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The association between periodontitis and obstructive sleep apnea: a preliminary study

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Background and Objective: Periodontitis is becoming a highly prevalent disease worldwide. Obstructive sleep apnea (OSA) is a common disorder that is characterized by repeated disruptions in breathing during sleep, and mouth breathing is a common characteristic among patients with OSA. We aimed to assess the hypothesis that OSA is associated with the onset and progression of periodontal disease.

Material and Methods: This is a cross-sectional study of a total of 687 participants (460 men and 227 women), 47–77 years of age, who were examined between August 2009 and September 2010 as part of the Korean Genome and Epidemiology Study. The participants underwent standard polysomnography, clinical periodontal examination and health-screening examinations. Periodontitis was defined as clinical attachment level (CAL) $\geq$ 6 mm and probing pocket depth $\geq$ 4 mm. OSA was determined using the apnea–hypopnea index (AHI), and an AHI score of $\geq$ 5 was the cut-off used to indicate the presence of OSA.

Results: The results showed that 17.5% of the participants had periodontitis, 46.6% had OSA and 60.0% who were diagnosed with periodontitis had OSA. In our study, old age, male gender, current smoking status, mouth breathing during sleep and high AHI were identified as risk factors for periodontitis. OSA was positively associated with periodontitis [odds ratio (OR) = 1.84, 95% confidence interval (CI) = 1.18–2.87], probing pocket depth (OR = 2.22, 95% CI = 1.30–3.77) and CAL (OR = 1.86, 95% CI = 1.07–3.21) in a dose–response manner. Additionally, OSA was positively associated with periodontitis (OR = 2.51, 95% CI = 1.37–4.62) in subjects $\geq$ 55 years of age, but not in subjects < 55 years of age.

Conclusion: There is a significant association between OSA and periodontal disease. Further research is needed to clarify the causal relationship between the two conditions.

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Key words: mouth breathing; obstructive sleep apnea; periodontal disease; periodontitis

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Periodontitis is becoming a highly prevalent disease worldwide and is one of the most controversial diseases in dental medicine. It is a chronic infectious and inflammatory disease of the gums and supporting tissues of the teeth. It is caused by pathogenic bacteria that trigger an inflammatory response in these tissues (1), as well as by factors indicative of poor oral hygiene, such as dental plaque and gingivitis (2). Recently, periodontitis has received increasing attention because it may have systemic effects, including diabetes (3–5), coronary

heart disease (6), rheumatoid arthritis (7), osteoporosis (8) and malignancy (9). Hence, for preventing periodontitis and possible systemic diseases, it is important to know the risk factors.

The apnea–hypopnea index (AHI) is used to determine the presence of obstructive sleep apnea (OSA). An AHI score of ≥ 5 is indicative of the presence of OSA, a common disorder characterized by repeated obstructions of breathing during sleep and known to be prevalent in 24–38% of middle-aged men in western countries (10–12) and in 42% of middle-aged men in Korea (13). Common symptoms are chronic and loud snoring, mouth breathing, interrupted sleep and excessive daytime sleepiness. Some patients with OSA are also known to have increased levels of systemic inflammation, which have been reported to be associated with stroke and cardiovascular disease (14, 15).

The relationship between periodontitis and OSA had been not investigated before the study by Gunaratnam *et al.* (16). These authors surmised that both periodontitis and OSA are associated with systemic inflammation and cardiovascular disease and found that the prevalence of periodontitis in patients with OSA was fourfold higher than the national average.

Well-known risk factors for periodontitis (6,9,17) in adults are male gender, old age, smoking, drinking, obesity and diabetes, which are also relatively common in OSA (18). In addition to the common risk factors, both periodontitis and OSA are also associated with increased systemic inflammation. The mechanism of association between OSA and systemic inflammation is unclear. Moreover, elevated levels of inflammatory markers in patients with OSA may be related to other factors such as gingivitis and inflammation in the oral cavity. Such inflammation in the oral cavity can also influence the development of periodontitis.

Here, we investigated the prevalence of periodontitis among patients with OSA in a population-based study, and aimed to find the possible association between OSA and periodontitis among OSA patients.

Material and methods

Study participants

The study population was recruited as part of the Korean Genome and Epidemiology Study (KoGES) (13), an ongoing prospective cohort study that started in 2001. The original 5020 cohort members from Ansan were followed with biennial examinations that included a range of demographic characteristics, medical history, health status and sleep-related factors.

Periodontal examination was included in the study protocol in 2006, and polysomnography (PSG) was added from 2009. Thus, we conducted a cross-sectional study on the individuals who completed both periodontal and PSG examinations in 2009 and 2010 (the fifth evaluation cycle). Among 3262 individuals who were enrolled in this examination cycle, 906 underwent PSG and 1591 underwent clinical periodontal examination, and 722 subjects who underwent both examinations were targeted for this study.

Participants with recording errors/excessive artifacts in the PSG ($n = 8$), or missing information on self-reported smoking status, alcohol consumption, household income and/or habitual snoring and mouth breathing ($n = 27$), were excluded from the study. After these exclusions, 687 participants (460 men and 227 women), 47–77 years of age, were included in the final analyses. Written, informed consent was obtained from all participants, and all procedures were approved by the Institutional Review Board of Korea Center for Disease Control and Prevention (AS0624).

Data collection

All participants were asked to complete a self-administered questionnaire on their demographic characteristics, such as age, gender, cigarette-smoking status, alcohol consumption, personal medical history, socio-economic status (e.g. household income), medication use and sleep habits (e.g. habitual snoring and mouth breathing in sleep). Habitual snoring was defined as a snoring frequency of more than 4 d/wk. At the time of screening, each participant's height and weight were measured and used to calculate their body mass index [weight (in kg) divided by height (in m^2)]. Using the information collected, three categories were established for smoking status (non-, ex- and current), alcohol consumption (non-, ex- and current) and household income (< 1 million, 1–4 million and > 4 million Korean won), and two categories were constructed for the occurrence of habitual snoring (yes or no), mouth breathing (yes or no) and a past medical history of diabetes mellitus (yes or no).

Diagnosis of periodontitis

Participants underwent a complete clinical periodontal examination. All periodontal data were collected using a William-Fox Hu-Friedy World Health Organization-style periodontal probe (Hu-Friedy, Inc., Chicago, IL, USA) and then recorded on a periodontal chart. The protocols were followed by a trained single dentist who was blinded to the OSA variables such as AHI, habitual snoring and mouth-breathing habits. Periodontal assessments in this study included the following standard measures: bleeding on probing, probing pocket depth, gingival recession, clinical attachment level (CAL), Silness and Loe plaque index and gingival index. We distinguished bleeding on probing as bleeding from the sulcus or periodontal pocket, and probing pocket depth as the distance between the gingival margin and the periodontal probe tip, which was taken to be at the apical extent of the gingival sulcus. Furthermore, gingival recession was defined as the distance between the cemento–enamel junction and the gingival margin, and CAL was defined as the distance between the cemento–enamel junction and the bottom of the sulcus where gingival recession is present. The plaque index was measured to indicate the amount of plaque present, and similarly, gingival index was used to represent the level of gingival inflammation present. All measurements were taken at six

sites of all existing Ramfjord's teeth (nos 16, 21, 24, 36, 41 and 44) and were rounded up or down to the nearest millimeter.

Periodontitis cannot be assessed by visual examination alone. Previous population-based studies have used several combinations of CAL and probing pocket depth to establish periodontitis case definitions (19). The National Health and Nutrition Examination Survey set the criteria for periodontitis to be at least two sites with probing pocket depth $\geq$ 3 mm and at least three sites with CAL $\geq$ 4 mm (20). The National Center for Health Statistics set the criteria for periodontitis of at least one periodontal pocket with a probing pocket depth of $\geq$ 4 mm and CAL $\geq$ 3 mm at the same site on one tooth (21). The Health and Human Services Vital and Health Statistics Series 11 Report (Series 11) case definition requires at least one site to have a probing pocket depth of $\geq$ 4 mm and CAL of $\geq$ 3 mm (9). The Centers for Disease Control and Prevention and the American Academy of Periodontology define periodontitis as a condition where two or more interproximal sites are present with CAL of $\geq$ 6 mm or where one or more interproximal sites with a probing pocket depth of $\geq$ 5 mm are present on different teeth (19). Using these definitions, we defined periodontitis by the presence of at least four teeth with one or more interproximal sites with a probing pocket depth of $\geq$ 4 mm and CAL $\geq$ 6 mm at the same site on a tooth.

Polysomnography

Each participant underwent standard PSG using a computerized PSG device (Embletta® X-100; Embla Systems, Broomfield, CO, USA) at home or at the sleep laboratory on site. All PSG results were manually scored by an experienced sleep technologist according to standard criteria. The AHI was defined as the average number of apneic and hypopnea events per sleep hour, and the presence of OSA was determined as an AHI score of $\geq$ 5. Apnea was defined as the absence of airflow for 10 s, and hypopnea was defined as a discernible reduction of the airflow associated with a reduction of oxygen saturation of 4% from the baseline value.

Statistical analysis

The differences between the mean values were evaluated using the *t*-test, and the differences in the percentages were evaluated using the chi-square test. To assess the association between OSA and periodontitis, multiple logistic regression models were used to calculate odds ratios (ORs) and the 95% confidence interval (CI). Age, gender, body mass index, smoking status, alcohol use, habitual snoring and mouth breathing in sleep were included as covariates in all models. We added a separate analysis using age group (< 55 and $\geq$ 55 years) in order to examine the possibility of effect modification by age. All analyses were conducted using SAS software version 9.2 (SAS Institute Inc., Cary, NC, USA), and a two-sided *p*-value of <0.05 was considered to be statistically significant.

Results

Table 1 shows demographic characteristics and sleep-habits factors stratified by periodontitis status. Among the 687 participants who were included in the final analysis, 460 were men (67.0%), 227 were women (33.0%) and the mean ($\pm$ SD) age was 55.85 $\pm$ 6.63 years. Based on our definition, the prevalence of periodontitis was determined as 17.5% of all participants. Among all participants, 46.6% had OSA (AHI $\geq$ 5) and 60.0% who were diagnosed with periodontitis had OSA. According to the self-reports, 24.5% had habitual snoring and 8.3% had mouth breathing during sleep. Male gender (p = 0.004), smoking status (p = 0.005) and AHI (p = 0.003) were significantly higher in the periodontitis group than in the nonperiodontitis group. Mouth breathing in sleep was also related to periodontitis, but the association was only marginally significant (p = 0.066).

Table 2 shows the means and standard deviations for the periodontal variables and their association with OSA (AHI $\geq$ 5). The incidence of periodontitis in the OSA group was significantly higher than that in the non-OSA group (22.5% vs.13.0%, p = 0.017). In addition, the prevalence of probing pocket depth ($\geq$ 4 mm) and CAL ($\geq$ 6 mm) was higher in the OSA group.

Table 3 presents the results of multivariate logistic regression analyses of the association between OSA and periodontitis, and their variables, including probing pocket depth and CAL. OSA was positively associated with periodontitis (OR = 1.84, 95% CI = 1.18–2.87), probing pocket depth (OR = 2.22, 95% CI = 1.30–3.77) and CAL (OR = 1.86, 95% CI = 1.07–3.21) compared with the non-OSA group. Additionally, when AHI was categorized into three groups (< 5, 5–10 and $\geq$ 10), higher AHI was associated with increased odds for periodontitis (OR = 1.83, 95% CI = 1.10–3.04), probing pocket depth (OR = 2.20, 95% CI = 1.20–4.02) and CAL (OR = 1.97, 95% CI = 1.07–3.65) in a dose–response manner. We also analyzed the association based on different age groups: < 55 years of age and $\geq$ 55 years of age.

OSA was positively associated with periodontitis (OR = 2.51, 95% CI = 1.37–4.62), probing pocket depth (OR = 2.72, 95% CI = 1.33–5.35) and CAL (OR = 3.89, 95% CI = 1.76–8.59) in the age group $\geq$ 55 years, whereas no association was observed in the age group < 55 years. Likewise, there was a positive association between a high AHI (AHI $\geq$ 10) and periodontitis (OR = 2.98, 95% CI = 1.50–5.91), probing pocket depth (OR = 2.89, 95% CI = 1.31–6.36) and CAL (OR = 5.14, 95% CI = 2.15–12.25) in the age group $\geq$ 55 years, but not in the age group < 55 years.

Discussion

This preliminary study identified an association between periodontitis and OSA among Korean adults. Periodontitis was more prevalent in patients with OSA than in non-OSA subjects,

Table 1. Demographic characteristics of study participants stratified by periodontitis

Demographic characteristics	All participants (n = 687)	Periodontitis No(n = 567)	Yes (n = 120)	p-value
Age (years)	55.85 ± 6.63	55.57 ± 6.58	57.20 ± 6.71	0.014
Body mass index (kg/)	24.85 ± 2.79	24.89 ± 2.77	24.70 ± 2.89	0.504
Gender				
Male	460 (66.96)	366 (64.55)	94 (78.33)	0.004
Female	227 (33.04)	201 (35.45)	26 (21.67)	
Smoking status				
Never	333 (48.47)	288 (50.79)	45 (37.50)	0.005
Former	251 (36.54)	201 (35.45)	50 (41.67)	
Current	103 (14.99)	78 (13.76)	25 (20.83)	
Alcohol drinking				
Never	291 (42.36)	245 (43.21)	46 (38.33)	0.222
Former	24 (3.49)	22 (3.88)	2 (1.67)	
Current	372 (54.15)	300 (52.91)	72 (60.00)	
Household income (million Korean won/month)				
	62 (9.02)	53 (9.35)	9 (7.50)	0.904
<1 million Korean won				
	384 (55.90)	314 (55.38)	70 (58.33)	
1–4 million Korean won				
	241 (35.08)	200 (35.27)	41 (34.17)	
≥ 4 million Korean won				
Habitual snoring				
No	519 (75.55)	424 (74.78)	95 (79.17)	0.310
Yes	168 (24.45)	143 (25.22)	25 (20.83)	
Mouth breathing in sleep				
No	630 (91.70)	525 (92.59)	105 (87.50)	0.066
Yes	57 (8.30)	42 (7.41)	15 (12.50)	
AHI				
< 5	367 (53.42)	319 (56.26)	48 (40.00)	0.003
5–10	129 (18.78)	100 (17.64)	29 (24.17)	
≥ 10	191 (27.80)	148 (26.10)	43 (35.83)	

Values are given as mean ± standard deviation or n (%).
AHI, apnea–hypopnea index.

Table 2. Characteristics of periodontal variables in subjects with and without obstructive sleep apnea (OSA)

Periodontal variables	Without OSA:AHI < 5(n = 367)	With OSA:AHI ≥ 5(n = 320)	p-value
Bleeding on probing	0.05 ± 0.09	0.06 ± 0.11	0.171
Gingival recession	1.36 ± 1.00	1.49 ± 1.03	0.089
Plaque index	1.18 ± 0.54	1.25 ± 0.58	0.113
Gingival index	0.71 ± 0.35	0.79 ± 0.34	0.005
Probing pocket depth	2.09 ± 0.61	2.22 ± 0.61	0.005
< 4 mm	337 (91.83)	268 (84.28)	
≥ 4 mm	30 (8.17)	50 (15.72)	
Clinical attachment level	3.45 ± 1.25	3.71 ± 1.34	0.008
< 6 mm	339 (92.37)	273 (85.85)	
≥ 6 mm	28 (7.63)	45 (14.15)	

Values are given as mean ± standard deviation or n (%).AHI, apnea–hypopnea index.

and among the OSA patients, those who reported excessive mouth breathing were at a higher risk of developing periodontal disease compared with those who did not. Our results also signified a positive trend between age and the severity of OSA, as well as the risk for periodontitis.

Recently, periodontitis has received increasing attention because it may have systemic effects, including infective endocarditis, coronary heart disease, diabetes mellitus, respiratory diseases, osteonecrosis and even malignancy (8, 22–26). Periodontitis is not just a local inflammation in the oral cavity, but rather is a systemic inflammation that can influence the development of other diseases. Hence, it is important to identify the risk factors and enhance periodontitis prevention.

In our study, the overall prevalence of periodontitis was 17.5% (n = 120), which is similar to the prevalence shown in a previous report from another general population study in Korea (14.3% in individuals 40–70 years of age) (27) and 13.3% from the National Health and Nutrition Examination Survey III (1988–1994) data in the US population (28).

Querido *et al.* (29) reported that intermittent hypoxia as a result of airway obstruction would not be responsible for systemic inflammation, which may support that increased systemic inflammation in OSA patients may be more closely associated with other factors. In our study, we found old age, male gender, current smoking status and high AHI level as risk factors of periodontitis. Our results indicated that although mouth breathing in sleep was also related to periodontitis, this association was only marginally significant (p = 0.066). The relationship between mouth breathing and periodontitis was stronger when diabetes was excluded from our model. Because diabetes is known to correlate with periodontitis (3–5), we also performed our analyses after excluding individuals with diabetes and found that mouth breathing was significantly associated with periodontitis (p = 0.019). Mouth breathing in OSA may be a mediating factor that links OSA and the development of periodontitis. Among healthy subjects free of nasal disease, oral breathing consists of only about 4% of the total ventilation, irrespective of sleep stage or body position (30), and this number increases with ageing as the proportion of nasal breathing is reported to decrease. Gleeson *et al.* (31) reported that the proportion of oronasal breathing is higher in persons with OSA, particularly in the elderly. Kawashima *et al.* (32) reported that oral breathing in 89% of Japanese children with OSA and poor oral health was also prevalent in this

Table 3. Multivariate logistic regression analyses of the association between obstructive sleep apnea [OSA; determined using the apnea–hypopnea index (AHI)] and periodontitis, probing pocket depth and clinical attachment level in the two age groups of subjects (< 55 years and ≥ 55 years)

		All(n = 687)				Age < 55 years(n = 373)				Age ≥ 55 years(n = 314)			
	AHI	Crude		Adjusted*		Crude		Adjusted**		Crude		Adjusted**	
Periodontitis	< 5	1		1		1		1		1		1	
	≥ 5	1.93	1.29–2.88	1.84	1.18–2.87	1.46	0.80–2.68	1.01	0.50–2.05	2.00	1.13–3.54	2.51	1.37–4.62
	< 5	1		1		1							
	5–10	1.93	1.15–3.22	1.85	1.08–3.19	1.88	0.87–4.07	1.41	0.61–3.22	1.73	0.85–3.51	2.00	0.95–4.22
	≥ 10	1.93	1.23–3.05	1.83	1.10–3.04	1.19	0.56–2.53	0.74	0.31–1.77	2.20	1.18–4.09	2.98	1.50–5.91
Probing pocket	< 5	1		1		1		1		1		1	
depth (≥ 4 mm)	≥ 5	2.13	1.32–3.44	2.22	1.30–3.77	1.56	0.76–3.24	1.29	0.55–3.05	2.26	1.15–4.45	2.72	1.33–.5.55
	< 5	1		1		1		1		1		1	
	5–10	2.18	1.20–3.97	2.24	1.19–4.21	1.83	0.72–4.66	1.56	0.57–4.30	2.17	0.96–4.92	2.52	1.08–5.90
	≥ 10	2.09	1.22–3.59	2.20	1.20–4.02	1.39	0.58–3.35	1.09	0.39–3.02	2.32	1.11–4.85	2.89	1.31–6.36
CAL (≥ 6 mm)	< 5	1		1		1		1		1		1	
	≥ 5	2.03	1.24–3.34	1.86	1.07–3.21	0.94	0.42–2.10	0.53	0.21–1.34	3.01	1.43–6.31	3.89	1.76–8.59
	< 5	1		1		1		1		1		1	
	5–10	1.84	0.97–3.48	1.71	0.87–3.36	1.45	0.55–3.83	0.94	0.33–2.69	2.16	0.87–5.37	2.64	1.01–6.87
	≥ 10	2.17	1.25–3.76	1.97	1.07–3.65	0.62	0.20–1.88	0.28	0.08–1.00	3.63	1.66–7.95	5.14	2.15–12.25

Values are given as odds ratios and 95% confidence intervals.
*Adjusted for age, gender, body mass index, smoking, alcohol drinking, snoring, mouth breathing in sleep and diabetes mellitus.
**Adjusted for gender, body mass index, smoking, alcohol drinking, snoring, mouth breathing in sleep and diabetes mellitus.

group. Patients with OSA often present with oral breathing and dryness of the oral cavity and the pharynx (33, 34). Drying of the mouth can impair the self-cleaning ability of the oral cavity and lead to gingivitis and increased bacterial colonization (1, 35, 36). OSA may thus increase susceptibility to periodontitis. Based on these results, persons at a higher risk for OSA can be identified with prevailing complaints of mouth breathing and dry mouth, as well as periodontal disease.

We also explored potential effect modification of the relationship between periodontitis and OSA by age (range, 47–77 years, dichotomized at a mean age of 55 years). Our findings showed that periodontitis was associated with OSA in subjects over 55 years of age, whereas no association was observed in the age group < 55 years. Previous studies (16, 19, 28, 37, 38) have reported that increasing age could be a potential risk factor for periodontal disease because of the age-related changes in the biochemical, immunological and physiological processes of periodontal tissues. The National Institute of Dental Research found that the prevalence of CAL of ≥ 4 mm was 13.8% in subjects 25–34 years of age and 53.6% in subjects 55–64 years of age, while probing pocket depth of 4–6 mm was 5.7% in subjects 25–34 years of age and 18.1% in subjects 55–64 years of age, with increased frequency in the older age groups (37). In the National Health and Nutrition Examination Survey III survey, the prevalence and extent of CAL, and the prevalence of periodontitis, increase considerably with age. In the age group 56–90 years, the prevalence of CAL was higher at buccal sites than at mesial sites ($p < 0.01$), and 50% of the individuals had periodontitis compared with subjects in the age group 30–55 years (28).

This preliminary study had two clinical limitations. First, as the data are cross-sectional it was not possible to ascertain whether mouth breathing and OSA led to periodontitis. Second, the case definition of mouth breathing was based on a self-reported questionnaire. This might lead to underestimation as a result of the participants' low response rate arising from the misinterpretation of the term 'mouth breathing (oro-nasal breathing)'. They may have used the term interchangeably with pure mouth breathing (sleeping with the mouth wide open). Some studies reporting that mouth breathing is correlated with AHI and increased OSA severity (39, 40) found discrepancies between self-report and bed partner reports about mouth breathing (40). Therefore, in terms of these findings and our study, we suggest that AHI is a more significant indicator for mouth breathing during sleep than are self-reports. Nonetheless, it should be recommended that more objective evidence for mouth breathing is sought in the next investigation.

The strengths of our study compared with previous reports are as follows. First, to the best of our knowledge, the present investigation is the first to suggest that OSA relates to mouth breathing and periodontitis. This finding has implications for periodontitis prevention, and further research in this area may ultimately lead to new strategies to prevent periodontitis. Second, our results report the characteristics of a general population study, in which the potential for selection bias is minimized compared with a clinical dental conditions study. The subjects in the study of Gunaratnam *et al.* had a very high AHI (mean ± SD = 36.55 ± 25.77), and the prevalence of periodontitis was 77–79% (16), which was about fourfold higher than the prevalence in the general population. In contrast,

our study sample exhibited mean (±SD) AHI of 7.86 ± 9.51 and is representative of the general population of Korea.

In conclusion, this study revealed that there is a significant association between OSA and periodontitis. We suggest that OSA may be a risk factor for periodontal disease and that the treatment of OSA may prevent progression of periodontal disease, but further research is needed to establish the causal relationship between the two conditions.

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Conflict of interest

None of the authors has a financial relationship with a commercial entity that has an interest in the subject of this manuscript.

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