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Relationship between obesity, glucose tolerance, and periodontal disease in Japanese women: the Hisayama study

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Background: Recent studies have reported a relationship between obesity and periodontal disease. Obesity is the strongest risk factor for type 2 diabetes, which is, in turn, a risk factor for periodontal disease. An oral glucose tolerance test is necessary to diagnose diabetes; however, no study has examined the relationship between obesity and periodontal disease by taking oral glucose tolerance test results into consideration.

Methods: In all, 584 Japanese women aged between 40 and 79 years old, with at least 10 teeth, underwent health examinations. Body mass index, waist–hip ratio, body fat, and oral glucose tolerance test results were used as independent variables with known risk factors for periodontal disease. Mean probing pocket depth and mean attachment loss were used as the dependent variables.

Results: In all of the analyses, body mass index, body fat, and waist–hip ratio were significantly associated with the highest quintile of mean probing pocket depth, even when adjusted for oral glucose tolerance test results. In the multivariate analysis, the subjects with the highest quartile of body mass index had a significantly higher odds ratio (OR) for the highest quintile of mean probing pocket depth [OR, 4.3; 95% confidence interval (CI), 2.1–8.9; $p < 0.001$], whereas neither impaired glucose tolerance nor diabetes were significantly associated with deep pockets. The relationships between the obesity indexes and mean attachment loss did not reach statistical significance.

Conclusion: Obesity was associated with deep pockets in Japanese women, even after adjusting for oral glucose tolerance test.

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Obesity, which is increasing worldwide, is a major risk factor for adult diseases such as type 2 diabetes, hyperlipemia, hypertension, cholelithiasis, arteriosclerosis, and cardiovascular and cerebrovascular disease (1). Of these disorders, the risk of type 2 diabetes is increased most by obesity, which reduces the glucose tolerance status (1, 2). The results of a Japanese national survey conducted in 1997 revealed that 53% of Japanese with diabetic conditions had previously been obese (body mass index ≥ 26.4) (3). Recent studies have reported that obesity, especially upper-body obesity, is significantly associated with probing pocket depth in the Japanese population (4–6). In the Third National Health and Nutrition Examination Survey (NHANES III), there was a significant association between obesity and periodontal disease in the United States population (7, 8). In addition, type 2 diabetes is a well-documented risk factor for periodontal disease (9–12). Since both type 2 diabetes and periodontal disease take a long time to develop and to manifest in middle-aged people, impaired glucose tolerance as a pre-diabetic condition, caused by obesity, may be a true risk factor for periodontal disease. This implies that obesity and impaired glucose condition are confounding factors associated with periodontal disease. However, no increased risk of periodontal disease with impaired glucose tolerance as a pre-diabetic condition has been reported. A fasting 75-g oral glucose tolerance test is used to diagnose diabetes, as it constitutes the definitive method for assessing a patient's glucose tolerance (13). Although previous reports have considered the role of diabetes in the relationship between obesity and periodontal disease, such studies did not use the oral glucose tolerance test to diagnose diabetic condition. The aforementioned studies used glycosylated hemoglobin A1C, the fasting plasma glucose, or a simple questionnaire about the history of diabetes; therefore, their assessment of diabetes was insufficient. The purpose of this study was to clarify the association between obesity and periodontal disease, with a precise assessment of glucose tolerance status using oral glucose tolerance test, in community-dwelling Japanese women.

Material and methods

From July to September 1998, a total of 982 Hisayama residents aged 40–79 years (21.6% of the total population in that age group) underwent a comprehensive health examination that included both a periodontal examination and a fasting 75-g oral glucose tolerance test (14). In this study, we analyzed 584 women with at least 10 teeth (15, 16).

Following the method of NHANES III (17), a periodontal examination was performed on two randomly selected quadrants, one maxillary and one mandibular, by four trained dentists, using a normal dental chair. Mean probing pocket depth and attachment loss were analyzed. The subjects were divided into quintiles with respect to each of the two periodontal measurements: mean pocket depth and mean attachment loss. Oral hygiene status was evaluated using the plaque index (18).

Blood samples were collected from the antecubital vein the morning after an overnight fast and analyzed using previously described methods (14). The World Health Organization criteria for the diagnosis of diabetes were applied (13). These are as follows: normal glucose tolerance (NGT; fasting plasma glucose level < 110 mg/dl and 2-h post-challenge glucose < 140 mg/dl), diabetes (fasting ≥ 126 mg/dl or 2-h post-challenge ≥ 200 mg/dl), and impaired glucose tolerance (other than the above, including impaired fasting glucose).

Trained nurses measured the subjects' weight, height, and waist and hip circumferences. The waist circumference was measured at the level of the umbilicus. All measurements were taken after the subjects exhaled. The hip circumference was measured around the buttocks 4 cm below the anterior superior iliac spine. As a measure of obesity, three indexes were used. Body mass index (the weight in kilograms divided by the square of the height in meters) and waist–hip ratio were calculated and the body fat of the subjects was measured by the bio-impedance method using a Body Fat Analyzer (TBF-202, TANITA Co., Japan). Each subject completed a self-administered questionnaire in advance, which was checked by trained nurses. Smoking history was estimated from the number of cigarettes smoked per day, multiplied by the number of years smoked; 4.3% of the subjects were current smokers and 2.2% of the subjects were former smokers. Social class was defined from the subjects' occupations as follows: (i) managerial position, (ii) office worker, (iii) primary industry, (iv) factory worker, and (v) homemaker or unemployed.

The differences between the mean values were evaluated using Student's *t*-test and the differences in the percentages were evaluated using the chi-squared test. Logistic regression analyses were used to determine the effect of each variable on the highest quintile of each periodontal parameter (≥ 1.9 mm for mean probing depth; ≥ 2.42 mm for mean attachment loss), and the odds ratio (OR) and 95% confidence interval (CI) were calculated. In bivariate analyses, one of the obesity indexes and the oral glucose tolerance test result were analyzed as independent variables. In the multivariate analysis, age, plaque index, smoking history, and social class were added as independent variables, as known risk factors of periodontal disease (9, 10). SPSS version 11.0 (SPSS Japan Inc., Tokyo, Japan) was used for the analyses. The design of the study and procedures for obtaining informed consent were approved by the Ethics Committee of Kyushu University Faculty of Dental Science and the Department of Health and Welfare of Hisayama town.

Results

The characteristics of the subjects were compared between subjects with the highest quintile of each periodontal parameter (≥ 1.9 mm for mean probing depth; ≥ 2.42 mm for mean attachment loss) and subjects with the four lower quintiles (Table 1). The mean body mass index, body fat, waist–hip ratio, and fasting and 2-h plasma glucose, and the proportion of social class categories differed significantly between subjects with deep and shallow pockets. In comparing the subjects with severe and non-severe attachment loss, the mean fasting and 2-h plasma glucose, hemoglobin A1C, and the proportion of social class categories differed significantly (Table 1). There were fewer teeth and the plaque index was higher in the more aggravated periodontal conditions.

Figure 1 shows the proportion of subjects with each quintile of mean probing pocket depth, according to the quartiles of body mass index, body fat, and waist–hip ratio. The proportion of subjects with the highest quintile of mean probing pocket depth increased significantly in a linear fashion with the quartiles of body mass index ($p < 0.0001$), body fat ($p = 0.0003$), and waist–hip ratio ($p = 0.007$). Figure 2

Table 1. Characteristics of subjects in each periodontal condition in Japanese women

Characteristics	Mean PD < 1.9 mm $n = 469$	Mean PD ≥ 1.9 mm $n = 114$	p*	Mean AL < 2.42 mm $n = 467$	Mean AL ≥ 2.42 mm $n = 116$	p*
	Mean (SD)			Mean (SD)		
Age (years)	55.5 (8.9)	56.8 (8.3)	0.14	54.8 (8.6)	59.4 (8.3)	< 0.0001
Number of teeth	25.4 (3.6)	23.5 (4.3)	< 0.0001	25.5 (3.6)	22.8 (4.0)	< 0.0001
Mean PD (mm)	1.4 (0.3)	2.3 (0.4)	< 0.0001	1.4 (0.4)	2.1 (0.5)	< 0.0001
Mean AL (mm)	1.7 (0.5)	2.7 (0.6)	< 0.0001	1.6 (0.5)	2.9 (0.5)	< 0.0001
Plaque index	0.9 (0.5)	1.4 (0.6)	< 0.0001	0.9 (0.5)	1.3 (0.6)	< 0.0001
Body mass index (kg/m^2)	22.9 (3.5)	24.1 (2.9)	0.0004	23.0 (3.5)	23.6 (3.1)	0.09
Body fat (%)	28.0 (6.1)	30.4 (5.7)	0.0002	28.3 (6.1)	29.1 (6.1)	0.26
Waist–hip ratio	0.93 (0.06)	0.94 (0.05)	0.027	0.93 (0.06)	0.94 (0.06)	0.057
Fasting blood glucose (mg/dl)	97 (13)	103 (19)	0.0002	97 (13)	102 (19)	0.003
2-h blood glucose (mg/dl)	122 (42)	132 (52)	0.033	120 (40)	138 (57)	0.0001
Hemoglobin A1C (%)	5.2 (0.4)	5.3 (0.6)	0.053	5.2 (0.4)	5.3 (0.6)	0.005
	Number of subjects			Number of subjects		
Smoking (packyear)						
0	440	105	0.82	436	109	0.95
1–19	17	6		19	4	
20–39	11	3		11	3	
≥ 40	1	0		1	0	
Social class						
Managerial position	20	5	0.002	21	4	0.02
Office worker	101	19		103	17	
Primary industry	23	18		26	15	
Factory worker	9	3		8	4	
Homemaker or unemployed	316	69		309	76	

*Student's t-tests for mean values and chi-squared tests for the number of subjects were performed. $n = 583$.
PD, probing pocket depth; AL, attachment loss.

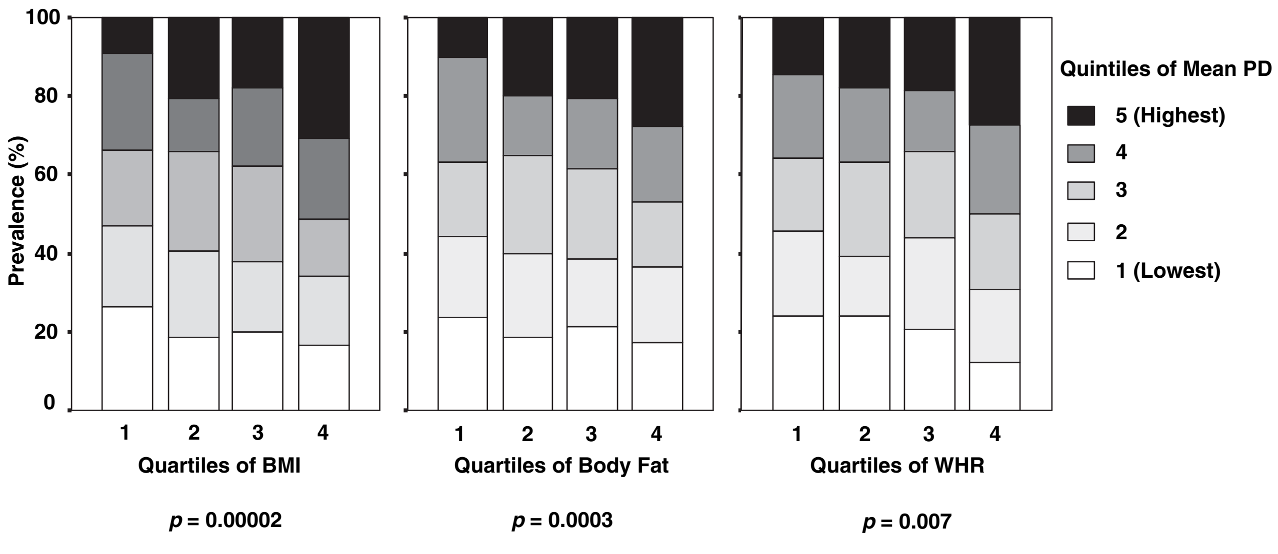

Fig. 1. Proportion of subjects with each quintile of mean probing pocket depth according to quartiles of each obesity index in Japanese women. Mantel–Haenszel chi-squared tests were performed in comparison between the highest quintile of mean probing pocket depth and the combination of lower 4 quintiles. PD, probing pocket depth; BMI, body mass index; WHR, waist–hip ratio.

shows the proportion of subjects with each quintile of mean attachment loss according to each quartile of the three obesity indexes. It is similar to Fig. 1; the highest quintile of mean attachment loss increased significantly with the quartiles of body mass index (p = 0.02), whereas it did not reach statistical significance when compared with the quartiles of body fat and waist–hip ratio (Fig. 2). There was a close association between every obesity

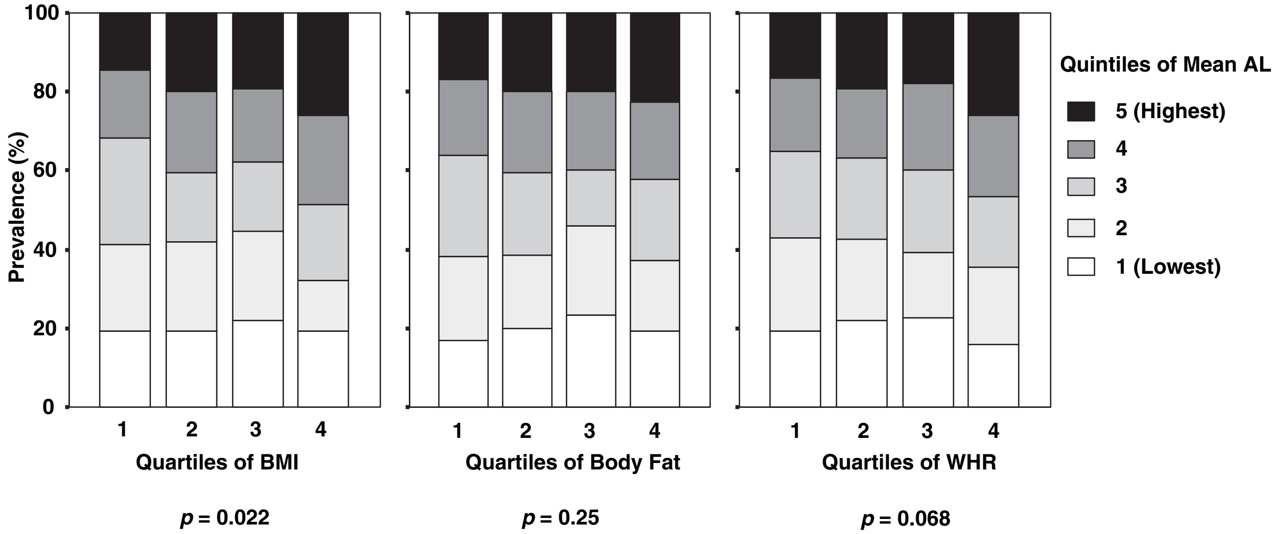

Fig. 2. Proportion of subjects with each quintile of mean attachment loss according to quartiles of each obesity index in Japanese women. Mantel–Haenszel chi-squared tests were performed in comparison between the highest quintile of mean attachment loss and the combination of lower 4 quintiles. AL, attachment loss; BMI, body mass index; WHR, waist–hip ratio.

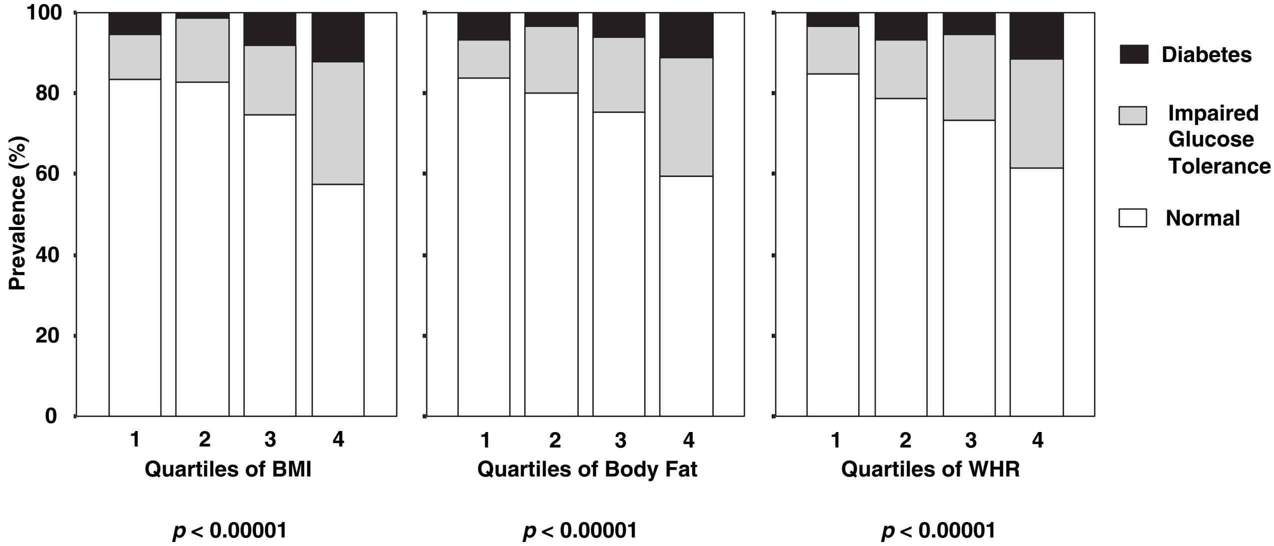

Fig. 3. Proportion of subjects with normal glucose tolerance, impaired glucose tolerance and diabetes according to quartiles of each obesity index in Japanese women. Mantel–Haenszel chi-squared tests were performed in comparison between normal glucose tolerance and the combination of impaired glucose tolerance and diabetes. BMI, body mass index; WHR, waist–hip ratio.

index and the prevalence of impaired glucose tolerance and diabetes; this was to be expected, as this association is well known (Fig. 3, $p < 0.0001$). Figure 4 shows the proportion of subjects with each quintile of the mean probing pocket depth and with each quintile of the mean attachment loss, in the subjects at each glucose tolerance status. The poorer the glucose tolerance status, the greater was the proportion of subjects with the highest quintile of mean probing pocket depth ($p = 0.008$) and mean attachment loss ($p < 0.001$) (Fig. 4). Both obesity and the oral glucose tolerance test results were significantly associated with periodontal disease in these simple comparisons.

To compare the effect of obese condition and glucose tolerance condition on periodontal disease, both variables were subject to a logistic regression analysis as independent variables, simultaneously (Tables 2A–C and Tables 3A–C). A higher body mass index was significantly associated with deep pockets, adjusted for the oral glucose tolerance test results and the other risk factors of periodontal disease (Table 2A). In the multivariate analysis, subjects with the highest quartile of body mass index had a significantly

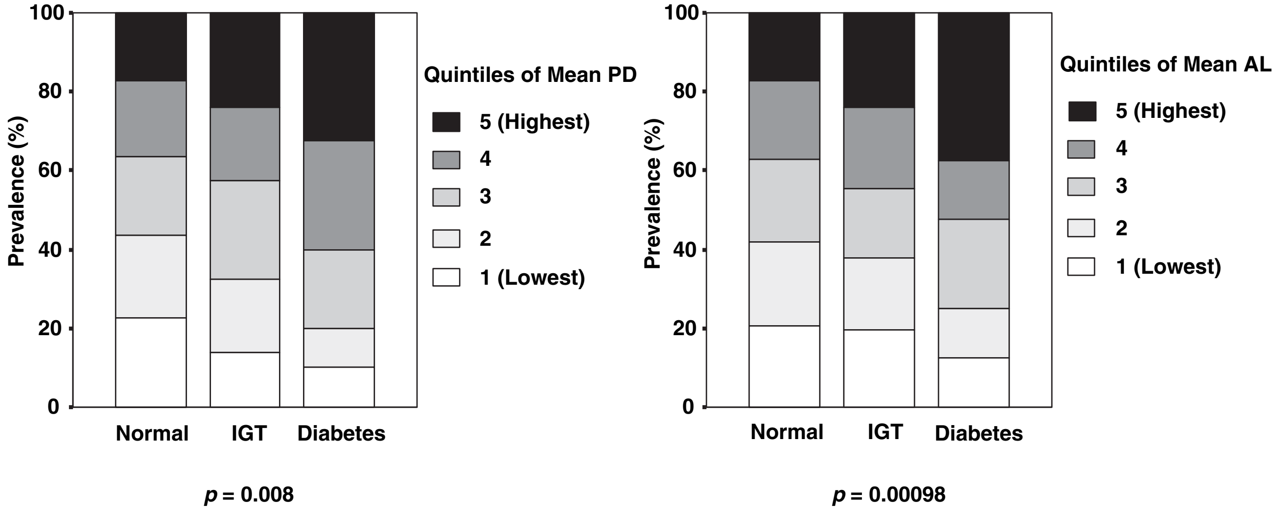

Fig. 4. Proportion of subjects with each quintile of mean probing pocket depth and with each quintile of mean attachment loss according to results of oral glucose tolerance test in Japanese women. Mantel–Haenszel chi-squared tests were performed in comparison between the highest quintile of each periodontal parameter and the combination of lower 4 quintiles. PD, probing pocket depth; AL, attachment loss; IGT, impaired glucose tolerance.

higher OR for the highest quintile of mean probing pocket depth (OR, 4.3; 95% CI, 2.1–8.9; $p < 0.001$), whereas neither impaired glucose tolerance nor diabetes were significant. In all the univariate, bivariate, and multivariate logistic regression models (Tables 2A–C), higher body mass index and body fat (highest for waist–hip ratio) were significantly associated with the highest quintile of mean probing pocket depth, even when adjusted for the oral glucose tolerance test results. The relationship between the oral glucose tolerance test results and mean probing pocket depth did not reach statistical significance when adjusted for every obesity index. Similar analyses were completed using the mean attachment loss as a dependent variable in Tables 3A–C. The results were similar to those in Tables 2A–C, although the OR of each obesity index was smaller, and was not significant, except for the crude analysis of body mass index. In the bivariate models, diabetes was significantly associated with severe attachment loss, whereas the obesity indexes were not. This differed from the results of the analysis using the mean probing pocket depth in Tables 2A–C.

Table 2A. Odds ratio for the highest quintile of mean probing pocket depth according to each quartile of body mass index and results of oral glucose tolerance test in Japanese women

	Mean PD (mm)		Odds ratio (95% CI)		
Variable	< 1.9	≥ 1.9	Univariate	Bivariate	Multivariate
BMI quartiles (kg/m^2)					
1 (15.5–20.8)	132	13	1	1	1
2 (20.8–22.7)	116	30	2.6 (1.3–5.3)†	2.7 (1.3–5.4)†	3.0 (1.4–6.3)†
3 (22.7–24.9)	120	26	2.2 (1.1–4.5)*	2.1 (1.0–4.3)*	2.3 (1.1–5.0)*
4 (25.0–46.7)	101	45	4.5 (2.3–8.8)‡	4.2 (2.1–8.2)‡	4.3 (2.1–8.9)‡
OGTT					
Normal	360	75	1	1	1
IGT	82	26	1.5 (0.9–2.5)	1.2 (0.7–2.1)	0.9 (0.5–1.7)
Diabetes	27	13	2.3 (1.1–4.7)*	2.0 (1.0–4.2)	1.4 (0.6–3.2)

Bivariate included BMI and OGTT as independent variables.
Multivariate included BMI, OGTT, age, plaque index, smoking history, and occupation as independent variables. *$p < 0.05$, †$p < 0.01$, ‡$p < 0.001$.
PD, probing pocket depth; CI, confidence interval; BMI, body mass index, OGTT, oral glucose tolerance test; IGT, impaired glucose tolerance.

Discussion

The relationship between obesity and deep pockets was observed after adjusting for the glucose tolerance status determined using the oral glucose tolerance test, which is used for the definitive diagnosis of diabetes (13). These results suggest that obesity is associated with deep pockets, independently of the glucose tolerance status, whereas obesity and glucose tolerance status are closely associated (Fig. 3). This suggests that the mechanism linking obesity and periodontal tissue differs from the reported mechanism operative in the effects of diabetes on the periodontium (10–12). Recent studies indicate that adipose tissue is an important organ that secretes several bioactive substances known as adipocytokines, which include tumor necrosis factor-α (19). These appear to be directly related to periodontal disease, as we discussed in a previous study (6). Although diabetes was significantly associated with both deep pockets and severe attachment loss in the crude analyses, the significant relationship between diabetes and deep pockets disappeared after adjusting for the obesity

Table 2B. Odds ratio for the highest quintile of mean probing pocket depth of each quartile of body fat and results of oral glucose tolerance test in Japanese women

Variable	Mean PD (mm) < 1.9	≥ 1.9	Odds ratio (95% CI) Univariate	Bivariate	Multivariate
Body fat quartiles (%)					
1 (7.9–24.1)	132	15	1	1	1
2 (24.2–27.9)	116	29	2.2 (1.1–4.3)*	2.2 (1.1–4.4)*	2.6 (1.2–5.3)*
3 (28.0–32.5)	116	30	2.3 (1.2–4.4)*	2.2 (1.1–4.4)*	2.8 (1.3–5.7)†
4 (32.6–52.5)	105	40	3.4 (1.8–6.4)‡	3.1 (1.6–6.0)‡	3.3 (1.6–6.8)†
OGTT					
Normal	360	75	1	1	1
IGT	82	26	1.5 (0.9–2.5)	1.3 (0.8–2.2)	1.0 (0.5–1.8)
Diabetes	27	13	2.3 (1.1–4.7)*	2.1 (1.0–4.4)	1.5 (0.7–3.5)

Bivariate included body fat and OGTT as independent variables.
Multivariate included Body Fat, OGTT, age, plaque index, smoking history, and occupation as independent variables. *$p < 0.05$, †$p < 0.01$, ‡$p < 0.001$.
PD, probing pocket depth; CI, confidence interval; OGTT, oral glucose tolerance test; IGT, impaired glucose tolerance.

Table 2C. Odds ratio for the highest quintile of mean probing pocket depth of each quartile of waist–hip ratio and results of oral glucose tolerance test in Japanese women

Variable	Mean PD (mm) < 1.9	≥ 1.9	Odds ratio (95% CI) Univariate	Bivariate	Multivariate
WHR quartiles					
1 (0.75–0.89)	124	21	1	1	1
2 (0.89–0.94)	120	26	1.3 (0.7–2.4)	1.2 (0.7–2.3)	1.4 (0.7–2.8)
3 (0.94–0.97)	119	27	1.3 (0.7–2.5)	1.3 (0.7–2.4)	1.2 (0.6–2.4)
4 (0.97–1.12)	106	40	2.2 (1.2–4.0)†	2.0 (1.1–3.6)*	2.1 (1.1–4.1)*
OGTT					
Normal	360	75	1	1	1
IGT	82	26	1.5 (0.9–2.5)	1.4 (0.8–2.3)	1.1 (0.6–1.9)
Diabetes	27	13	2.3 (1.1–4.7)*	2.0 (1.0–4.2)	1.5 (0.7–3.4)

Bivariate included WHR and OGTT as independent variables.
Multivariate included WHR, OGTT, age, plaque index, smoking history, and occupation as independent variables. *$p < 0.05$, †$p < 0.01$.
PD, probing pocket depth; CI, confidence interval; WHR, waist–hip ratio; OGTT, oral glucose tolerance test; IGT, impaired glucose tolerance.

Table 3A. Odds ratio for the highest quintile of mean attachment loss of each quartile of body mass index and results of oral glucose tolerance test in Japanese women

Variable	Mean AL (mm) < 2.42	≥ 2.42	Odds ratio (95% CI) Univariate	Bivariate	Multivariate
BMI quartiles (kg/m^2)					
1 (15.5–20.8)	124	21	1	1	1
2 (20.8–22.7)	117	29	1.5 (0.8–2.7)	1.5 (0.8–2.8)	1.6 (0.8–3.1)
3 (22.7–24.9)	118	28	1.4 (0.8–2.6)	1.3 (0.7–2.5)	1.3 (0.7–2.6)
4 (25.0–46.7)	108	38	2.1 (1,1–3.8)*	1.8 (1.0–3.3)	1.8 (0.9–3.4)
OGTT					
Normal	360	75	1	1	1
IGT	82	26	1.5 (0.9–2.5)	1.4 (0.8–2.3)	1.1 (0.6–1.9)
Diabetes	25	15	2.9 (1.4–5.7)*	2.7 (1.3–5.5)†	1.5 (0.7–3.2)

Bivariate included BMI and OGTT as independent variables.
Multivariate included BMI, OGTT, age, plaque index, smoking history, and occupation as independent variables. *$p < 0.05$, †$p < 0.01$.
AL, attachment loss; CI, confidence interval; BMI, body mass index; OGTT, oral glucose tolerance test; IGT, impaired glucose tolerance.

indexes (Tables 2A–C). Nevertheless, the significant relationship between diabetes and severe attachment loss remained after adjusting for the obesity indexes in the bivariate models (Tables 3A–C). In the multivariate models, the increased ORs between diabetes and both periodontal parameters did not reach statistical significance, which may be due simply to the small number of subjects, since there were only 40 diabetic subjects in this study. The oral glucose tolerance test results show the subjects' metabolic control status on that day, whereas the duration of their diabetic condition is important when studying the effects of diabetes on complications (12). Given this and the low number of subjects, this study cannot clarify the association between diabetes and periodontal disease. By contrast, impaired glucose tolerance seemed to have no association with either deep pockets or severe attachment loss in any multivariate model, despite the greater number of subjects ($n = 108$), as compared with diabetes ($n = 40$). Impaired glucose tolerance, which is an intermediate glucose condition between diabetes and normal glucose tolerance, may not have any effect on periodontal disease. This concurs with our recent report, in which deep pockets were more closely associated with the development of glucose intolerance from a normal glucose condition than with the past glucose tolerance condition itself, suggesting that deep pockets are a cause of impaired glucose tolerance (16).

In the analyses using attachment loss as a dependent variable, even the highest quartile of obesity indexes had no significant association with severe attachment loss, although the tendency was similar to the analyses using pocket depth. Although both pocket depth and attachment loss are important parameters of periodontal disease, they have slightly different meanings. A deep pocket usually means existing periodontal inflammation, whereas severe attachment loss usually represents a history of periodontal destruction, which does not always mean periodontal inflammation. Of course, the mean pocket depth and mean attachment loss are closely related ($r = 0.79$,

Table 3B. Odds ratio for the highest quintile of mean attachment loss of each quartile of body fat and results of oral glucose tolerance test in Japanese women

	Mean AL (mm)		Odds ratio (95% CI)		
Variable	< 2.42	≥ 2.42	Univariate	Bivariate	Multivariate
Body fat quartiles (%)					
1 (7.9–24.1)	122	25	1	1	1
2 (24.2–27.9)	116	29	1.2 (0.7–2.2)	1.2 (0.7–2.3)	1.3 (0.7–2.5)
3(28.0–32.5)	117	29	1.2 (0.7–2.2)	1.2 (0.6–2.1)	1.3 (0.7–2.5)
4 (32.6–52.5)	112	33	1.4 (0.8–2.6)	1.3 (0.7–2.3)	1.2 (0.6–2.3)
OGTT					
Normal	360	75	1	1	1
IGT	82	26	1.5 (0.9–2.5)	1.5 (0.9–2.5)	1.1 (0.6–2.0)
Diabetes	25	15	2.9 (1.4–5.7)*	2.8 (1.4–5.7)†	1.6 (0.7–3.4)

Bivariate included body fat and OGTT as independent variables.
Multivariate included body fat, OGTT, age, plaque index, smoking history, and occupation as independent variables. *$p < 0.05$, †$p < 0.01$.
AL, attachment loss; CI, confidence interval; OGTT, oral glucose tolerance test; IGT, impaired glucose tolerance.

Table 3C. Odds ratio for the highest quintile of mean attachment loss of each quartile of waist–hip ratio and results of oral glucose tolerance test in Japanese women

	Mean AL (mm)		Odds ratio (95% CI)		
Variable	< 2.42	≥ 2.42	Univariate	Bivariate	Multivariate
WHR quartiles					
1 (0.75–0.89)	121	24	1	1	1
2 (0.89–0.94)	118	28	1.2 (0.7–2.2)	1.1 (0.6–2.1)	1.2 (0.6–2.4)
3 (0.94–0.97)	120	26	1.1 (0.6–2.0)	1.0 (0.6–1.9)	1.0 (0.5–1.9)
4 (0.97–1.12)	108	38	1.8 (1.0–3.1)	1.5 (0.9–2.8)	1.3 (0.7–2.5)
OGTT					
Normal	360	75	1	1	1
IGT	82	26	1.5 (0.9–2.5)	1.4 (0.9–2.4)	1.1 (0.6–2.0)
Diabetes	25	15	2.9 (1.4–5.7)*	2.6 (1.3–5.3)†	1.5 (0.7–3.2)

Bivariate included WHR and OGTT as independent variables.
Multivariate included WHR, OGTT, age, plaque index, smoking history, and occupation as independent variables. *$p < 0.05$, †$p < 0.01$.
AL, attachment loss; CI, confidence interval; WHR, waist–hip ratio; OGTT, oral glucose tolerance test; IGT, impaired glucose tolerance.

$p < 0.0001$). Therefore, the tendencies in Tables 2A-C and 3A-C were similar and, given sufficient subjects, the relationship might reach statistical significance. Nevertheless, the weak or non-significant association between obesity and attachment loss found in this study suggests that the relationship between obesity and periodontal disease is limited to a relationship between obesity and the primary stage of periodontal disease. Since periodontal destruction, such as alveolar bone loss, is a result of inflammation, with the mechanism of the destruction arising as a consequence of inflammation (10), obesity may be related to the primary stage of periodontal disease and may not be related to the subsequent stage of periodontal destruction.

The NHANES III study found a relationship between obesity and periodontal disease in young adults only, using a combination of deep pockets and attachment loss as criteria of periodontal disease (7). As elderly people lose their teeth as a result of periodontal disease, the relationship between obesity and periodontal disease in the elderly could disappear. Since we limited the subjects of our study to those with ≥ 10 teeth, a relationship between obesity and deep pockets should be more easily detected in our study, as compared to the NHANES III study, which included subjects with fewer than 10 teeth. Although we could not analyze each age group separately, due to the small number of subjects, a relationship between obesity and deep pockets might be detected in the elderly if the subjects were to be limited to those with many teeth. Tobacco smoking is a well-documented risk factor for periodontal disease (9, 10). In this study, however, smoking history was not associated with either deep pockets or severe attachment loss, probably because there was a very low proportion of smokers among our female subjects. The prevalence of obesity is very low among Japanese as compared to the US population, whereas the prevalence of diabetes is about the same (1, 3, 12). As the effect of obesity on health is thought to differ among races, Japanese women may show different relationships between obesity, diabetes, and periodontal disease compared to other races. Since our study and other reports on the relationship between obesity and periodontal disease were cross-sectional studies, a prospective cohort study with different age groups and sexes is required.

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