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The Prevalence and Associated Factors of Periodontitis According to Fasting Plasma Glucose in the Korean Adults

The 2012–2013 Korea National Health and Nutrition Examination Survey

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Abstract: Although the relationship between diabetes and periodontitis is well established, the association between periodontitis and prediabetes has been investigated less extensively. Furthermore, there has been little research on the prevalence of periodontitis among individuals with prediabetes and diabetes as well as in the overall population using nationally representative data.

Among 12,406 adults (≥19 years' old) who participated in the 2012–2013 Korea National Health and Nutrition Examination Survey, a total of 9977 subjects completed oral and laboratory examinations and were included in this analysis. Periodontitis was defined as a community periodontal index score of ≥3 according to the World Health Organization criteria. The fasting plasma glucose level was categorized into the following 5 groups: normal fasting glucose (NFG) 1 (<90 mg/dL), NFG 2 (90–99 mg/dL), impaired fasting glucose (IFG) 1 (100–110 mg/dL), IFG 2 (111–125 mg/dL), and diabetes (≥126 mg/dL).

Overall, the weighted prevalence of periodontitis among the Korean adult population was 24.8% (23.3–26.4%) (weight n = 8,455,952/34,086,014). The unadjusted weighted prevalences of periodontitis were 16.7%, 22.8%, 29.6%, 40.7%, and 46.7% in the NFG 1, NFG 2, IFG 1, IFG 2, and diabetes groups, respectively ($P < 0.001$). After adjusting for age, sex, smoking history, heavy alcohol drinking, college graduation, household income, waist circumference, serum triglyceride level, serum high-density lipoprotein cholesterol level, and the presence of hypertension, the adjusted weighted prevalence of periodontitis increased to 29.7% in the IFG 2 group ($P = 0.045$) and 32.5% in the diabetes group ($P < 0.001$), compared with the NFG 1 group (24%). The odds ratios for periodontitis with the above-mentioned variables as covariates were 1.42 (95% confidence interval [CI] 1.14–1.77, $P = 0.002$) in the diabetes group and 1.33 (95% CI 1.01–1.75, $P = 0.044$) in the IFG 2 group, respectively, compared with the NFG1 group.

In conclusion, a higher range of IFG levels as well as diabetes, were positively associated with chronic periodontitis in a representative sample of Korean adults. This study suggests that individuals with a higher range of IFG levels before diabetes are at risk of periodontitis, and may benefit from dental screening.

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Abbreviations: BMI = body mass index, CI = confidence interval, CPI = The community periodontal index, FPG = fasting plasma glucose, IFG = impaired fasting glucose, KNHANES = Korea National Health and Nutrition Examination Survey, NFG = normal fasting glucose, OR = odds ratio, TG = triglyceride.

INTRODUCTION

Periodontitis is a chronic inflammatory condition characterized by destruction of the periodontal tissues and resulting in loss of connective tissue attachment, loss of alveolar bone, and the formation of pathological pockets around the affected teeth.[1,2]

Recent epidemiologic studies showed that >50% of the adult population is affected by periodontitis.[3–5] Severe periodontitis, which may result in tooth loss, is found in 5% to 20% of the adult population worldwide.[6]

Periodontitis is associated with age, inadequate oral hygiene, smoking, obesity, socioeconomic status, and chronic diseases, such as cardiovascular disease, osteoporosis, and diabetes.[6–13] Among the above-mentioned risk factors, diabetes, especially, is regarded as a major risk factor for periodontitis.[14,15] Epidemiological studies and meta-analyses of studies in various diabetic populations have shown that diabetes increases the risk of developing periodontitis approximately 3-fold when compared with nondiabetic individuals.[16] Furthermore, subjects with poorly controlled diabetes had a greater risk of severe periodontal disease compared with subjects with better-controlled diabetes.[17]

Although the relationship between diabetes and periodontitis is well established, the association between periodontitis and prediabetes has been relatively understudied. A few studies suggested that periodontal disease was positively associated with impaired glucose tolerance or impaired fasting glucose (IFG),[18–20] but other studies found no association between periodontal disease and impaired glucose tolerance.[21,22] Furthermore, there has been little research on the prevalence of periodontitis between individuals with prediabetes and diabetes, as well as in the overall population, using nationally representative data.

Herein, we investigated the prevalence and associated risk factors of periodontitis according to fasting plasma glucose (FPG) level in the Korean adult population using the data from the 2012–2013 Korea National Health and Nutrition Examination Survey (KNHANES).

METHODS

Study Population and Data Collection

This study is based on data from the 2012–2013 KNHANES, a cross-sectional and nationally representative

survey conducted by the Korea Centers for Disease Control and Prevention (KCDC). The KNHANES has been conducted periodically since 1998 to assess the health and nutritional status of the civilian, noninstitutionalized population of Korea. Participants were selected using proportional allocation-systemic sampling with multistage stratification. A standardized interview was conducted in the homes of the participants to collect information on demographic variables, family history, medical history, medications usage, and a variety of other health-related variables. The Health Interview included an established questionnaire to determine the demographic and socioeconomic characteristics of the subjects including age, education level, occupation, income, marital status, smoking habits, alcohol consumption, exercise, previous and current diseases, and family disease history.

Subjects were asked whether they exercise at an intensity that leaves them sweating or with light difficulty breathing. Subjects who exercised regularly and at a moderate intensity were asked about the frequency with which they exercised per week and the length of time per exercise session. Regular exercise was defined as exercising $\geq$5 times per week. Alcohol consumption was assessed as the subject's drinking behavior during the month before the interview. Heavy alcohol use was categorized as drinking $\geq$4 times per week during the month before the interview. Hypertension was defined as systolic blood pressure (BP) $\geq$140 mmHg, diastolic BP $\geq$90 mmHg, or use of antihypertensive medications irrespective of BP. Diabetes was defined as a FPG level $\geq$7.0 mmol/L, current antidiabetes medication usage, or a previous diagnosis of diabetes by a physician.

Height and weight were obtained using standardized techniques and equipment. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seriter, Bismarck, ND). Weight was measured to the nearest 0.1 kg using a Giant-150N calibrated balance-beam scale (Hana, Seoul, Korea). Body mass index (BMI) was calculated by dividing weight by the square of the height (kg/m^2). Systolic and diastolic BP were measured by standard methods using a sphygmomanometer while the patient was seated. Three measurements were recorded for all subjects at 5-minute intervals, and the average of the second and third measurements was used in the analysis.

Assessment of Periodontitis

The community periodontal index (CPI) was used to assess the severity of periodontitis. Oral examination of periodontal health was conducted by trained dentists and included an examination for bleeding upon application of 20 g of pressure using a CPI probe meeting the WHO guidelines (WHO, 1997), the existence of dental plaque, and the existence of periodontal pockets with measurement of pocket depths. The examination was performed in each of the 6 sextants: posterior right maxilla, anterior maxilla, posterior left maxilla, posterior right mandible, anterior mandible, and posterior left mandible. The CPI was scored on a scale of 0 to 4, with each of the scores defined as follows: 0 = healthy periodontal tissue (no bleeding, calculus, or pocket depth $\geq$3.5 mm); 1 = bleeding periodontal tissue (bleeding on probing but no calculus or pocket depth $\geq$3.5 mm); 2 = periodontal tissue with plaques (supra- or subgingival calculus, no pocket depth $\geq$3.5 mm); 3 = periodontal tissue with shallow periodontal pockets (3.5$\leq$ pocket depth $<$5.5 mm); and 4 = periodontal tissue with deep periodontal pockets (pocket depth $\geq$5.5 mm). All teeth of each sextant were examined, and the highest score was recorded. A periodontal pocket depth of $\geq$3.5 mm (CPI $\geq$ 3) was considered significant periodontitis (Inagaki et al, 2005). In this study, a participant was considered to have periodontitis if a CPI score of $\geq$3 was found in any of the sextants. A CPI score of 4 was considered to be a more severe form of periodontitis. As a form of quality control, training was provided to the research specialists performing the oral health examination to minimize errors in the measurement of periodontal pocket depth owing to differences in the pressure applied by each examiner during the examination. Through the standardization process, the intra- and interexaminer agreements expressed as kappa values were determined to be 0.93 and 0.88, respectively (KCDC, 2008).

Laboratory Methods

Blood samples were collected in the morning after fasting for at least 8 h. Total cholesterol, FPG, triglyceride (TG), and high-density lipoprotein (HDL)-cholesterol levels were measured by using a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan). HbA1c was measured using high-performance liquid chromatography (HLC-723G7, Tosoh, Tokyo, Japan).

Ethics Statement

This study was approved by the Institutional Review Board of Ilsan Paik Hospital, Republic of Korea. After approval of the study proposal, the KNHANES dataset was made available at the request of the investigator. Because the dataset did not include any personal information, and participants' consent had already been given for the KNHANES, our study was exempt from the requirement for participant consent.

Statistical Analyses

The KNHANES participants were not sampled randomly. The survey was designed using a complex, stratified, multistage probability-sampling model; thus, individual participants were not equally representative of the Korean population. To obtain representative prevalence rates from the dataset, it was necessary to consider the power of each participant (sample weight) as representative of the Korean population. Following approval from the KCDC, we received a survey dataset that included information regarding the survey location, strata by age, sex, and various other factors, and the sample weight for each participant. The survey sample weights, which were calculated by taking into account the sampling rate, response rate, and age/sex proportions of the reference population (2005 Korean National Census Registry), were used in all of the analyses to provide representative estimates of the non-institutionalized Korean civilian population.

Difference in age according to the presence of periodontitis was evaluated by analysis of variance, and the percentage of females was evaluated by the χ^2-test. To compare the age- and sex-adjusted weighted clinical characteristics according to the presence of periodontitis, analysis of covariance (ANCOVA) and the Bonferroni *post hoc* test were used. A logistic regression analysis was used to evaluate the odds ratios for periodontitis and severe periodontitis as covariates with age, sex, smoking, heavy alcohol drinking, household income, college graduation, waist circumference, serum HDL-cholesterol, serum TG, hypertension, and FPG level. General linear models were used to assess the weighted prevalence of periodontitis according to the FPG level range before (Model 1) and after (Models 2–5) adjustment for confounders. Age and sex were adjusted in Model 2. In Model 3, smoking history, heavy alcohol drinking, college graduation, household income as well as age and sex were adjusted for in the analysis. In Model 4, waist circumference, serum TG, serum

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TABLE 1. Demographic and Clinical Characteristics of Korean Population, Aged 19 years and older, in 2012–2013 Korea National Health and Nutrition Examination Survey

Number (unweighted/weighted)	44.8 (44.3–45.3)
Age, y	44.8 (44.3–45.3)
Women (%)	49.3 (48.3–50.2)
Current smoking (%)	24.1 (23.0–25.4)
Heavy alcohol drinking (%)	6.4 (5.7–7.1)
Regular exercise (%)	9.9 (9.2–10.7)
College graduation (%)	32.6 (31.0–34.2)
Household income (×1000 KRW/month)	410.7 (387.4–434.1)
Daily energy intake, kcal/day	2073 (2042–2104)
BMI, kg/m^2	23.8 (23.7–23.9)
Waist circumference, cm	80.7 (80.4–81.1)
Systolic BP, mmHg	116.9 (116.4–117.4)
Diastolic BP, mmHg	75.8 (75.4–76.1)
Anti-hypertensive medication (%)	13.5 (12.6–14.5)
Hypertension (%)	24.4 (23.1–25.7)
Fasting plasma glucose, mg/dL	97.7 (97.1–98.3)
HbA1c (%)	5.76 (5.73–5.78)
Anti-diabetes medication (%)	5.2 (4.7–5.8)
Diabetes (%)	8.7 (8.0–9.4)
Serum total cholesterol, mg/dL	188.0 (187.0–189.0)
Serum triglyceride, mg/dL	136.1 (132.9–139.3)
Serum HDL-cholesterol, mg/dL	52.0 (51.6–52.3)
CPI score	
0	28.5 (26.8–30.2)
1	7.0 (6.1–8.0)
2	39.7 (38.1–41.4)
Mild periodontitis 3	18.2 (16.9–19.5)
Severe periodontitis 4	6.6 (5.9–7.5)

Data are expressed as mean with 95% CI. Heavy alcohol drinking, $\geq \times 4$ alcoholic drinks/week. Regular exercise, $\geq \times 5$ exercise/week. Hypertension, systolic blood pressure $\geq$140 mmHg, diastolic blood pressure $\geq$90 mmHg, or current antihypertensive medication. Diabetes, fasting plasma glucose $\geq$126 mg/dL, or current anti-diabetes medication or a previous diagnosis of diabetes by a doctor. CPI = Community periodontal index, HDL = high-density lipoprotein.

HDL-cholesterol, and the presence of hypertension were adjusted for, in addition to the parameters in Model 3. We classified FPG levels into the following five groups: normal fasting glucose (NFG) 1 (<90 mg/dL), NFG 2 (90–99 mg/dL), IFG 1 (100–110 mg/dL), IFG 2 (111–125 mg/dL) and diabetes, defined as either FPG $\geq$ 126 mg/dL, treatment with anti-diabetes drugs, or a history of diabetes diagnosed by a physician.[23] Logistic regression analysis was used to evaluate the odds ratios of the presence of diabetes or IFG for periodontitis and severe periodontitis according to age group using the above-mentioned variables as covariates. All of the tests were 2-sided, and P values <0.05 indicate statistical significance. Statistical analyses were performed using the SPSS software (ver. 21.0 for Windows; SPSS, Chicago, IL).

RESULTS

Demographics and Clinical Characteristics of the Study Population

The weighted demographics and clinical characteristics of the study population are presented in Table 1.

Among 12,406 adults ($\geq$19 years' old) who participated in the 2012–2013 KNHANES, a total of 9977 subjects completed oral and laboratory examinations and were included in this analysis. The average age of the participants was 44.8 years, and the percentage of females was 49.3%. The prevalences of periodontitis (CPI score $\geq$3) and severe periodontitis (CPI score = 4) were 24.8% and 6.6%, respectively. The prevalence of hypertension was 24.4%, and 8.7% of participants were diabetic.

Estimated Prevalence of Periodontitis in the Korean Diabetic Population and Adult Population According to Age and Sex

Overall, the weighted prevalences of periodontitis among the Korean diabetic population and adult population were 46.7% [42.7–50.7] (n = 1,382,511/2,962,422) and 24.8% [23.3–26.4] (n = 8,455,952/34,086,014), respectively. The weighted prevalence of periodontitis increased with age in both the diabetic population ($P = 0.001$) and adult population ($P < 0.001$) (Table 2). Males demonstrated a higher percentage of periodontitis compared with females (29.7% [27.6–31.8] vs 19.8% [18.2–21.4], $P < 0.001$). Among the diabetic population, males were also more likely to be affected than were females (50.8% [45.4–56.2] vs 41.1% [36.1–46.9], $P = 0.014$).

Age- and Sex adjusted Clinical Characteristics According to the Presence of Periodontitis

Data for age- and sex-adjusted clinical characteristics in the presence of periodontitis are presented in Table 3. Subjects with periodontitis demonstrated greater rates of current smoking, heavy alcohol drinking, hypertension, and diabetes compared with subjects without periodontitis. The levels of serum TG, FPG, HbA1c, BMI and waist circumference were also higher in adults with periodontitis compared with adults without periodontitis. In contrast, the proportions of subjects having a college graduation, household income, and serum HDL-cholesterol level were higher in those without periodontitis versus with periodontitis.

Factors Associated With Periodontitis

In the logistic regression analysis for periodontitis, age, male sex, current smoking, and diabetes were associated with periodontitis and/or severe periodontitis (Table 4). The odds ratios of age (per 10-year increase) for periodontitis and severe periodontitis were 1.66 (1.59–1.74) and 1.53 (1.42–1.64), respectively. Subjects with diabetes were ~1.5-fold more likely to have periodontitis and/or severe periodontitis ($P = 0.002$) compared with subjects with a FPG level <89 mg/dL (NFG 1). Subjects with a FPG level of 111–125 mg/dL (IFG 2) had a 33% increased risk of periodontitis ($P = 0.044$), but not of severe periodontitis ($P = 0.204$), compared with NFG1. Neither IFG 1 nor NFG 2 influenced the risk of developing periodontitis and/or severe periodontitis.

College graduation and serum HDL-cholesterol levels were inversely correlated with periodontitis and/or severe periodontitis.

Ex-smokers and current smokers had an increased risk of developing periodontitis, relative to non-smokers, by 25% ($P = 0.030$) and 89% ($P < 0.001$), respectively. With regard to severe periodontitis, only current smoking, rather than former smoking, was associated with severe periodontitis. Waist circumference was correlated with only periodontitis, and not severe periodontitis.

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TABLE 2. Estimated Prevalence of Periodontitis in the Korean Diabetic Population and Adult Population According to Age and Sex

	Korean Diabetic Population			Korean Population		
	Unweighted Prevalence, % (n = 1043)	Weighted Prevalence, % (n = 2,962,422) [95% CI]	*P*	Unweighted Prevalence (n = 9977), %	Weighted Prevalence (n = 34,086,014),% [95% CI]	*P*
Total % (n)	**45.8 (478)**	**46.7 [42.7–50.7] (1,382,511)**		**27.3 (2728)**	**24.8 [23.3–26.4] (8,455,952)**	
Age, y			0.001			<0.001
19–39	27.3 (27/99)	28.5 [19.7–39.3] (117,944/414,162)		11.5 (472/4106)	11.5 [10.2–12.9] (2,008,182/17,485,100)	
40–64	48.2 (238/494)	49.7 [44.1–55.3] (790,692/1,590,176)		35.5 (1348/3802)	36.7 [34.2–39.3] (4,581,284/12,477,498)	
≥65	47.3 (213/450)	49.5 [43.5–55.4] (473,874/958,084)		43.9 (908/2069)	45.3 [42.1–48.5] (1,866,487/4,123,416)	
Sex			0.014			<0.001
Men	51.0 (269/527)	50.8 [45.4–56.2] (842,975/1,659,268)		33.8 (1455/4306)	29.7 [27.6–31.8] (5,132,832/17,297,346)	
Women	40.5 (209/516)	41.1 [36.1–46.9] (539,536/1,303,153)		22.4 (1273/5671)	19.8 [18.2–21.4] (3,323,121/16,788,668)	

Heavy alcohol drinking, household income, serum TG level, and hypertension were not associated with the risk of periodontitis and/or severe periodontitis.

Adjusted Weighted Prevalence of Periodontitis According to FPG Level

The unadjusted weighted prevalences of periodontitis were 16.7%, 22.8%, 29.6%, 40.7%, and 46.7% in the NFG 1, NFG 2, IFG 1, IFG 2, and diabetes groups, respectively ($p < 0.001$) (Table 5, Model 1).

We assessed the adjusted weighted prevalence of periodontitis according to the FPG level, after adjusting for age, sex, smoking history, heavy alcohol drinking, college graduation, household income, waist circumference, serum TG level, serum HDL-cholesterol level, and the presence of hypertension (Table 5, Models 2–4).

The adjusted weighted prevalence of periodontitis was 29.7% in the IFG 2 group ($P = 0.045$) and 32.5% in the diabetes group ($P < 0.001$), which were significantly different compared with that of the NFG 1 group (24%) (Figure 1).

Effect of the Presence of Diabetes or IFG on the Development of Periodontitis According to Age

The odds ratios of the presence of diabetes or IFG for periodontitis according to age group are shown in Table 6. The presence of diabetes increased the risk of periodontitis by

TABLE 3. Age- and Sex-adjusted Clinical Characteristics According to the Presence of Periodontitis

Weighted n	Periodontitis (−) (n = 7249) 25,630,062	Periodontitis (+) (n = 2728) 8,455,952	*P*
Age, y	41.7 (41.2–42.3)	54.0 (53.2–54.8)	<0.001
Women (%)	53.0 (51.0–54.0)	39.0 (37.0–41.0)	<0.001
College education	34.3 (32.6–36.1)	27.4 (25.2–29.6)	<0.001
Household income (×1000 KRW/month)	421.2 (394.1–448.3)	378.7 (343.3–414.2)	0.043
Current smoking (%)	22.0 (20.8–23.3)	30.6 (28.4–32.7)	<0.001
Heavy alcohol drinking (%)	5.8 (5.1–6.6)	8.0 (6.6–9.4)	0.006
Regular exercise (%)	10.2 (9.3–11.1)	9.0 (7.6–10.5)	0.189
Daily calories intakes, kcal/day	2069 (2037–2101)	2084 (2034–2135)	0.566
Body mass index, kg/m^2	23.7 (23.6–23.8)	24.1 (23.8–24.2)	0.005
Waist circumference, cm	80.5 (80.2–80.8)	81.5 (81.0–82.1)	0.001
Systolic blood pressure, mmHg	116.8 (116.3–117.3)	117.1 (116.2–117.9)	0.588
Diastolic blood pressure, mmHg	75.7 (75.3–76.1)	76.0 (75.4–76.6)	0.356
Anti-hypertensive medication (%)	13.0 (12.1–13.9)	15.1 (13.3–16.9)	0.054
Hypertension (%)	23.4 (22.2–24.6)	27.3 (25.1–29.5)	0.002
Serum cholesterol, mg/dL	188.1 (187.0–189.2)	187.7 (186.0–189.5)	0.734
Serum triglyceride, mg/dL	133.0 (129.6–136.5)	145.4 (138.9–152.0)	0.001
Serum HDL-cholesterol, mg/dL	52.4 (52.0–52.8)	50.8 (50.1–51.4)	<0.001
Anti-lipid medication (%)	5.2 (4.6–5.7)	5.1 (4.0–6.2)	0.905
Fasting plasma glucose, mg/dL	96.8 (96.3–97.3)	100.4 (99.0–101.8)	<0.001
HbA1c (%)	5.72 (5.70–5.74)	5.86 (5.81–5.91)	<0.001
Anti-diabetes medication (%)	4.9 (4.3–5.4)	6.2 (4.9–7.4)	0.072
Diabetes (%)	7.60 (6.90–8.30)	12.0 (10.3–13.7)	<0.001

Data are expressed as mean with 95% CI. Heavy alcohol drinking, ≥ × 4 alcoholic drinks/week. Regular exercise, ≥ × 5 exercise/week. Hypertension, systolic blood pressure ≥140 mmHg, diastolic blood pressure ≥90 mmHg, or current anti-hypertensive medication. Diabetes, fasting plasma glucose ≥126 mg/dL, or current anti-diabetes medication or a previous diagnosis of diabetes by a doctor. HDL = high-density lipoprotein.

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TABLE 4. Logistic Regression Analyses for Periodontitis

	Periodontitis		Severe Periodontitis	
	Odds Ratio (95% CI)	***P***	**Odds Ratio (95% CI)**	***P***
Age (10 years' increase)	1.66 (1.59–1.74)	<0.001	1.53 (1.42–1.64)	<0.001
Men	1.40 (1.19–1.63)	<0.001	1.35 (1.02–1.79)	0.035
Smoking				
Nonsmoking	Reference		Reference	
Past smoking	1.25 (1.02–1.52)	0.030	1.19 (0.87–1.63)	0.265
Current smoking	1.89 (1.58–2.26)	<0.001	1.74 (1.29–2.35)	<0.001
Heavy alcohol drinking	1.18 (0.93–1.49)	0.166	1.34 (0.94–1.90)	0.102
Household income (100,000KRW increase)	1.00 (0.98–1.01)	0.567	1.00 (1.00–1.01)	0.447
College graduation	0.73 (0.62–0.86)	<0.001	0.61 (0.46–0.81)	0.001
Waist circumference (10-cm increase)	1.04 (1.01–1.08)	0.023	1.04 (0.98–1.10)	0.200
Serum high-density lipoprotein cholesterol (10-mg/dL increase)	0.91 (0.86–0.97)	0.005	0.90 (0.82–0.99)	0.033
Serum triglyceride (20-mg/dL increase)	1.00 (0.99–1.01)	0.368	1.00 (0.98–1.01)	0.693
Hypertension	1.08 (0.94–1.24)	0.277	1.03 (0.83–1.27)	0.797
Fasting plasma glucose				
<90 mg/dL	Reference		Reference	
90–99 mg/dL	1.02 (0.86–1.20)	0.861	1.11 (0.84–1.46)	0.467
100–110, mg/dL	0.99 (0.83–1.19)	0.944	1.07 (0.79–1.45)	0.644
111–125, mg/dL	1.33 (1.01–1.75)	0.044	1.29 (0.87–1.93)	0.204
Diabetes	1.42 (1.14–1.77)	0.002	1.60 (1.19–2.15)	0.002

2.06- (CI 1.23–3.45, $P = 0.006$) and 1.46- (CI 1.15–1.86, $P = 0.002$) fold in adults aged 19 to 39 years and 40 to 64 years, respectively. However, the presence of diabetes did not increase the risk of periodontitis in adults older than 65 years. The presence of diabetes or IFG 2 also increased the risk of periodontitis in adults aged 19 to 39 years and 40 to 64 years, but not in adults older than 65 years. With regard to severe periodontitis, we obtained similar results. However, the presence of diabetes or IFG 1 or 2 increased the risk of severe periodontitis by 2.03-fold (CI 1.28–3.24, $P = 0.003$) only in those aged 19 to 39 years.

DISCUSSION

Using data from the KNHANES 2012–2013, we demonstrated a weighted prevalence of 24.8% for periodontitis in the Korean population aged 19 years or older, and 6.6% had severe periodontitis, similar to the rate in China. During China's 2010 Chronic Disease and Risk Factor Surveillance survey among adults aged 18 years and older, 25.9% had periodontitis (CPI $\geq$3), with 1.9% having severe periodontitis.[4] According to the 2009–2012 US NHANES, a large number of people (46%, 64.7 million US adults) suffer from periodontitis, with 8.9% having severe periodontitis.[3]

The unadjusted weighted prevalence of periodontitis showed a tendency to increase as the FPG level increased (16.7%, 22.8%, 29.6%, 40.7%, and 46.7% in the NFG 1, NFG 2, IFG 1, IFG 2, and diabetes groups, respectively). After adjustment for potential confounders, the weighted prevalence of periodontitis increased significantly in subjects with a FPG level of 111–125 mg/dL as well as in those with diabetes,

TABLE 5. The Adjusted Weighted Prevalence of Periodontitis According to the Fasting Plasma Glucose Level

	NFG 1 (<90 mg/dL)	**NFG2 (90–99 mg/dL)**	**IFG1 (100–110 mg/dL)**	**IFG2 (111–125 mg/dL)**	**Diabetes**	***P***
Number (unweighted/ weighted)	3107/11,442,229	3701/12,780,068	1551/5,079,244	575/1,822,052	1043/2,962,422	
Model 1	16.7 ± 0.8	22.8 ± 1.2	29.6 ± 1.6	40.7 ± 2.7	46.7 ± 2.0	<0.001
Model 2	23.6 ± 0.9	23.2 ± 1.1	24.1 ± 1.5	30.7 ± 2.6	33.9 ± 2.0	<0.001
Model 3	23.4 ± 0.9	23.3 ± 1.1	23.7 ± 1.4	30.6 ± .6	34.0 ± 2.0	<0.001
Model 4	24.0 ± 0.9	23.4 ± 1.1	23.2 ± 1.4	29.7 ± 2.7	32.5 ± 2.0	<0.001

IFG = impaired fasting glucose, NFG = normal fasting glucose. Model 1: unadjusted; Model 2: adjusted for age and sex; Model 3: model 2 + smoking history (past or current), heavy alcohol drinking, college graduation, and household income; Model 4: model3 + waist circumference, serum triglyceride, serum high-density lipoprotein cholesterol, and the presence of hypertension.

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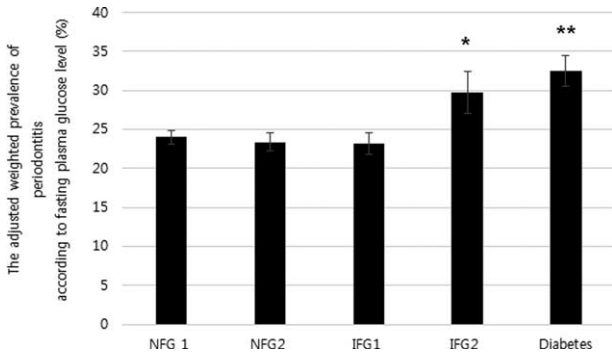

FIGURE 1. After adjusting for age, sex, smoking history, heavy alcohol drinking, college graduation, household income, waist circumference, serum triglyceride, serum high-density lipoprotein cholesterol, and the presence of hypertension, the adjusted weighted prevalence of periodontitis was 29.7% in the IFG 2 group ($P = 0.045$) and 32.5% in the diabetes group ($P < 0.001$), which were significantly different compared with of the NFG 1 group (24%). $^{*}P < 0.05$ (NFG 1 vs IFG2), $^{**}P < 0.001$ (NFG 1 vs diabetes).

compared with subjects with a FPG level <89 mg/dL. To date, no study has evaluated the prevalence of periodontitis according to FPG level using nationally representative data.

In the logistic regression, subjects with diabetes were ~1.5-fold more likely to have periodontitis and/or severe periodontitis, and subjects with pre-diabetes (FPG level 111–125 mg/dl) also had a 33% increased risk of periodontitis ($P = 0.044$), compared with subjects with a FPG level <89 mg/dL. These associations between the risk of periodontitis and diabetes and/or prediabetes were more apparent among younger age groups.

The positive association between IFG and periodontal disease has been the subject of previous studies. Choi et al[20] reported that chronic periodontitis measured by clinical attachment loss and pocket depth was positively associated with IFG and diabetes in a dose-dependent manner in the US population. Another study using data from periodic medical examinations for 815 nondiabetic adults showed that the prevalence of alveolar bone loss was higher among individuals with a FPG level ≥100 mg/dL versus <100 mg/dL ($P = 0.032$)[18] Similarly, Islam et al[24] reported an increased prevalence of IFG before the onset of diabetes in patients with periodontitis, compared with subjects without periodontitis, and vice versa (28.5% vs 17.7%).

A dysregulated inflammatory response, involving immune functioning, neutrophil activity, and cytokine biology, is an important pathologic mechanism linking diabetes and periodontitis.[11] A hyperglycemic status leads to the activation of pathways that increase inflammation, including prostaglandin E2, interleukin (IL)-1β, IL-6, and tumor necrosis factor (TNF)-α, and an impact on periodontal tissues.[11] A recent meta-analysis showed that individuals with type 2 diabetes and chronic periodontitis have significantly higher levels of IL-1β in gingival crevicular fluid (a fluid exudate that flows from the gingival margins) compared with systemically healthy individuals with chronic periodontitis.[25] However, impaired glucose homeostasis may result from chronic subclinical systemic inflammation, which is an early manifestation of type 2 diabetes. IL-6 and TNF-α are the main inducers of acute-phase proteins and impair intracellular insulin signaling, potentially contributing to insulin resistance.[26] Therefore, these findings suggest a 2-way relationship between hyperglycemia and periodontitis, with hyperglycemia increasing the risk of periodontitis, and periodontal inflammation negatively influencing glycemic status.[11] During a 4-year follow-up in adults without diabetes, Timonen et al[27] reported that the homeostasis model assessments of insulin resistance and β-cell indices were associated with periodontal pocket formation, suggesting that

TABLE 6. Effect of the Presence of Diabetes or Impaired Fasting Glucose on the Development of Periodontitis According to Age

Periodontitis	Odds Ratio (95% CI)	*P*	Severe Periodontitis, Odds Ratio (95% CI)	*P*
The presence of diabetes				
Age, y				
19–39	2.06 (1.23–3.45)	0.006	2.82 (1.18–6.74)	0.020
40–64	1.46 (1.15–1.86)	0.002	1.52 (1.13–2.04)	0.006
≥65	1.16 (0.90–1.50)	0.244	1.19 (0.83–1.71)	0.345
All ages	1.36 (1.13–1.64)	0.001	1.45 (1.13–1.85)	0.004
The presence of diabetes or IFG2 (111–125 mg/dl)				
Age, y				
19–39	1.64 (1.09–2.48)	0.019	2.62 (1.39–4.92)	0.003
40–64	1.41 (1.14–1.76)	0.002	1.34 (1.00–1.78)	0.048
≥65	1.13 (0.90–1.410	0.283	1.05 (0.75–1.46)	0.773
All ages	1.38 (1.17–1.63)	<0.001	1.38 (1.11–1.72)	0.004
The presence of diabetes or IFG2 (111–125 mg/dL) or IFG1 (100–110 mg/dL)				
Age, y				
19–39	1.23 (0.95–1.59)	0.122	2.04 (1.28–3.24)	0.003
40–64	1.08 (0.90–1.29)	0.434	0.93 (0.72–1.21)	0.579
≥65	1.04 (0.84–1.30)	0.701	1.19 (0.83–1.70)	0.338
All ages	1.16 (1.02–1.32)	0.029	1.19 (0.98–1.44)	0.078

Covariates: age, sex, smoking (past or current), heavy alcohol drinking, household income, college graduation, waist circumference, serum high-density lipoprotein-cholesterol, serum triglyceride, and hypertension. CI = confidence interval, IFG = impaired fasting glucose.

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impaired glucose metabolism predicts the breakdown of periodontal tissues. Reversely, Demmer et al[28] demonstrated that the baseline periodontal status was related to 5-year HbA1c progression in a population-based cohort in Germany comprising 2973 diabetes-free participants.

In this study, we confirmed several risk factors for periodontitis in addition to hyperglycemia. Age, male sex, and current smoking increased the risk of developing both periodontitis and severe periodontitis, consistent with previous reports.[6] The most powerful controllable risk factor was current smoking, which had a higher odds ratio than that of age. Tobacco smoking modifies the host response to microbial dental plaque and exerts a substantial destructive effect on the periodontal tissues.[29,30] Actually, smoking cessation may have a beneficial effect on periodontal healing and on reducing the severity of chronic periodontitis.[31]

The major strength of our study was the large, nationally representative sample of adult Koreans analyzed. To our knowledge, few other studies have performed a national-level demographic assessment according to FPG level and factors associated with periodontitis. We also adjusted for several potential confounders—such as smoking, alcohol drinking, college graduation, household income, waist circumference, serum TG level, serum HDL-cholesterol level, and the presence of hypertension—which might have attenuated the strength of the association between periodontitis and IFG.

This study has some limitations. First, residual or hidden confounding variables cannot be excluded, similar to other cross-sectional studies. We also cannot draw an inference as to causality owing to the cross-sectional design of the study.

In conclusion, a higher range of IFG as well as diabetes was positively associated with chronic periodontitis in a representative sample of Korean adults. This study suggests that individuals with a higher range of IFG before diabetes are at risk of periodontitis, and may benefit from dental screening.

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REFERENCES

1. Löe H. Periodontal disease. The sixth complication of diabetes mellitus. *Diabetes Care.* 1993;16:329–334.
2. Highfield J. Diagnosis and classification of periodontal disease. *Aust Dent J.* 2009;54(Suppl 1):S11–26.
3. Eke PI, Dye BA, Wei L, et al. Update on Prevalence of Periodontitis in Adults in the United States: NHANES 2009 to 2012. *J Periodontol.* 2015;86:611–622.
4. Zhang Q, Li Z, Wang C, et al. Prevalence and predictors for periodontitis among adults in China, 2010. *Glob Health Action.* 2014;7:24503.
5. Schutzhold S, Kocher T, Biffar R, et al. Changes in prevalence of periodontitis in two German population-based studies. *J Clin Periodontol.* 2015;42:121–130.
6. AlJehani YA. Risk factors of periodontal disease: review of the literature. *Int J Dent.* 2014;2014:182513.
7. de Moura Grec PG, Marsicano JA, Carvalho CA, et al. Obesity and periodontitis: systematic review and meta-analysis. *Ciência e saúde coletiva.* 2014;19:1763–1772.
8. Lee J, Park J, Choi J, et al. Association of Lifestyle-Related Comorbidities With Periodontitis: A Nationwide Cohort Study in Korea. *Medicine.* 2015;94:e1567.
9. Lin T, Lung C, Su H, et al. Association between periodontal disease and osteoporosis by gender: a nationwide population-based cohort study. *Medicine.* 2015;94:e553.
10. Nakajima T, Yamazaki K. Periodontal disease and risk of atherosclerotic coronary heart disease. *Odontology.* 2009;97:84–91.
11. Preshaw PM, Alba AL, Herrera D, et al. Periodontitis and diabetes: a two-way relationship. *Diabetologia.* 2012;55:21–31.
12. Renvert S, Persson RE, Persson GR. Tooth loss and periodontitis in older individuals: results from the Swedish National Study on Aging and Care. *J Periodontol.* 2013;84:1134–1144.
13. Tomar SL, Asma S. Smoking-attributable periodontitis in the United States: findings from NHANES III. National Health and Nutrition Examination Survey. *J Periodontol.* 2000;71:743–751.
14. Salvi GE, Carollo Bittel B, Lang NP. Effects of diabetes mellitus on periodontal and peri-implant conditions: update on associations and risks. *J Clin Periodontol.* 2008;35(8 Suppl):398–409.
15. Chávarry NG, Vettore MV, Sansone C, et al. The relationship between diabetes mellitus and destructive periodontal disease: a meta-analysis. *Oral Health Prevent Denti.* 2009;7:107–127.
16. Mealey BL, Ocampo GL. Diabetes mellitus and periodontal disease. *Periodontol 2000.* 2007;44:127–153.
17. Tsai C, Hayes C, Taylor GW. Glycemic control of type 2 diabetes and severe periodontal disease in the US adult population. *Community Dent Oral Epidemiol.* 2002;30:182–192.
18. Zadik Y, Bechor R, Galor S, et al. Periodontal disease might be associated even with impaired fasting glucose. *Br Dent J.* 2010;208:E20.
19. Saito T, Murakami M, Shimazaki Y, et al. The extent of alveolar bone loss is associated with impaired glucose tolerance in Japanese men. *J Periodontol.* 2006;77:392–397.
20. Choi Y, McKeown RE, Mayer Davis EJ, et al. Association between periodontitis and impaired fasting glucose and diabetes. *Diabetes Care.* 2011;34:381–386.
21. Marugame T, Hayasaki H, Lee K, et al. Alveolar bone loss associated with glucose tolerance in Japanese men. *Diabetic Med.* 2003;20:746–751.
22. Noack B, Jachmann I, Roscher S, et al. Metabolic diseases and their possible link to risk indicators of periodontitis. *J Periodontol.* 2000;71:898–903.
23. Oh JY, Lim S, Kim DJ, et al. A report on the diagnosis of intermediate hyperglycemia in Korea: a pooled analysis of four community-based cohort studies. *Diabetes Res Clin Pract.* 2008;80:463–468.
24. Islam SA, Seo M, Lee YS, et al. Association of periodontitis with insulin resistance, beta-cell function, and impaired fasting glucose before onset of diabetes. *Endocr J.* 2015;62:981–989.
25. Atieh MA, Faggion CM, Seymour GJ. Cytokines in patients with type 2 diabetes and chronic periodontitis: A systematic review and meta-analysis. *Diabetes Res Clin Pract.* 2014;104:e38–45.
26. Rotter V, Nagaev I, Smith U. Interleukin-6 (IL-6) induces insulin resistance in 3T3-L1 adipocytes and is, like IL-8 and tumor necrosis factor-alpha, overexpressed in human fat cells from insulin-resistant subjects. *J Biol Chem.* 2003;278:45777–45784.
27. Timonen P, Saxlin T, Knuuttila M, et al. Role of insulin sensitivity and beta cell function in the development of periodontal disease in adults without diabetes. *J Clin Periodontol.* 2013;40:1079–1086.
28. Demmer RT, Desvarieux M, Holtfreter B, et al. Periodontal status and A1C change: longitudinal results from the study of health in Pomerania (SHIP). *Diabetes Care.* 2010;33:1037–1043.
29. Kubota M, Tanno-Nakanishi M, Yamada S, et al. Effect of smoking on subgingival microflora of patients with periodontitis in Japan. *BMC Oral Health.* 2011;11:1.

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30. Vouros ID, Kalpidis CD, Chadjipantelis T, et al. Cigarette smoking associated with advanced periodontal destruction in a Greek sample population of patients with periodontal disease. *J Int Acad Periodontol.* 2009;11:250–257.

31. Fiorini T, Musskopf ML, Oppermann RV, et al. Is there a positive effect of smoking cessation on periodontal health? A systematic review. *J of Periodontol.* 2014;85:83–91.

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