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Visceral fat area-defined obesity and periodontitis among Koreans

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Abstract

Aim: Although the association of periodontitis with body mass index (BMI)-defined obesity has been studied, it remains controversial. Hence, this study aims to determine whether the obesity is associated with periodontitis among Koreans and to determine the most significant indicator of the obesity on the link.

Materials and Methods: From the Sihwa–Banwol Environmental Health Cohort, 1046 subjects 15 years of age or older were cross-sectionally surveyed. All participants underwent periodontal and medical health examinations. Age, gender, monthly family income, smoking, drinking, frequency of daily teeth brushing and physical activity were evaluated through interviews. The community periodontal index (CPI) was used to assess periodontitis. BMI, waist circumference (WC), waist hip ratio and visceral fat area (VFA) were used to assess obesity. Multivariate linear and logistic regression analyses were applied.

Results: BMI, WC and VFA had a dose–effect relationship with the number of sextants with periodontitis. Although subgroup analysis revealed several significant associations between obesity and periodontitis (CPI 3–4), the greatest association between VFA and periodontitis was found in males, age 45–54 (odds ratio = 3.30; 95% confidence interval: 1.53–7.09).

Conclusions: Obesity was associated with periodontitis. VFA was the most suitable indicator of obesity in relation to periodontitis. Obesity may be a substantial risk factor for periodontitis.

Key words: epidemiology; Korean; obesity; periodontitis; visceral fat area

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Obesity is a risk factor for several chronic diseases, most notably hypertension, type 2 diabetes, dyslipidaemia and coronary heart disease (Calle et al. 1999, Kopelman 2000). Although obesity was once considered a health problem only in wealthy countries, the prevalence of obesity has increased dramatically over the past decades in less-developed countries (World Health Organization 2000). The Korean National Health and Nutrition Survey showed that the prevalence of obesity [body mass index (BMI)$\geqslant$25 kg/m^2] has increased among the adults from 26% (males) and 26.5% (females) in 1998 (Korea Ministry of Health and Welfare 1999) to 33.5% (male) and 29.3% (female) in 2001 (Korea Ministry of Health and Welfare 2002), which correlates with an increase in mortality from diabetes from 6.8% to 24.3% in 100,000 people between 1985 and 2004 (Korea National Statistical Office 2005).

Periodontitis is also one of the most common chronic diseases throughout the world and is closely related to diabetes (Grossi & Genco 1998) and stroke (Sim et al. 2008). These several systemic diseases have a common risk factor such as smoking (Tomar & Asma 2000). The first study on the relationship between obesity and periodontal disease showed that obese-hypertensive rats are more likely to have periodontal tissue deterioration than normal rats (Perlstein & Bissada 1977). In humans, obese Japanese subjects were more likely to have periodontal disease (Saito et al. 1998). In the Third National Health and Nutrition Examination Survey (NHANES III) in the United States, there was a significant association between obesity and periodontal disease in the American population (Al-Zahrani et al. 2003). However, this remains controversial, as there are several dissents on the relationship between obe-

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sity and periodontal disease. Al-Zahrani et al. (2003) reported a relationship in younger subjects but not in subjects who were middle-aged or older. Dalla Vecchia et al. (2005) found an association in women but not in men. Linden et al. (2007) showed that obesity was associated with periodontitis among European men over 60 years of age. Although the majority of studies used BMI as an indicator of obesity, the accuracy of the BMI for setting obesity standards is controversial. BMI does not take into account both frame size and body composition about whether the weight is fat or muscle. The distribution of adipose tissue appears to be more important for developing atherosclerotic diseases than the amount of fat, and waist hip ratio (WHR) is a stronger predictor of cardiovascular events than is BMI (Yusuf et al. 2005). Visceral adipose tissue has been reported to be an independent risk factor for future myocardial infarction in elderly women (Nicklas et al. 2004). Hence, more studies are necessary to clarify the association between visceral adiposity and periodontitis. In particular, no study exists on obesity as a risk factor for periodontitis in the Korean populations.

The aim of this study was twofold: to investigate whether obesity is associated with periodontitis in the Korean population and to determine which indicator of obesity is the most appropriate to evaluate the association with periodontitis among BMI, waist circumference (WC), WHR and visceral fat area (VFA).

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 written informed consent.

Oral health as well as other systemic diseases has been assessed by many health professionals with the project. Information regarding socio-demographic status, health-related behaviours including oral health was obtained from questionnaire through interviews. Systemic and dental health status and anthropometric measurements were obtained from clinical examinations.

Study design and participants

This is a cross-sectional study comprised of baseline data from a large cohort study. The prospective Sihwa–Banwol Environmental Health Cohort (SBEHC) is a study currently being conducted in two Korean cities, Sihwa and Banwol, which are located on the west coast of South Korea and are adjoined by a large industrial complex of small- and medium-sized factories. Since 2005, the study has been recruiting participants to determine the influences of the environmental pollution and health-related behaviours, 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 1853 residents agreed to enter this survey and completed the health assessment and questionnaires in Sihwa and Banwol from July 2005 to August 2006. Out of the total participants, 1364 residents 15 years of age or older were targeted for this study. Out of the target population of 1364 residents, the final number of subjects included was 1046, and the response rate was 76.7% (1046/1364). The participants were included in this study of their own accord.

The exclusion criteria were threefold (1) subjects having <20 natural teeth excluding wisdom teeth, (2) subjects with a single missing value in the health assessment or questionnaires and (3) subjects who hope to quit during the survey. The subjects were comprised of 476 men and 570 women with ages ranging from 15 to 84 years, with a mean and standard deviation (SD) of 40.8 ± 14.1 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 because it is used widely in the survey of large populations. 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 a deep periodontal pocket of 5.5 mm or more (CPI 4). The measurements were made using a CPI probe at six sites (mesiobuccal, midbuccal, distobuccal, distolingual, midlingual and mesiolingual) per tooth. Ten 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 teeth in that sextant were 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). The number of sextants with periodontitis (CPI 3 or CPI 4) was also counted as the extent of periodontitis.

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, a 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 ten times, five times for intra-examiner reliability and five times for inter-examiner reliability. The intra-examiner reliability of the two dentists resulted in a κ index of 0.84 and 0.97 for the two categories (non-periodontitis of CPI 0–2 *versus* periodontitis of CPI 3–4). The inter-examiner reliability between dentists had a κ index of 0.62.

Assessment of obesity

For evaluating weight, height, hip circumference (HC) and WC, trained examiners measured the subjects wearing light clothing and no shoes. VFA was measured using tetrapolar bioelectrical impedance analysis (Inbody 3.0®, Biospace, Seoul, Korea), which measures two parameters, fat and lean tissue, using previously validated empirically derived formulas. The results correlated well with those obtained through underwater weighing of Asian subjects as well as Caucasians (Kuriyan et al. 1998, Vache et al. 1998). BMI was calculated as the weight (kg) divided by the square of height (m^2). WHR was calculated as the ratio of WC to HC (WHR = WC/HC).

Obesity was defined as a BMI $\geqslant 25$ kg/m^2 and overweight was defined as a BMI between 23 and 25 kg/m^2 (WHO Expert Consultation 2004). Regarding WC, obesity was defined as a WC $\geqslant 90$ cm for men and $\geqslant 85$ cm for women (Lee et al.

2006). Considering WHR, obesity was defined as a WHR $\geqslant$ 0.90 for men and $\geqslant$ 0.80 for women (Suk et al. 2003). As for VFA, obesity was defined as a VFA $\geqslant$ 100 cm^2 (Examination Committee of Criteria for ''Obesity Disease'' in Japan; Japan Society for the Study of Obesity 2002).

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 by a trained interviewer using structured questionnaires.

Statistical analysis

Periodontitis was an outcome variable, and obesity was a main explanatory variable. Confounders such as age, gender, monthly family income, health-related behaviours such as smoking, drinking, the frequency of daily teeth brushing and physical activity were placed into logistic regression models. The initial strategy consisted of testing the association and the dose–effect relationship between obesity and periodontitis adjusting for socio-demographic factors and general health/oral health-related behaviours. Next, interaction terms between the obesity indicators and the demographic/behavioural factors such as age, gender and the smoking experience were added to the models. Finally, the subsequent subgroup analyses were performed to identify the effect modification on the association between obesity and periodontitis.

Characteristic variables of the subjects were described using frequency distributions for the categorical variables and the means and the SDs for the continuous variables. The χ^2-test was used to assess the differences in the categorical variables. To determine the strength of association and the dose–effect relationship between the severity of periodontitis (continuous variable: the number of sextants with periodontitis) and the obesity indicator scores (continuous variable), multivariate linear regression analyses were performed to evaluate the adjusted and standardized correlation coefficient (partial *r*) estimates between periodontitis and the obesity indicators. Multivariate logistic regression analysis was also used to evaluate the adjusted odds ratio (AOR) estimates between periodontitis (category: periodontitis *versus* non-perioodntitis) and the obesity indicators (category). Participants were categorized based on the standards mentioned previously. Especially, BMI was categorized into three and used for rectifying the dose–response trend of the association. Adding to the interaction terms between obesity indicators and age/gender/smoking experience in the multivariate logistic models, the change of association between pre and post was evaluated. For assessing whether age, gender and smoking experience over 20 packs in a lifetime could modify the associations, subgroup analyses were performed. Subsequent analysis using stratification by age was performed. Additional subgroup analyses were performed by gender and smoking experience over 20 packs in a lifetime, respectively. Moreover, subgroup analyses by gender in the 45–54-years-old group were applied to exclude the combined effects of age and gender.

In cross-sectional studies or case–control studies, the odds ratio (OR) is the estimates of association in cross-sectional studies or case–control studies and provides a good estimate of the relative risk (Hulley et al. 2001). For interpreting the association, the attributable fraction (AF) of the main explanatory variables was estimated using the equation AF = (OR − 1)/OR in case of OR > 1.

Table 1. Crude associations between characteristic variables and periodontitis ($n = 1046$)

Characteristic	Total *N*	Periodontitis (CPI 3 or 4) *N* (%)	p^*
Age (years)			**<0.001**
15–34	275	22 (8.0)	
35–44	427	151 (35.4)	
45–54	198	88 (44.4)	
55+	146	78 (53.4)	
Gender			**<0.001**
Male	476	188 (39.5)	
Female	570	151 (26.5)	
Monthly family income			0.664
< 2000 USD	288	101 (35.1)	
2000–4000 USD	579	182 (31.4)	
4000–6000 USD	136	44 (32.4)	
$\geqslant$6000 USD	43	12 (27.9)	
Smoked over 20 packs in lifetime			**<0.001**
No	727	199 (27.4)	
Yes	319	140 (43.9)	
Alcohol drinking			**0.002**
Frequently	168	75 (44.6)	
Occasionally	365	117 (32.1)	
Past drinking	29	12 (41.4)	
Seldom	252	72 (28.6)	
No	232	63 (27.2)	
Frequency of daily teeth brushing			**<0.001**
<2	516	203 (39.3)	
$\geqslant$2	530	136 (25.7)	
Physical activity			**0.045**
No	316	92 (29.1)	
Just walking	413	151 (36.6)	
Moderate activity	117	29 (24.8)	
Severe activity	200	67 (33.5)	

*p-value obtained from the χ^2-test.
Bold denotes statistical significance.

Results

The number of subjects with no periodontal problems (CPI 0), gingivitis (CPI1 and/or 2) and periodontitis (CPI3 and/or 4) were 114 (10.9%), 593 (56.7%) and 339 (32.4%), respectively (data not shown). In crude association, periodontitis was more prevalent in older subjects and in males (Table 1). The periodontitis group brushed their teeth less frequently. They smoked and drank heavily. No dose–effect relationship was evident between the level of performance of physical activity and periodontitis.

All the obesity indices significantly correlated each other ($p < 0.01$ by Pearson's correlation relationship, data not shown). In the linear regression models, BMI, WC and VFA showed significant associations with the extent of periodontitis after controlling for various confounders, illustrating the dose–effect relationship between obesity and periodontitis (Table 2). The association of VFA showed the strongest partial r among the models.

BMI [OR = 1.60, 95% confidence interval (CI): 1.13–2.25] and VFA (OR = 1.47, 95% CI: 1.04–2.09) were significantly associated with periodontitis after controlling for age, gender, monthly income, smoking, drinking, frequency of daily teeth brushing and physical activity (Table 3). In particular, BMI (tri-categorical variable) showed a dose–effect trend. Considering the interaction term between each obesity indicator and demographic-behavioural factors, the strength of association between the obesity indicator and periodontitis increased from OR = 1.47 to 3.72 for VFA in the age interaction model, and from OR = 1.30 to 3.11 for BMI in the gender interaction model.

When considering the results of the separate subgroup analyses by age groups, VFA was associated with periodontitis in the 35–44-year-old group (OR = 1.72, 95% CI: 1.02–2.91) and in the 45–54-year-old group (OR = 3.30, 95% CI: 1.53–7.09) after controlling for various confounders (Table 4). Regarding the results of gender subgroup analyses, VFA and BMI had a higher association with periodontitis in males than in females (OR: 1.71 *versus* 1.05 for VFA, 2.04 *versus* 1.17 for BMI), and BMI showed a dose–effect trend (Table 5). Considering the results of subgroup analyses by smoking experience over 20 packs in lifetime, VFA and BMI had a higher association with periodontitis in the smoked over 20 packs in a lifetime than in the others (OR: 1.68 *versus* 1.21 for VFA, 1.85 *versus* 1.32 for BMI), but BMI lost the significant dose–effect trend (Table 6). According to the subsequent subgroup analyses by gender in the 45–54-year-old group, VFA for males (OR = 3.50, 95% CI: 1.30–9.40) and WC for females (OR = 2.76 95% CI: 1.05–7.27) showed significant associations with periodontitis (Table 7).

The AF of the association between VFA and periodontitis in the 45–54-year-old group was 69.7%: AF = (OR-1)/OR = (3.30-1)/3.30. If people aged 45–55 years had no VFA obesity, 69.7% of the cases of periodontitis among obese people aged 45–55 years could be prevented from having periodontitis.

Table 2. Linear relationship between obesity indicator scores and severity of periodontitis ($n = 1046$)

Models	β	SE	p-value	95% CI	Adjusted R^2	Partial r
BMI* (continuous)	**0.064**	0.013	**0.037**	[0.002, 0.054]	0.118	**0.065**
WC* (continuous)	**0.067**	0.005	**0.050**	[0.000, 0.020]	0.117	**0.061**
WHR* (continuous)	0.063	0.818	0.089	[− 0.213, 2.998]	0.117	0.053
VFA* (continuous)	**0.094**	0.002	**0.025**	[0.001, 0.009]	0.118	**0.070**

*Adjusted for age (continuous), gender, monthly family income, smoking, drinking, the frequency of daily teeth brushing and physical activity (categorical).
Bold denotes statistical significance.
CI, confidence interval; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

Discussion

The link between periodontits and obesity is still controversial. Saito et al. (2001) reported that WHR was asso-

Table 3. Adjusted associations between obesity and periodontitis in total subjects ($n = 1046$)

Indicator of obesity	*N* (%)	OR (95% CI)			
		model A*	model B†	model C‡	model D§
BMI					
Normal	468 (44.7)	1	1	1	1
Overweight	258 (24.7)	1.31 (0.91–1.89)	1.13 (0.42–3.02)	1.54 (0.46–5.20)	2.27 (0.74–6.94)
Obese	320 (30.6)	**1.60 (1.13–2.25)**	1.83 (0.75–4.44)	**3.11 (1.02–9.53)**	1.11 (0.38–3.21)
Trend p-value		**0.027**	0.402	0.131	0.309
Interaction			0.94 (0.67–1.33)	0.64 (0.32–1.29)	1.28 (0.62–2.64)
WC					
Normal	732 (70.0)	1	1	1	1
Obese	314 (30.0)	1.08 (0.79–1.48)	1.11 (0.47–2.66)	1.72 (0.65–4.54)	0.56 (0.21–1.48)
Interaction			1.00 (0.73–1.39)	0.75 (0.40–1.40)	1.63 (0.85–3.13)
WHR					
Normal	433 (41.4)	1	1	1	1
Obese	613 (58.6)	1.20 (0.87–1.66)	1.16 (0.54–2.46)	1.73 (0.65–4.59)	1.32 (0.51–3.45)
Interaction			1.02 (0.76–1.38)	0.78 (0.41–1.47)	0.94 (0.50–1.76)
VFA					
Normal	755 (72.2)	1	1	1	1
Obese	291 (27.8)	**1.47 (1.04–2.09)**	**3.72 (1.49–9.27)**	2.27 (0.82–6.30)	1.34 (0.47–3.80)
Interaction			0.69 (0.49–0.96)	0.71 (0.35–1.44)	1.05 (0.54–2.03)

*Model A, adjusted for age (continuous), gender, monthly family income, smoking, drinking, the frequency of daily teeth brushing and physical activity.
†Model B, adjusted for all confounders in the model A and interaction between each obesity indicator and age group.
‡Model C, adjusted for all confounders in the model A and interaction between each obesity indicator and gender.
§Model D adjusted for all confounders in the model A and interaction between each obesity indicator and smoking experience over 20 packs in a lifetime.
Bold denotes statistical significance.
CI, confidence interval; OR, odds ratio; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

Table 4. Adjusted associations between obesity and periodontitis across age subgroups

Indicator of obesity	Age subgroups (years) OR* (95% CI) 15–34	35–44	45–54	55+
BMI				
Normal	1	1	1	1
Overweight	0.28 (0.05–1.55)	1.33 (0.79–2.24)	1.20 (0.55–2.60)	1.51 (0.59–3.87)
Obese	0.85 (0.23–3.07)	1.60 (0.96–2.65)	1.91 (0.93–3.91)	1.38 (0.58–3.33)
Trend *p*	0.339	0.185	0.188	0.671
WC				
Normal	1	1	1	1
Obese	0.61 (0.14–2.61)	1.03 (0.64–1.65)	1.82 (0.96–3.44)	1.12 (0.55–2.25)
WHR				
Normal	1	1	1	1
Obese	0.48 (0.12–1.85)	1.31 (0.83–2.06)	1.69 (0.85–3.39)	1.37 (0.52–3.57)
VFA				
Normal	1	1	1	1
Obese	0.80 (0.18–3.62)	**1.72 (1.02–2.91)**	**3.30 (1.53–7.09)**	1.07 (0.48–2.40)

*OR adjusted for age (continuous), gender, monthly family income, smoking, drinking, the frequency of daily teeth brushing and physical activity.
Bold denotes statistical significance.
CI, confidence interval; OR, odds ratio; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

Table 5. Adjusted associations between obesity and periodontitis by gender

Indicator of obesity	Male ($n = 476$)		Female ($n = 570$)	
	N (%)	OR* (95% CI)	*N* (%)	OR* (95% CI)
BMI				
Normal	175 (36.8)	1	293 (51.4)	1
Overweight	127 (26.7)	1.47 (0.86–2.51)	131 (23.0)	1.19 (0.72–1.98)
Obese	174 (36.6)	**2.04 (1.25–3.31)**	146 (25.6)	1.17 (0.70–1.94)
Trend *p*		**0.017**		0.753
WC				
Normal	302 (63.4)	1	430 (75.4)	1
Obese	174 (36.6)	1.27 (0.83–1.92)	140 (24.6)	0.87 (0.53–1.42)
WHR				
Normal	278 (58.4)	1	155 (27.2)	1
Obese	198 (41.6)	1.36 (0.89–2.08)	415 (72.8)	1.07 (0.65–1.76)
VFA				
Normal	257 (54.0)	1	498 (87.4)	1
Obese	219 (46.0)	**1.71 (1.10–2.64)**	72 (12.6)	1.05 (0.56–1.97)

*OR adjusted for age (continuous), monthly family income, smoking, drinking, the frequency of daily teeth brushing and physical activity.
Bold denotes statistical significance.
CI, confidence interval; OR, odds ratio; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

ciated with periodontitis independent of BMI and body fat. Several studies showed an association between periodontitis and the central obesity indicator including WC (Al-Zahrani et al. 2003, Reeves et al. 2006) and fat per cent (Khader et al. 2008), although other studies showed no such association (Torrungruang et al. 2005). Moreover, there are no data concerning the association between obesity and periodontitis among Korean adults. Therefore, we performed this study to provide additional evidence of an association between obesity and periodontitis in Korean adults.

To the best of our knowledge, this is the first study that has used VFA as an obesity indicator to show a positive association (OR = 3.30) between obesity and periodontitis. For evaluating the association between obesity and periodontitis, we used both visceral adiposity (WC, WHR, VFA) and total body adiposity (BMI) as indicators of obesity. We also included several socio-demographic and general health/oral health-related behaviours in the models. Collectively, obesity was found to be independently associated with periodontitis in the Korean general population, which supported the previous studies with positive associations. A number of epidemiological studies have examined the association between obesity and periodontitis in many countries such as Japan, United States, Brazil, United Kingdom and Jordan (Saito et al. 2001, Al-Zahrani et al. 2003, Dalla Vecchia et al. 2005, Reeves et al. 2006, Linden et al. 2007, Ekuni et al. 2008, Khader et al. 2008). A majority of studies showed associations between periodontitis and obesity indicators such as BMI, WC, WHR and fat per cent. Hence, we added VFA as an obesity indicator for evaluating the association between obesity and periodontitis for the first time.

The visceral fat accumulation that is frequently observed in abdominal adiposity increases the risk of cardiovascular diseases (Nakamura et al. 1994). Because the adipose tissue is an endocrine organ producing numerous proteins collectively referred to as adipokines (Trayhurn & Beattie 2001), we assumed that visceral fat accumulation might be associated with periodontitis. The results from the present study showing that VFA had a positive association supported the previous studies showing a positive association between abdominal obesity and periodontitis (Saito et al. 2001, Reeves et al. 2006). We speculated that visceral fat accumulation might affect the progression of periodontitis through the production of various inflammatory mediators.

In the subgroup analyses, we found that age moderated the relationship between obesity and periodontitis. Our results showed that 35–54-year-old group was a high-risk group for the link between periodontitis and obesity and in particular, the 45–54-year-old group is at the highest risk. In the middle age group, the progression of periodontitis may be accelerated by the decreased function of the immune system. However, this result is in contrast to previous studies that have reported an association in younger adults (Al-Zahrani et al. 2003, Reeves et al. 2006, Ekuni et al. 2008). Al-Zahrani et al. (2003) reported that both BMI and WC were associated with periodontitis in a subset of young adults aged 18–34 years but not in the middle and older age groups. BMI was significantly associated with periodontitis in young Japanese (Ekuni et al. 2008). Linden et al. (2007) reported that BMI was associated with periodontitis in 60–70-year-old European men, and BMI at 21 years of

Table 6. Adjusted associations between obesity and periodontitis by smoking experience

Indicator of obesity	Smoked over 20 packs in a lifetime			
	no ($n = 727$)		yes ($n = 319$)	
	N (%)	OR* (95% CI)	*N* (%)	OR* (95% CI)
BMI				
Normal	354 (48.7)	1	114 (35.7)	1
Overweight	179 (24.6)	1.45 (0.91–2.31)	79 (24.8)	1.06 (0.56–2.01)
Obese	194 (26.7)	1.32 (0.82–2.11)	126 (39.5)	**1.85 (1.06–3.22)**
Trend *p*		0.266		0.057
WC				
Normal	532 (73.2)	1	200 (62.7)	1
Obese	195 (26.8)	0.83 (0.53–1.28)	119 (37.3)	1.56 (0.96–2.56)
WHR				
Normal	264 (36.3)	1	169 (53.0)	1
Obese	463 (63.7)	1.15 (0.74–1.78)	150 (47.0)	1.32 (0.80–2.20)
VFA				
Normal	582 (80.1)	1	173 (54.2)	1
Obese	145 (19.9)	1.21 (0.72–2.04)	146 (45.8)	**1.68 (1.01–2.81)**

*OR adjusted for age (continuous), gender, monthly family income, drinking, the frequency of daily teeth brushing and physical activity.
Bold denotes statistical significance.
CI, confidence interval; OR, odds ratio; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

Table 7. Adjusted associations between obesity and periodontitis by gender in the 45–54-year-old group

Indicator of obesity	Male ($n = 96$)		Female ($n = 102$)	
	N (%)	OR* (95% CI)	*N* (%)	OR* (95% CI)
BMI				
Normal	26 (27.1)	1	43 (42.2)	1
Overweight	26 (27.1)	1.11 (0.33–3.74)	30 (29.4)	1.14 (0.39–3.28)
Obesity	44 (45.8)	2.50 (0.85–7.38)	29 (28.4)	1.47 (0.52–4.16)
Trend *p*		0.162		0.763
WC				
Normal	55 (57.3)	1	73 (71.6)	1
Obesity	41 (42.7)	1.46 (0.60–3.59)	29 (28.4)	**2.76 (1.05–7.27)**
WHR				
Normal	46 (47.9)	1	19 (18.6)	1
Obesity	50 (52.1)	2.40 (0.93–6.20)	83 (81.4)	1.30 (0.42–4.00)
VFA				
Normal	41 (42.7)	1	91 (89.2)	1
Obesity	55 (57.3)	**3.50 (1.30–9.40)**	11 (10.8)	3.25 (0.83–12.78)

*OR adjusted for age (continuous), monthly family income, smoking, drinking, the frequency of daily teeth brushing and physical activity.
Bold denotes statistical significance.
CI, confidence interval; OR, odds ratio; BMI, body mass index; WC, waist circumference; WHR, waist hip ratio; VFA, visceral fat area.

age did not predict later periodontitis. There is no consistent opinion regarding which age group shows the strongest association between periodontitis and obesity. Although our data did not show the association among young age groups, interpretation should be made with caution because of the small number of study participants. Several affected teeth had been extracted in the older subjects and many of the remaining teeth were healthier, which could make it difficult to detect the relationship between obesity and periodontitis. Ageing decreased the immunologic response to the external environment, which could deteriorate periodontal health. More age-specific studies are necessary to clarify the age group at a high risk for the link between obesity and periodontitis.

In this study, we could not find an effect of smoking on the association between obesity and periodontal disease. This is contrary to the previous results (Dalla Vecchia et al. 2005, Nishida et al. 2005). In our study, questionnaires on smoking dealt with only smoking experience of over 20 packs in a lifetime and we could not include the information about the amount of smoking. This might affect the insignificant effect of smoking on the association between obesity and periodontitis. However, our data showed that the association was stronger in those who smoked over 20 packs in a lifetime. Therefore, more prospective data will be needed to clarify this.

Our data showed that the association between obesity and periodontitis is stronger in males than in females, which differs from the previous result showing a positive association for females (Dalla Vecchia et al. 2005). Generally, gender influences a number of individual features such as size, nutrition, genetics and hormone status, which in turn affect niche differentiation, leading back to differences in exposure and susceptibility. The differences by gender may be due to an increased exposure to harmful factors in men. Men drink and smoke more than women, and they work and spend time mostly outdoors. Moreover, in the present study, VFA was significantly associated with periodontitis in the 45–54-year-old males. However, WC also showed a significant association in 45–54-year-old females. Although the association of VFA for females was nearly the same as that of males (OR: 3.25 *versus* 3.30) in the 45–54-year-old group, there was no significance in females because of the small number of subjects. Because stratified subgroup analyses reduced the sample size, there were only 11 cases of obese females in the 45–54-year-old group. A higher number of subjects could have provided more conclusive results in stratified subgroup analyses by the combination of age and gender.

Periodontitis, a chronic inflammatory oral disease, may have profound effects on systemic health by affecting the host susceptibility to systemic diseases due to the accumulation of Gram-negative bacteria and inflammatory mediators (Iacopino & Cutler 2000). Obesity has been shown to affect host immunity. Mice with diet-induced obesity infected by *Porphyromonas gingivalis* were examined for periodontal pathology and systemic immune responses (Amar et al. 2007). Shimomura et al. (1996) have indicated that adipose tissue, especially visceral adipose tissue, is an important organ that secretes plasminogen activator inhibitor-1 (PAI-1), and it may have a role in the development of vascular disease. Thus, PAI-1 may also decrease periodontal blood flow in obese subjects, promoting initiation of periodontitis and progression. Lundin et al. (2004) showed that tumour necrosis factor-α in gingival crevicular fluid is correlated with BMI in subjects with a BMI $\geqslant 40\,\text{kg/m}^2$. Reactive oxygen species (ROS), such as hydrogen peroxide, are responsible for the alveolar bone loss accompanied by decreased endothelial nitric oxide synthase expression in metabolic syndrome model mice (Ohnishi et al. 2009). Because VFA and WC represent the abdominal adiposity, our results suggest a link between abdominal adiposity and ROS, which may affect periodontal tissue. Further study is needed to evaluate the biological mechanisms between periodontitis and obesity-related disorders using relevant biomarkers.

Because obesity and intra-abdominal fat (IF) accumulations are primarily induced by physical inactivity and excess energy intake, increased physical activity and dietary modification could be an effective way to reduce metabolic disorders (Okura et al. 2002, Tanaka et al. 2004). Regular exercise may be more effective than dietary modification at decreasing IF accumulations; regular exercise was found to decrease the IF area without a substantial weight change and to preferentially reduce the IF area compared with subcutaneous fat (Ross et al. 2000). Hence, we included physical activity as a confounding factor in relation to an association between obesity and periodontitsis.

Regarding the interpretation of our results, we decided that the main result of the association between obesity and periodontitis was the OR of 3.30 for VFA in the age subgroup. Because the association was age-specific, the association changed dramatically according to age groups. VFA had the highest association among all analyses. Although VFA had the strongest association in 45–54-year-old males (OR = 3.50), the subjects in the group were not adequate enough to generalize the results. Therefore, we speculated that the AF of obesity on periodontitis was 69.7% by using an OR of 3.30.

There were some limitations in the present study. First, because the subjects in our study were sampled conveniently, participation bias could have occurred. Second, the CPI for defining periodontitis may have several shortcomings (Kingman & Albandar 2002). A CPI 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 the direction of the observed associations of this study. In the future study, attachment loss will be a reference parameter for destructive periodontal disease. Third, the inter-examiner reliability for CPI measurement was relatively small. This might be interpreted as an inaccurate measurement and may have an effect on the quality of this study. Fourth, the cross-sectional design did not allow us to infer causal relationships. Further well-designed prospective investigations are required to determine the causality between obesity and periodontitis to reduce the above-mentioned limitations. Especially, biological, environmental and genetic attributes also need to be included in the next study to clarify the association between periodontitis and obesity.

However, the study herein did include several strengths. The number of subjects was relatively large, and the participants were sampled from the general population. The oral examination and anthropometric measurements were performed clinically by dentists and a trained examiner. Finally, various confounders such as age, gender, monthly family income and general/oral health-related behaviours were included.

Collectively, the results from the present study suggest that obesity is associated with periodontitis. VFA may be the most appropriate indicator of obesity for evaluating the association. In particular, the association between periodontal disease and VFA obesity could be higher in adults 45–54 years of age. Obesity could be a substantial risk factor for periodontitis. Periodontists should include VFA as an obesity indicator when evaluating periodontal risk factors and try to consult the patients on how to prevent abdominal adiposity.

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Clinical Relevance

Scientific rationale for the study: The association between periodontitis and obesity remains controversial. Although the use of VFA is increasing, most dental studies have focused on BMI.

Principal findings: Obesity was associated with periodontitis among Koreans, showing a dose–effect relationship. A VFA $\geqslant 100\,cm^2$ was the most suitable indicator of the association. The association between obesity (as measured by VFA) and periodontitis appears to be greatest in adult men, age 45–55.

Practical implications: Obesity appears to be associated with periodontitis in Koreans. Additional study is needed to determine whether preventing obesity has any impact on the prevalence or the severity of periodontitis.