we aimed to investigate whether MS is associated with periodontitis in the Korean population.

Materials and Methods

This study was approved by the Institutional Review Board for Human Subjects of the School of Dentistry, Seoul National University (approval number: S-020060000). All subjects participated voluntarily and provided a written informed consent.

Study design and participants

This was a cross-sectional study comprised of baseline data from a large cohort study, the Shiwha–Banwol Environmental Health Study (Han et al. 2009). The study has currently been conducted in two Korean cities, Shiwha and Banwol, since 2005. The study has aimed to determine the influences of the environmental pollution on health including oral health, and is scheduled to continue for the next 20 years.

At baseline, residents in the two cities were contacted by telephone, advertisements in local newspapers, and door-to-door campaigns. A total of 1932 residents agreed to enter this survey and completed the health assessment and questionnaires in Shiwha and Banwol from July 2005 to August 2006. The participants were included in this study of their own accord.

Oral health and general health status were assessed by many health professionals in the cohort project. Information regarding socio-demographic status and health-related behaviours, including oral health, was obtained from the questionnaire through an interview. General and oral health status and anthropometric measurements were obtained from clinical examinations. Exclusion criteria were fourfold: (1) subjects aged under 18 years, (2) subjects having <20 natural teeth excluding wisdom teeth, (3) subjects with a single missing value in the health assessment or questionnaires, and (4) subjects who want to quit participating. The final number of subjects included was 1046, and the response rate was 85.5% among subjects over 18 years ($n = 1223$). The subjects were comprised of 457 men and 589 women aged from 18 to 84 years with a mean and standard deviation of 42.3 ± 12.2 years.

Assessment of periodontitis

Two experienced dentists examined the oral health status of each of the participants. Periodontal condition was assessed using a community periodontal index (CPI) selected as a tool for evaluating the periodontal health status of population by the World Health Organization (WHO 1997). The five CPI scores used to evaluate the periodontal health status were as follows: normal (CPI 0), gingival bleeding (CPI 1), calculus (CPI 2), shallow periodontal pocket of 3.5–5.5 mm (CPI 3), and deep periodontal pocket of 5.5 mm or more (CPI 4). The measurements of periodontal pocket depth were made using a CPI probe at six sites (mesiobuccal, midbuccal, distobuccal, distolingual, midlingual, and mesiolingual) per tooth. According to the guidelines of WHO (1997), 10 teeth were selected for the periodontal examination, the two molars in each posterior sextant and the upper right and lower left central incisors. If no index teeth or tooth were present in a qualifying sextant, the adjacent remaining tooth in that sextant was examined. The highest resulting score was recorded as the CPI score for each individual. Groups were categorized according to periodontal status; non-periodontitis (CPI 0 to CPI 2 including normal and gingivitis) *versus* periodontitis (CPI 3 or CPI 4). For assessing the dose–response relationship, periodontal status was reevaluated: healthy and gingivitis (CPI 0–2), and the number of sextants with periodontitis (CPI 3 or 4).

Before the main survey, the two dentists underwent a calibration training procedure for CPI measurements. The first step of the procedure was dictation and discussion using slides to verify the validity. The next step was a test–retest examination on 43 subjects to verify the reproducibility. During the main survey, 845 individuals were examined by one dentist and 201 individuals were examined by the other dentist. Total of 100 subjects were selected to evaluate the inter/intra-examiner reliability and the validity. One procedure of inter- or intra-examiner reliability used 10 subjects to perform repeated measurements. The procedures to evaluate the test–retest reliability were performed 10 times, five times for intra-examiner reliability and five times for inter-examiner reliability. The intra-examiner reliability (the binary variable: non-periodontitis of CPI 0–2 *versus* periodontitis of CPI 3–4) of the two dentists resulted in a κ-index of 0.84 and 0.97, respectively. The inter-examiner reliability between two dentists was a κ-index of 0.62.

Assessment of MS

Assessment of MS was based on the following five components: central obesity (waist circumference ≥ 90 cm for men and ≥ 85 cm for women) (Lee et al. 2007); hypertriglyceridaemia (triglycerides >150 mg/dl); low HDL cholesterol (<40 mg/dl for men and <50 mg/dl for women); high blood pressure (systolic: >130 mmHg or diastolic: >85 mmHg or on blood pressure medication); and high plasma glucose (>110 g/dl) (Alberti et al. 2009). Waist circumference was measured using a measuring tape by trained examiner. Waist size was measured midway between the inferior margin of the ribcage and the iliac crest horizontally. For

biochemical variables, 12-h fasting blood samples were drawn at recruitment. Serum biomarkers included fasting plasma glucose, triglycerides, and HDL) cholesterol. Routine procedures of biochemical tests for glucose (mg/dl), HDL cholesterol (mg/dl), and triglycerides were applied. The blood pressure (systolic and diastolic) (mmHg) of the subjects was measured in the sitting position using a mercury manometer two times with 15-min. intervals, and the mean value of two trials was used for the analysis. Two physicians measured blood pressure and diagnosed hypertension.

MS was considered to be present in participants exceeding the threshold limits for at least three of these components (Alberti et al. 2009).

Assessment of confounders

Socio-demographic status and general/oral health-related behaviours were selected as confounders. Age, gender, and monthly family income were selected as socio-demographic factors (Table 1). General/oral health-related behaviours included smoking, drinking, frequency of daily teeth brushing, and physical activity. In order to obtain information regarding the potential confounders, the subjects were interviewed face-to-face by a trained interviewer using structured questionnaires.

Statistical analysis

Characteristic variables of the subjects were described using frequency distributions for the categorical variables. χ^2-test was used to assess the differences in the categorical variables. Logistic regression analyses were used to evaluate the association between MS and periodontitis adjusted for the effect of confounders (age, gender, monthly family income, health-related behaviours such as smoking, drinking, the frequency of daily teeth brushing, and physical activity). The initial strategy consisted of testing the relationship between MS (explanatory variable) and periodontitis (outcome variable) using binary variables. Additionally, we tested the dose–effect relationship to determine the impact of the number of positive components of MS on periodontitis. Although the interactions of MS with age, gender, and smoking were not significant ($p > 0.05$), subgroup analyses by age, gender, and smoking were performed to assess whether age, gender, and smoking could modify the associations. The second strategy was to identify which component of MS has a more powerful effect on periodontitis. Because diabetes and hypertension were well-known risk factors for periodontitis and low HDL cholesterol was the significant individual component on periodontitis in this data set, these three components were selected to evaluate the combined effect of them in MS on periodontitis. Among the three candidate risk factors (diabetes, hypertension, and low HDL cholesterol), combination impacts of two components of MS were tested with the reference of the healthy (non-MS) subjects.

Table 1. Characteristics of subjects according to the periodontal status ($n = 1046$)

Variables	Total *N*	Non-periodontitis (CPI 0–2) *N* (%)	Periodontitis (CPI 3–4) *N* (%)	*p*-value*
Age (years)				
18–34	223	202 (90.6)	21 (9.4)	<0.001
35–44	457	298 (65.2)	159 (34.8)	
45–64	289	157 (54.3)	132 (45.7)	
65–	77	33 (42.9)	44 (57.1)	
Gender				
Male	457	258 (56.5)	199 (43.5)	<0.001
Female	589	432 (73.3)	157 (26.7)	
Monthly income (USD)				
<2000	298	189 (63.4)	109 (36.6)	0.536
2–4000	576	387 (67.2)	189 (32.8)	
≥ 4000	172	114 (66.3)	58 (33.7)	
Smoking over 20 packs in lifetime				
No	769	539 (70.1)	230 (29.9)	<0.001
Yes	277	151 (54.5)	126 (45.5)	
Alcohol drinking				
No	473	325 (68.7)	148 (31.3)	0.005
Sometimes	403	271 (67.2)	132 (32.8)	
Frequently	170	94 (55.3)	76 (44.7)	
Frequency of tooth brushing (times/day)				
<2	599	353 (58.9)	246 (41.1)	<0.001
≥ 2	447	337 (75.4)	110 (24.6)	
Physical activity in a week				
No	314	218 (69.4)	96 (30.6)	0.005
Walking	411	247 (60.1)	164 (39.9)	
Exercise	321	225 (70.1)	96 (29.9)	

*Obtained from χ^2-test.
CPI, community periodontal index.

Results

Characteristics of subjects

The periodontitis (CPI 3–4) group had more elders, males, smokers, and drinker than the non-periodontitis (CPI 0–2) group (Table 1). The periodontitis group brushed their teeth less frequently than the non-periodontitis group. With regard to the MS, the periodontitis group showed a higher prevalence of the MS and each component of MS (Table 2).

Relationship between MS and periodontitis

MS was significantly associated with periodontitis [the adjusted odds ratio (OR): 1.70, 95% confidence interval (CI): 1.22–2.37] (Table 3). The association showed a dose–effect relationship; the adjusted OR was 1.53 (95% CI: 1.05–2.23) for MS with three components, and 2.20 (95% CI: 1.28–3.78) for MS with four or five components.

Subgroup analysis

According to the results of stratified analysis by subgroup (Table 4), the association was higher among elders aged 65 years or more compared with those aged 45–64 years (OR: 6.03 *versus* 2.12), males than females (1.92 *versus* 1.35), and smokers than non-smokers (2.38 *versus* 1.38).

MS component analysis

Compared with non-MS, MS with high glucose and hypertension had a higher association with periodontitis with the dose–effect relationship (Table 5): OR was 1.99 for MS with high glucose, 1.94

Table 2. Characteristics of metabolic syndrome and its components according to the periodontal status ($n = 1046$)

Variables	Total *N*	Non-periodontitis (CPI 0–2) *N* (%)	Periodontitis (CPI 3–4) *N* (%)	*p*-value*
Metabolic syndrome				
No	812	581 (71.6)	231 (28.4)	<0.001
Yes	234	109 (46.6)	125 (53.4)	
Waist circumference (cm)				
<90 (85)	713	499 (70.0)	214 (30.0)	<0.001
≥90 (85)	333	191 (57.4)	142 (42.6)	
HDL cholesterol (mg/dl)				
≥40 (50)	668	464 (69.5)	204 (30.5)	0.002
<40 (50)	378	226 (59.8)	152 (40.2)	
Hypertriglyceridaemia (mg/dl)				
<150	680	492 (72.4)	188 (27.6)	<0.001
≥150	366	198 (54.1)	168 (45.9)	
High glucose (mg/dl)				
<110	838	579 (69.1)	259 (30.9)	<0.001
≥110	208	111 (53.4)	97 (46.6)	
High blood pressure				
No	777	552 (71.0)	225 (29.0)	<0.001
Yes	269	138 (51.3)	131 (48.7)	

*Obtained from χ^2-test.
CPI, community periodontal index; HDL, high-density lipoprotein.

Table 3. Association of the metabolic syndrome with periodontitis (CPI 3–4) ($n = 1046$)

Model	Variables		OR*	95% CI	*p*-value
Model I					
	Number of positive components of metabolic syndrome	<3 ($n = 812$)	1		
		3–5 ($n = 234$)	**1.70**	**1.22–2.37**	**0.002**
	Age (continuous)		**1.05**	**1.04–1.06**	**<0.001**
	Gender (male: reference)		**0.63**	**0.44–0.91**	**0.015**
	Monthly family income		1.06	0.86–1.31	0.596
	Smoking		1.20	0.82–1.77	0.350
	Alcohol drinking		0.85	0.69–1.04	0.106
	Frequency of tooth brushing		**0.72**	**0.62–0.84**	**<0.001**
	Physical activity		1.07	0.89–1.28	0.498
Model II					
	Number of positive components of metabolic syndrome	<3 ($n = 812$)	1		
		3 ($n = 160$)	**1.53**	**1.05–2.23**	**0.026**
		4–5 ($n = 74$)	**2.20**	**1.28–3.78**	**0.004**
				Trend $p =$ **0.004**	
	Age (continuous)		**1.05**	**1.04–1.06**	**<0.001**
	Gender (male: reference)		**0.63**	**0.43–0.90**	**0.012**
	Monthly family income		1.06	0.86–1.31	0.566
	Smoking		1.19	0.81–1.75	0.370
	Alcohol drinking		0.84	0.69–1.04	0.103
	Frequency of tooth brushing		**0.72**	**0.62–0.84**	**<0.001**
	Physical activity		1.07	0.89–1.28	0.498

*Odds ratio adjusted for the other variables in each model mutually.
Bold denotes statistical significance.
95% CI, 95% confidence interval; CPI, high-density lipoprotein; OR, odds ratio.

for MS with hypertension, and 2.19 for MS with both hypertension and high glucose. However, MS without low HDL cholesterol had a higher association than MS with low HDL cholesterol (OR: 2.33 *versus* 1.50).

Discussion

There has been a disagreement about the definition of MS as a common emerging disorder. Various diagnostic criteria have been proposed by different organizations over the past decade. The first formalized definition of the MS was proposed in 1998 by a consultation group on the definition of diabetes for WHO (Alberti & Zimmet 1998). This group emphasized insulin resistance as the major underlying risk factor and required evidence of insulin resistance for diagnosis. A diagnosis of the MS by WHO criteria could be made on the basis of several markers of insulin resistance plus two additional risk factors among obesity, hypertension, high triglyceride level, reduced HDL cholesterol level, or microalbuminuria. The other major criteria came from the National Cholesterol Education Program Adult Treatment Panel III (ATP III) in 2001 [National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) 2002]. ATP III criteria did not require a demonstration of insulin resistance per se. Moreover, no single factor was required for diagnosis, but instead, ATP III made the basis for establishing the diagnosis using the presence of three of the following five factors: abdominal obesity (which is highly correlated with insulin resistance), elevated triglyceride, reduced HDL cholesterol, elevated blood pressure, and elevated fasting glucose (impaired fasting glucose or type-2 diabetes mellitus). In 2005, the two major organizations of the International Diabetes Federation (IDF) and the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) attempted to reconcile the different clinical definitions. The IDF dropped the WHO requirement for insulin resistance but made abdominal obesity as one of necessary five factors required in the diagnosis, with a particular emphasis on waist measurement as a simple screening tool (Alberti et al. 2005); the remainder of the criteria was essentially identical to those provided by ATP III. The AHA/NHLBI slightly modified the ATP III criteria but did not mandate abdominal obesity as a required risk factor (Grundy et al. 2005). The remaining four risk factors were identical in definition to those of the IDF. Recently, several major organizations (the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society;

Table 4. Association between periodontitis (CPI 3–4) and metabolic syndrome according to age groups, gender, and smoking ($n = 1046$)

Subgroups	Category	OR*	95% CI	*p*-value
Age (years)	18–34	1.01	0.11–9.42	0.993
	35–44	1.23	0.73–2.05	0.439
	45–64	2.12	**1.25–3.59**	0.005
	<65	6.03	**1.76–20.72**	0.004
Gender	Male	1.92	**1.22–3.02**	0.005
	Female	1.35	0.82–2.24	0.239
Smoking	No	1.38	0.91–2.09	0.130
	Yes	2.38	**1.34–4.23**	0.003

*Adjusted for age, gender, monthly family income, smoking, alcohol drinking, frequency of tooth brushing, and physical activity except subgroup.
Bold denotes statistical significance.
OR, odds ratio; 95% CI, 95% confidence interval; CPI, community periodontal index.

Table 5. Adjusted association of metabolic syndrome with specific components with periodontitis (CPI 3–4) according to the type of metabolic syndrome ($n = 1111$)

Model	Variables	*N*	OR*	95% CI	*p*-value
Model I					
	Non-metabolic syndrome	812	1		
	MS (+) – high glucose (–)	119	1.48	0.97–2.26	0.067
	MS (+) – high glucose (+)	115	**1.99**	**1.28–3.10**	**0.002**
				Trend $p = \mathbf{0.004}$	
Model II					
	Non-metabolic syndrome	812	1		
	MS (+) – hypertension (–)	87	1.37	0.84–2.23	0.202
	MS (+) – hypertension (+)	147	**1.94**	**1.31–2.88**	**0.001**
				Trend $p = \mathbf{0.004}$	
Model III					
	Non-metabolic syndrome	812	1		
	MS (+) – low HDL cholesterol (–)	68	**2.33**	**1.33–4.08**	**0.003**
	MS (+) – low HDL cholesterol (+)	166	**1.50**	**1.03–2.19**	**0.036**
				Trend $p = \mathbf{0.003}$	
Model IV					
	Non-metabolic syndrome	812	1		
	MS (+) – hypertension (–) high glucose (–)	36	0.94	0.45–1.98	0.876
	MS (+) – hypertension (–) high glucose (+)	51	1.79	0.97–3.31	0.064
	MS (+) – hypertension (+) high glucose (–)	83	**1.79**	**1.10–2.92**	**0.019**
	MS (+) – hypertension (+) high glucose (+)	64	**2.19**	**1.23–3.90**	**0.008**
				Trend $p = \mathbf{0.010}$	
Model V					
	Non-metabolic syndrome	812	1		
	MS (+) – hypertension (–) low HDL cholesterol (–)	8	0.89	0.18–4.34	0.889
	MS (+) – hypertension (–) low HDL cholesterol (+)	79	1.42	0.86–2.36	0.172
	MS (+) – hypertension (+) low HDL cholesterol (–)	60	**2.66**	**1.46–4.85**	**0.001**
	MS (+) – hypertension (+) low HDL cholesterol (+)	87	1.58	0.97–2.58	0.068
				Trend $p = \mathbf{0.011}$	

*Adjusted for age, gender, monthly family income, smoking, alcohol drinking, frequency of tooth brushing, and physical activity.
Bold denotes statistical significance.
MS, metabolic syndrome; OR, odds ratio; 95% CI, 95% confidence interval; HDL, high-density lipoprotein; CPI, community periodontal index.

and International Association for the Study of Obesity) held discussions in an attempt to unify criteria. It was agreed that there should not be an obligatory component, but that waist measurement would continue to be a useful preliminary screening tool (Alberti et al. 2009). Three abnormal findings out of five components would qualify a person with the MS. A single set of cut points would be used for all components except waist circumference. In the interim, national or regional cut points for waist circumference can be used. In this study, we used the recent criteria of MS, and the national cut points for waist circumference were used (Lee et al. 2007).

To the best of our knowledge, our results show the first evidence that MS is independently associated with periodontitis among Koreans. The major strength of this study is threefold: (1) there were relatively large number of subjects from the general Korean population, (2) the oral and physical examination were performed clinically by dentists, physicians, and trained examiners, and (3) the association was controlled for various potential confounders, including socio-demographic features, and important behavioural factors.

Analysis of data from 13,710 participants in the NHANES III showed a direct relationship between periodontitis and the prevalence of MS (D'Aiuto et al. 2008). Severe periodontitis was associated with MS (OR: 1.74, 95% CI: 1.10–2.76) for participants aged older than 45 years, which was supported by our results that showed a positive association (OR: 2.12–6.03) among those aged 45 years or more. Our results showed that periodontitis was associated with MS only in older, males, and smokers but not in younger, females, and non-smokers. The positive association between periodontitis and MS might be likely due to residual confounding of age, gender, and smoking. Moreover, our results are not consistent in all subgroups but significant in some specific risky subgroups, which calls for further studies to elucidate the association. In another study (Shimazaki et al. 2007), larger waist circumference, low HDL cholesterol, and high glucose were associated with a significantly higher association for those with greater periodontal pocket depth, and persons exhibiting more components of MS had a significantly higher OR for a greater pocket depth and clinical attachment loss than did those with no components (OR = 6.6 for those with four or five components *versus* 4.1 for those with three components). This trend was supported by our results that showed the dose (number of component)–effect relationship in the association (OR = 2.20 for four or five components *versus* 1.53 for three components).

In general, there has been increasing evidence of a relationship between cardiovascular disease and periodontitis (Dietrich et al. 2008), and chronic periodontitis could influence certain features of hypertension such as increased aortic stiffness and increased central blood pressure, which may in turn increase the left ventricular mass in these patients (Franek et al. 2009). In addition, periodontal treatment significantly reduced

the blood levels of fibrinogen, CRP, and IL-6 in patients with severe periodontitis and refractory arterial hypertension (Higashi et al. 2008, Vidal et al. 2009). Our combined components analyses (Table 5) indicated that MS with hypertension had a higher association. In addition, the association between diabetes mellitus and periodontitis was well established with an evidence of the bidirectional relationship between diabetes and periodontal diseases (Taylor 2001). Diabetes had an adverse effect on periodontal health and periodontal infection also had an adverse effect on glycaemic control. Our data showed that MS including high glucose had a higher association with periodontitis. Moreover, MS encompassing both high glucose and hypertension had the stronger association than MS including high glucose or hypertension only. It was speculated that those with MS encompassing hypertension and high glucose could have an interaction effect on the link between periodontitis and MS. Two studies considered the possible relationships between periodontitis and lipid parameters (Nibali et al. 2007, Furukawa et al. 2007); however, some studies reported a non-association between periodontal disease and blood lipid levels (Machado et al. 2005, Valentaviciene et al. 2006) and oxidized LDL cholesterol (Turkoglu et al. 2008). Our results showed that MS including low HDL cholesterol had a lower association than MS without low HDL cholesterol (OR: 1.50 *versus* 2.33). Our ambiguous results indicate that a more well-designed research will clarify the effect of low HDL cholesterol on the relationship between MS and periodontitis.

The link between MS and periodontitis could be bidirectional. Oxidative stress lies at the heart of the two-way association. It is generally accepted that the origin of metabolic disorders is in a ''pro-inflammatory'' state derived from excessive caloric intake, overnutrition, and other chronic inflammatory conditions (Dandona et al. 2002, Ghanim et al. 2004, Hotamisligil 2006). The pro-inflammatory status also leads to an increase in oxidative stress, which has the potential to impair several crucial biological mechanisms (Tripathy et al. 2003, Hansel et al. 2004). Several studies demonstrated an increase in products of oxidative damage in peripheral blood from persons with periodontitis, which emphasized the influence of periodontitis on serum and/or plasma oxidative markers (Montebugnoli et al. 2004, Baltacioglu et al. 2008). On the other hand, reduced anti-oxidant capacity was found in persons with periodontitis (Akalin et al. 2009). Pro/anti-oxidant capacity between MS and periodontitis could add the evidence for elucidating the mechanism of the link between MS and periodontitis.

Our study had some limitations: (1) Because the subjects in our study were from the convenient cohort who have participated this survey voluntarily and may not fully represent the general Korean population, the selection bias could have occurred. Although our data were from the convenient sample, our data are valid and big enough to meet the aim of our study. (2) In handling the results from age-stratified analysis, interpretation should be made with caution because extraction of teeth in elders could make it difficult to detect the relationship between MS and periodontitis. Moreover, the small number of participants aged over 65 years ($n = 77$) was another weakness in addressing the high association for this age group. (3) The CPI for defining periodontitis may have several shortcomings (Kingman & Albandar 2002). A CPI of 3 or 4 is very unlikely to be associated with destructive disease among young subjects, and older subjects are likely to have gingival recession and shallow pockets. Therefore, the possibility of an underestimation in assessing periodontitis using CPI exists. A misclassification bias in using CPI could affect both the magnitude and direction of the observed associations of this study. The inter-examiner reliability for CPI measurement (the κ-index of 0.62) was not high but moderate. It might increase the chance of an inaccurate measurement. (4) The cross-sectional design prohibited us from inferring causal relationships. Further, well-designed prospective investigations are required to determine the causality between obesity and periodontitis to reduce the above-mentioned limitations. Notwithstanding these limitations, this study is suitable to meet the aims of this study.

Conclusions

Our results suggest that MS might be independently associated with periodontitis after controlling for various potential confounders encompassing the socio-demographic, behavioural factors. The association was higher in older, males, and smokers but not in younger, females, and non-smokers. However, it must be interpreted with caution because the link was confounded by age, gender, and smoking. MS with high glucose and hypertension might be more strongly associated with periodontitis. Our results suggest that MS could be the substantial risk of periodontal disease and dental professionals should take MS into consideration when evaluating periodontitis.

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Clinical Relevance

Scientific rationale for the study: MS is in a pro-inflammatory state and periodontitis is inflammatory. However, information on the relationship between MS and periodontal disease is limited.

Principal findings: MS might be associated with periodontitis among Koreans. The more components of MS showed the higher association with periodontal disease. However, the link was confounded by age, gender, and smoking. In addition, high glucose and hypertension were the two major components of MS in relation to the association.

Practical implications: Patients with MS may increase the potential risk of periodontal disease and dental professionals should consider MS when evaluating periodontitis.