Periodontal status and self-reported systemic health of periodontal patients regularly visiting dental clinics in the 8020 Promotion Foundation Study of Japanese Dental Patients

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Abstract: This nationwide cross-sectional survey investigated the association between periodontal disease and self-reported systemic health in periodontal patients who regularly visited private dental clinics in Japan. Data from 999 patients of 444 dental clinics were analyzed; the patients were aged 40 years or older, regularly visited dentists, and had diagnosed periodontal disease (defined as two or more teeth with a clinical attachment level ≥6 mm). Medical history was collected with a self-reported questionnaire. Number of teeth with a probing pocket depth (PPD) ≥5 mm was used to define periodontal status, and the highest quartile was used as the dependent variable. A Poisson regression model showed that histories of diabetes and hypertension were associated with a larger number of teeth with a PPD ≥5 mm (diabetes: prevalence rate ratio [PRR] 1.36, 95% confidence interval [CI] 1.00-1.85; hypertension: PRR 1.27, 95% CI 1.02-1.58) after adjusting for potential periodontal risk factors. These findings suggest that diabetes and hypertension are associated with worse periodontal disease. Dentists should confirm the diabetes and hypertension status of patients who receive maintenance care, because these conditions could affect periodontal management of patients.

Keywords: periodontal disease; diabetes; hypertension; obesity.

Introduction
Recurrence of periodontal disease cannot always be prevented, even in patients who receive regular maintenance, including oral hygiene instruction and subgingival debridement. The objective of regular dental visits for maintenance care is to prevent progression and recurrence of periodontal disease (1). In a study of patients with destructive periodontal disease, periodic dental visits...
for maintenance care after periodontal therapy helped maintain good oral hygiene, shallow periodontal pockets, and unaltered attachment levels (2). However, one study (3) reported that 25% of patients who received regular maintenance care developed additional attachment loss. Another study (4) noted that, in 20% of patients who were highly susceptible to periodontal disease and received regular maintenance care, periodontal disease continued to progress even after nonsurgical periodontal therapy. Thus, some patients who visit a dentist for regular maintenance care will continue to have periodontal problems.

Systemic conditions such as diabetes (5), obesity (6), and hypertension (7) are associated with periodontal disease and are thus hypothesized to contribute to poor control of periodontal disease during regular maintenance care. The effects of diabetes have been extensively investigated, and several studies have identified it as a risk factor for poor periodontal status during maintenance care (8-10). However, few studies have examined the effects of other systemic health conditions on periodontal disease in patients who receive maintenance care. Additionally, almost all studies of regular maintenance care were conducted in one or a small number of dental (4,9,11) or university clinics (8,12). No large-scale study has analyzed the association between systemic health and periodontal disease in patients receiving maintenance care.

In dental practice settings, self-reported data are useful for evaluating patients’ systemic condition, because data collection is straightforward, inexpensive, and noninvasive. Self-reporting of diabetes and hypertension is based on self-reported height and weight is highly correlated, although patient heights are generally overestimated and weights are underestimated (15). Measurement of weight and height in a dental setting is logistically difficult and inconvenient for dentists and patients. Therefore, calculation of body mass index (BMI) based on self-reported height and weight is useful in such a setting. To date, few studies have investigated the association between self-reported systemic health and periodontal status. This nationwide survey of patients in private dental clinics therefore evaluated this association among patients with diagnosed periodontal disease who regularly visited dentists.

Materials and Methods

Study population

The nationwide cross-sectional survey of dental patients in Japanese private dental clinics was conducted prospectively in 2014 and 2015 by the 8020 Promotion Foundation (The 8020 Promotion Foundation study of Japanese dental patients). The 8020 Promotion Foundation requested Prefecture Dental Associations (local branches of the Japanese Dental Association) to select 30 dental clinics in each Japanese prefecture. All 47 prefectures were represented: 1,354 dental clinics from 46 prefectures in 2014 and 30 dental clinics from one prefecture in 2015 were selected in a convenience sample and invited to participate in this survey. Among the 1,384 dental clinics, 1,237 clinics agreed to participate in this survey. Dental clinics recruited all new and current patients who had been followed up for longer than 2 months after their last visit, were aged 20 years or older, and had visited during the predetermined study period of 1 week. A total of 49,909 patients visited clinics during the study period (mean ± SD, 45.1 ± 70.7 patients per dental clinic), and 1,106 dental clinics responded to the questionnaire for dental clinics. Among the 1,237 dental clinics, 12,496 patients (10.1 ± 6.6 patients per dental clinic) agreed to participate in this survey.

Dental patients were enrolled by using the following inclusion criteria: (i) age 40 years and older; (ii) regular visits to dental clinics for check-up; (iii) no untreated dental caries (because this study comprised participants visiting dental clinics to prevent progression of periodontal disease); (iv) history of periodontal disease (defined as two or more teeth with a clinical attachment level [CAL] ≥6 mm (16); and (v) presence of ≥10 teeth (when periodontal condition is defined by number of teeth with a deep probing pocket depth [PPD], this definition depends greatly on the number of present teeth, and therefore patients with more teeth present were included). A total of 1,127 patients fulfilled all inclusion criteria. After excluding 128 participants with missing data, data from 999 participants (434 men and 565 women) from 444 dental clinics were included in the final analysis. The mean age of participants was 64.6 ± 10.0 years.

Ethical considerations

Informed consent was obtained from all study participants. The Ethics Committee of the Japanese Association for Dental Science, Tokyo, Japan, approved the study design, data collection methods, and the procedure for obtaining informed consent (ethical approval number 002).

Oral examination

Periodontal condition was assessed by using PPD and CAL. Periodontal disease cannot be accurately catego-
rized by using a single parameter (17). Although CAL is an accurate measure of periodontal destruction during the course of a person’s life, assessment of disease status requires measurement of PPD (17), as it is useful for assessing the risk of further damage in the immediate future (18). PPD and CAL were measured in individual teeth, and maximum values were recorded. This study used PPD and CAL values for all teeth except third molars, which frequently have pseudo-pockets when partially impacted. This study evaluated the number of teeth with a PPD ≥5 mm as periodontal disease in participants with two or more teeth with CAL ≥6 mm. This accorded with a previous definition of established periodontal disease (16), i.e., presence of CAL ≥6 mm in two or more teeth and one or more sites with a PPD ≥5 mm.

**Questionnaire**

Data on weight, height, history of diabetes, hypertension, hyperlipidemia, cerebrovascular disease, cardiovascular disease, and cancer, smoking status, tooth brushing frequency, interdental brush use, and education level were obtained from a self-reported questionnaire completed by the participants. Weight and height information were used to calculate BMI, and overweight was defined as a BMI of ≥25.0. Disease status was assessed by the question: “Are you currently being treated for diabetes, hypertension, dyslipidemia, cerebrovascular disease, cardiovascular disease, or cancer?”. Last dental visit was assessed by the question, “When was the last time that you visited a dentist?”, and was categorized as less than or more than 3 months ago. Smoking status was categorized as never smoker, past smoker, and current smoker. Frequency of tooth brushing was categorized as three times per day or more, twice per day, and once per day or less. Use of floss and interdental brushes was categorized as present and absent. Education level was classified as ≤12, 13-15, and ≥16 years of schooling.

**Statistical analysis**

Number of teeth with a PPD ≥5 mm was categorized by quartile (0, 1-2, 3-4, ≥5 teeth). In multivariate analysis, quartiles of teeth with a PPD ≥5 mm were divided into two groups: highest quartile vs the three lower quartiles. As logistic regression might have underestimated prevalence ratios, a Poisson regression model with robust standard errors was used because of the binary outcome and high prevalence (19). The multivariate association between the highest quartile of teeth with a PPD ≥5 mm (the dependent variable) and disease status (the independent variable) was examined, and prevalence rate ratios (PRRs) and 95% confidence intervals (CIs) were evaluated. The Poisson regression models included overweight, last dental visit, smoking, tooth brushing frequency, interdental brush and floss use, age, sex, number of present teeth, and education level as potential confounders. Evaluated diseases with a significance level for retention of $P < 0.1$ in bivariate models were included in multivariate models. Because overweight was closely associated with diabetes and hypertension, two models were investigated: (1) a model including diabetes and hypertension status and (2) a model including diabetes and hypertension status and overweight. SPSS for Windows software (ver. 19.0; IBM SPSS, Tokyo, Japan) was used for the data analyses, and a two-tailed $P$ value of <0.05 was considered to indicate statistical significance.

**Results**

The percentage of patients with at least one tooth with a PPD ≥5 mm was 79.6%. Table 1 shows the health characteristics of the patients. The mean age of patients was 64.6 ± 10.0 years, 56.6% were women, and 186 (18.3%) were overweight (BMI ≥25.0 kg/m²). The mean number of teeth present was 23.9 ± 4.8.

Poisson regression models showed that diabetes and hypertension status had a significance level for retention of $P < 0.1$ in the crude model. Model 1 indicated that the highest quartile of teeth with a PPD ≥5 mm was positively associated with diabetes (PRR 1.36, 95% CI 1.00-1.84) and hypertension (PRR 1.27, 95% CI 1.02-1.57) (Table 2). This model was adjusted for last dental visit, smoking status, frequency of tooth brushing, interdental brush and floss use, age, sex, number of present teeth, and education level. Model 2, which included overweight, showed a significant association of the highest quartile with diabetes (PRR 1.36, 95% CI 1.00-1.85) and hypertension (PRR 1.27, 95% CI 1.02-1.58) (Table 2).

In a sensitivity analysis the participants were stratified by sex (Table 3). In men but not women, diabetes was significantly associated with the highest quartile of teeth with a PPD ≥5 mm. Hypertension tended to be associated with the highest quartile in men and women, but the association was not significant. Additionally, a sensitivity analysis was performed to assess the effect of using different quartiles of teeth with a PPD ≥5 mm (Table 4). When patients were divided into two groups—third/highest quartile vs lowest/second quartile—diabetes and hypertension were still associated with number of teeth with a PPD ≥5 mm, although the association with hypertension was not significant in the model including overweight. When number of teeth with a PPD ≥5 mm was dichotomized as second/third/highest quartile vs lowest quartile, diabetes and hypertension
were not associated with number of teeth with PPD ≥5 mm. However, number of teeth with PPD ≥5 mm was associated with overweight.

**Discussion**

The primary finding of this study is that, after adjustment for covariates, diabetes and hypertension were associated with worse periodontal disease (defined as the highest quartile of teeth with a PPD ≥5 mm) in patients with periodontal disease (defined as two or more teeth with CAL ≥6 mm) who regularly visited private dental clinics. This result is consistent with those of previous studies, which reported an association between medical history of systemic disease and periodontal disease (20,21). However, the present study extends these previous findings by showing an association among patients who regularly visited dentists, as ascertained in a nationwide survey. Dental patients may present with various systemic

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**Table 1** Characteristics of participants, by quartile of number of teeth with a PPD ≥5 mm

| Number of teeth with a PPD ≥5 mm | 0 (quartile 1) (n = 204) | 1-2 (quartile 2) (n = 310) | 3-4 (quartile 3) (n = 201) | ≥5 (quartile 4) (n = 284) | Total |
|----------------------------------|--------------------------|---------------------------|---------------------------|--------------------------|-------|
| **Diabetes**                     |                          |                           |                           |                          |       |
| no                               | 190 (93.1)               | 294 (94.8)                | 182 (90.5)                | 253 (89.1)               | 919 (92.0) |
| yes                              | 14 (6.9)                 | 16 (5.2)                  | 19 (9.5)                  | 31 (10.9)                | 80 (8.0)  |
| **Cerebrovascular or cardiovascular disease** |                          |                           |                           |                          |       |
| no                               | 190 (93.1)               | 296 (95.5)                | 189 (94.0)                | 267 (94.0)               | 942 (94.3) |
| yes                              | 14 (6.9)                 | 14 (4.5)                  | 12 (6.0)                  | 17 (6.0)                 | 57 (5.7)  |
| **Cancer**                       |                          |                           |                           |                          |       |
| no                               | 197 (96.6)               | 300 (96.8)                | 198 (98.5)                | 275 (96.8)               | 970 (97.1) |
| yes                              | 7 (3.4)                  | 10 (3.2)                  | 3 (1.5)                   | 9 (3.2)                  | 29 (2.9)  |
| **Hypertension**                 |                          |                           |                           |                          |       |
| no                               | 149 (73.0)               | 225 (72.6)                | 138 (68.7)                | 187 (65.8)               | 699 (70.0) |
| yes                              | 55 (27.0)                | 85 (27.4)                 | 63 (31.3)                 | 97 (34.2)                | 300 (30.0) |
| **Dyslipidemia**                 |                          |                           |                           |                          |       |
| no                               | 174 (85.3)               | 271 (87.4)                | 172 (85.6)                | 255 (89.8)               | 872 (87.3) |
| yes                              | 30 (14.7)                | 39 (12.6)                 | 29 (14.4)                 | 29 (10.2)                | 127 (12.7) |
| **Overweight**                   |                          |                           |                           |                          |       |
| no                               | 178 (87.3)               | 256 (82.6)                | 155 (77.1)                | 224 (78.9)               | 813 (81.7) |
| yes (BMI ≥25.0 kg/m²)            | 26 (12.7)                | 54 (17.4)                 | 46 (22.9)                 | 60 (21.1)                | 186 (18.3) |
| **Last dental visit**            |                          |                           |                           |                          |       |
| <3 months previously             | 111 (54.4)               | 185 (59.7)                | 107 (53.2)                | 152 (53.5)               | 555 (55.6) |
| ≥3 months previously             | 93 (45.6)                | 125 (40.3)                | 94 (46.8)                 | 132 (46.5)               | 444 (44.4) |
| **Smoking**                      |                          |                           |                           |                          |       |
| never                            | 136 (66.7)               | 204 (65.8)                | 117 (58.2)                | 153 (53.9)               | 610 (61.1) |
| past                             | 52 (25.5)                | 82 (26.5)                 | 62 (30.8)                 | 92 (32.4)                | 288 (28.8) |
| current                          | 16 (7.8)                 | 24 (7.7)                  | 22 (10.9)                 | 39 (13.7)                | 101 (10.1) |
| **Tooth brushing frequency (per day)** |                          |                           |                           |                          |       |
| ≥3 times                         | 76 (37.3)                | 108 (34.8)                | 72 (35.8)                 | 89 (31.3)                | 345 (34.5) |
| 2 times                          | 107 (52.5)               | 169 (54.5)                | 106 (52.7)                | 149 (52.5)               | 531 (53.2) |
| ≤1 time                          | 21 (10.3)                | 33 (10.6)                 | 23 (11.4)                 | 46 (16.2)                | 123 (12.3) |
| **Daily use of interdental brush and floss** |                          |                           |                           |                          |       |
| yes                              | 49 (24.0)                | 66 (21.3)                 | 33 (16.4)                 | 54 (19.0)                | 202 (20.2) |
| no                               | 155 (76.0)               | 244 (78.7)                | 168 (83.6)                | 230 (81.0)               | 797 (79.8) |
| **Age**                          | 64.3 ± 10.1              | 65.6 ± 9.6                | 64.8 ± 10.2               | 63.5 ± 10.2              | 64.6 ± 10.0 |
| **Sex**                          |                          |                           |                           |                          |       |
| men                              | 78 (38.2)                | 119 (38.4)                | 100 (49.8)                | 137 (48.2)               | 434 (43.4) |
| women                            | 126 (61.8)               | 191 (61.6)                | 101 (50.2)                | 147 (51.8)               | 565 (56.6) |
| **Number of present teeth**      | 23.4 ± 5.0               | 23.6 ± 4.6                | 24.0 ± 5.0                | 24.3 ± 4.8               | 23.9 ± 4.8 |
| ≥16 years                        | 37 (18.1)                | 65 (21.0)                 | 36 (17.9)                 | 64 (22.5)                | 202 (20.2) |
| 13-15 year                       | 55 (27.0)                | 81 (26.1)                 | 37 (18.4)                 | 64 (22.5)                | 237 (23.7) |
| ≤12 year                         | 112 (54.9)               | 164 (52.9)                | 128 (63.7)                | 156 (54.9)               | 560 (56.1) |

*n (%) according to quartile of number of teeth with a PPD ≥5 mm.

PPD: probing pocket depth; CAL: clinical attachment level; BMI: body mass index; SD: standard deviation.
diseases. Therefore, associations of systemic conditions with periodontal disease need to be identified in dental patients. The present results indicate that dentists should confirm diabetes and hypertension status in patients receiving maintenance care, as these diseases can affect periodontal management of patients.

Periodontal disease was associated with diabetes and hypertension status. The positive relation between diabetes and periodontal disease has long been recognized. Among dental patients, presence of pre-diabetes or diabetes was associated with an increased number of teeth with a PPD ≥5 mm (22). A 5-year follow-up study of dental patients receiving maintenance care reported that, as compared to patients with well-controlled diabetes and those without diabetes, patients with poorly controlled diabetes had greater periodontal disease progression, as defined by interproximal CAL of ≥3 mm in at least two teeth (10). Hypertension is also associated with periodontal disease. Engström et al. (23) studied blood pressure before a dental examination and the association between hypertension and periodontal disease in patients undergoing annual dental check-ups. A high diastolic blood pressure and a history of hypertension were associated with the number of teeth with a PPD ≥5 mm (23).

| Table 2 | Prevalence ratios (PRRs) and 95% CI for highest quartile of number of teeth with a PPD ≥5 mm |
|---------|-----------------------------------------------------------------------------------------------|
|          | Prevalence for highest quartile of number of teeth (≥5 teeth) with PPD ≥5 mm                  |
|          | Crude PRR (95% CI)                                                                             |
|          | Adjusted PRR (95% CI)                                                                          |
|          | Model 1*                                                                                       |
|          | Model 2*                                                                                       |
| Diabetes |                                                                                               |
| no       | 27.5%                                                                                         |
| yes      | 38.8%                                                                                         |
|          | 1                                                                                             |
|          | 1                                                                                             |
|          | 1                                                                                             |
| Hypertension |                                                                                       |
| no       | 26.8%                                                                                         |
| yes      | 32.3%                                                                                         |
|          | 1                                                                                             |
|          | 1                                                                                             |
|          | 1                                                                                             |
| Dyslipidemia |                                                                                               |
| no       | 29.2%                                                                                         |
| yes      | 22.8%                                                                                         |
|          | 1                                                                                             |
|          | 0.78 (0.56-1.09)                                                                               |
| Cerebrovascular or cardiovascular disease |                                                                                               |
| no       | 28.3%                                                                                         |
| yes      | 31.0%                                                                                         |
|          | 1                                                                                             |
|          | 1.10 (0.63-1.90)                                                                               |
| Cancer |                                                                                               |
| no       | 28.4%                                                                                         |
| yes      | 31.0%                                                                                         |
|          | 1                                                                                             |
|          | 1.05 (0.70-1.59)                                                                               |
| Overweight (BMI ≥25 kg/m²) |                                                                                               |
| no       | 27.6%                                                                                         |
| yes      | 32.3%                                                                                         |
|          | 1                                                                                             |
|          | 1.17 (0.92-1.48)                                                                               |
|          | 0.99 (0.77-1.26)                                                                               |
| Last dental visit |                                                                                               |
| <3 months previously | 27.4%                                                                                         |
| ≥3 months previously | 29.7%                                                                                         |
| Smoke |                                                                                               |
| never | 25.1%                                                                                         |
| past | 31.9%                                                                                         |
| current | 38.6%                                                                                         |
| ≥3 times | 25.8%                                                                                         |
| 2 times | 28.1%                                                                                         |
| ≤1 time | 37.4%                                                                                         |
| Daily use of interdental brush and floss |                                                                                               |
| yes | 26.7%                                                                                         |
| no | 28.9%                                                                                         |
|          | 1                                                                                             |
|          | 1                                                                                             |
|          | 0.78 (0.56-1.09)                                                                               |
| Poisson regression models with robust standard error; the highest quartile of number of teeth with a PPD ≥5 mm was the dependent variable. |
| The crude model included one independent variable and dependent variable. |
| Model 1 included diabetes and hypertension status, and Model 2 additionally included overweight. |
| *Adjusted for age, sex, number of present teeth, and education level. |
| PPD: probing pocket depth; PRR: prevalence rate ratio; CI: confidence interval; BMI: body mass index. |
measurement of blood pressure in dental settings might help maintain good periodontal status in patients who regularly receive maintenance care at dental clinics.

Several hypotheses have been proposed to explain the causal relationships of periodontal disease with diabetes and hypertension. Endothelial dysfunction, oxidative stress, and worsening of systemic inflammation might increase susceptibility to bacterial infection or inflammatory mediator dissemination in periodontal lesions (24,25). However, the biological mechanisms involved remain to be clarified. Diabetes is associated with hyperglycemia, production of advanced glycation end-products, increased adiposity, and systemic changes in cytokine levels. These conditions affect immune dysregulation and cause periodontal destruction (26). Hypertension, as well as periodontal disease, is associated with oxidative stress and proinflammatory cytokines (27). Furthermore, hypertension-induced endothelial dysfunction and the subsequent reduction in blood supply to periodontal tissues increase susceptibility to periodontal inflammation (28).

The present data showed no association between dyslipidemia and periodontal status, although a positive association between periodontal disease and serum lipid level was previously reported (29,30). Patients with dyslipidemia typically receive drug treatment, and the

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**Table 3** Prevalence rate ratios (PRRs) and 95% CI for highest quartile of number of teeth with a PPD ≥5 mm in men and women

|                 | Men       |         | Women     |         |
|-----------------|-----------|---------|-----------|---------|
|                 | Adjusted PRR* (95% CI) | Adjusted PRR* (95% CI) |
|                 | Model 1   | Model 2 | Model 1   | Model 2 |
| **Diabetes**    |           |         |           |         |
| no              | 1         | 1       | 1         | 1       |
| yes             | 1.44 (1.02-2.05) | 1.19 (0.64-2.21) | 1.19 (0.64-2.21) | 1.18 (0.63-2.21) |
| **Hypertension**|           |         |           |         |
| no              | 1         | 1       | 1         | 1       |
| yes             | 1.29 (0.97-1.72) | 1.32 (0.96-1.82) | 1.32 (0.96-1.82) | 1.31 (0.94-1.81) |
| **Overweight (BMI ≥25 kg/m²)** |           |         |           |         |
| no              | 1         | 1       | 1         | 1       |
| yes             | 0.96 (0.71-1.31) | 1.05 (0.70-1.57) |           |         |

Poisson regression models with robust standard error; the highest quartile of number of teeth (≥5 teeth) with a PPD ≥5 mm was the dependent variable.

Model 1 included diabetes and hypertension status, and Model 2 additionally included overweight.

*Adjusted for last dental visit, smoking, tooth brushing frequency, daily use of interdental brush and floss, age, number of present teeth, and education level.

PPD: probing pocket depth; PRR: prevalence rate ratio; CI: confidence interval; BMI: body mass index.

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**Table 4** Prevalence rate ratios (PRR) and 95% CI for second or third to highest quartile of number of teeth with a PPD ≥5 mm

|                 | Adjusted PRR* (95% CI) | Adjusted PRR* (95% CI) |
|-----------------|-------------------------|-------------------------|
|                 | Second to highest quartile of number | Third to highest quartile of number |
|                 | of teeth (≥1 teeth) with a PPD ≥5 mm | of teeth (≥3 teeth) with a PPD ≥5 mm |
|                 | Model 1   | Model 2 | Model 1   | Model 2 |
| **Diabetes**    |           |         |           |         |
| no              | 1         | 1       | 1         | 1       |
| yes             | 1.02 (0.92-1.14) | 1.01 (0.91-1.13) | 1.29 (1.06-1.55) | 1.27 (1.05-1.54) |
| **Hypertension**|           |         |           |         |
| no              | 1         | 1       | 1         | 1       |
| yes             | 1.03 (0.97-1.11) | 1.02 (0.95-1.09) | 1.16 (1.01-1.33) | 1.14 (0.99-1.31) |
| **Overweight (BMI ≥25 kg/m²)** |           |         |           |         |
| no              | 1         | 1       | 1         | 1       |
| yes             | 1.08 (1.00-1.16) | 1.09 (0.94-1.27) |           |         |

Poisson regression models with robust standard error; the second or third to highest quartile of number of teeth (≥1 tooth or ≥3 teeth) with a PPD ≥5 mm was the dependent variable.

Model 1 included diabetes and hypertension status, and Model 2 additionally included overweight.

*Adjusted for last dental visit, smoking, tooth brushing frequency, daily use of interdental brush and floss, age, sex, number of present teeth, and education level.

PPD: probing pocket depth; PRR: prevalence rate ratio; CI: confidence interval; BMI: body mass index.
resulting decrease in lipid levels likely explains the lack of an association in this study.

This study showed an association between history of diabetes and periodontal status in men but not in women. Syrjälä et al. (31) investigated the relationship between dental self-efficacy (an important factor in human behavior), oral health behavior, and oral hygiene in diabetes patients. As compared with men, women had a higher level of brushing self-efficacy, brushed their teeth more frequently, and had a lower visible plaque index (31). Presumably, women with diabetes had a high level of oral health behavior and thus prevented progression of periodontal disease during regular maintenance care. This may explain the absence of a clear association between history of diabetes and periodontal status among women in the present study.

A sensitivity analysis was performed to assess the effect of using different quartile groupings of teeth with a PPD ≥5 mm (Table 4). When number of teeth with a PPD ≥5 mm was dichotomized as second/third/highest quartile vs lowest quartile, diabetes and hypertension were not associated with number of teeth with a PPD ≥5 mm. However, an association with overweight was observed. Overweight and obesity are pre-disease conditions in diabetes development (32). The second and higher quartiles of teeth (≥1 tooth) with a PPD ≥5 mm likely included mild periodontal disease, which is associated with a pre-disease state rather than a disease state.

Among patients with periodontal disease, 79.6% had at least one tooth with a PPD ≥5 mm in this study. Matuliene et al. (8) examined presence of PPD ≥5 mm after periodontal therapy in periodontal disease patients with a mean duration of maintenance care of 11 years: 99.4% had a PPD ≥5 mm before periodontal therapy, and 74.0% and 80.8% of patients had a PPD ≥5 mm after periodontal therapy and maintenance care, respectively, in private dental clinics (8). Although the duration and interval of maintenance care was not determined in the present study, most patients with periodontal disease had persistent PPD, even during maintenance care.

A strength of this study is that it was a nationwide survey. However, several limitations need to be discussed. First, non-calibrated dentists assessed periodontal status, and the maintenance protocol differed among dental clinics. However, because of the lack of large-scale studies, the present data are interesting and useful to clinicians. Nevertheless, caution is advised when interpreting results obtained from non-calibrated clinicians and different clinical protocols. Second, the cross-sectional design of this study makes it difficult to infer causal relationships. The association between diabetes and periodontal disease is considered bidirectional (25). Longitudinal evidence is required in order to confirm a causal relationship between systemic health and periodontal disease. Third, self-reported diabetes and hypertension status may not accurately reflect or fully capture a patient’s present condition and thus could lead to underestimation of the prevalences of these diseases. This may have biased results toward underestimation of the association between systemic health and periodontal disease. Finally, a previous study reported the effects of compliance on periodontal conditions during maintenance care (9). Information on compliance should be collected in future studies.

In conclusion, diabetes and hypertension were associated with worse periodontal disease in periodontal patients who regularly visited private dental clinics.

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**Conflict of interest**

The authors declare that they have no conflict of interest.

**References**

1. Wilson TG Jr (1996) Supportive periodontal treatment introduction—definition, extent of need, therapeutic objectives, frequency and efficacy. Periodontol 2000 12, 11-15.
2. Axelsson P, Lindhe J (1981) The significance of maintenance care in the treatment of periodontal disease. J Clin Periodontol 8, 281-294.
3. Lindhe J, Nyman S (1984) Long-term maintenance of patients treated for advanced periodontal disease. J Clin Periodontol 11, 504-514.
4. Rosling B, Serino G, Hellstrom MK, Socransky SS, Lindhe J (2001) Longitudinal periodontal tissue alterations during supportive therapy. Findings from subjects with normal and high susceptibility to periodontal disease. J Clin Periodontol 28, 241-249.
5. Chavarry NG, Vettore MV, Sansone C, Sheiham A (2009) The relationship between diabetes mellitus and destructive periodontal disease: a meta-analysis. Oral Health Prev Dent 7, 107-127.
6. Nascimento GG, Leite FR, Do LG, Peres KG, Correa MB, Demarco FF et al. (2015) Is weight gain associated with the incidence of periodontitis? A systematic review and meta-analysis. J Clin Periodontol 42, 495-505.
7. Martin-Cabezas R, Seelam N, Petit C, Agossa K, Gaertner S, Tenenbaum H et al. (2016) Association between periodontitis and arterial hypertension: a systematic review and meta-analysis. Am Heart J 180, 98-112.

8. Matulienė G, Pjetursson BE, Salvi GE, Schmidlin K, Bragger U, Zwahlen M et al. (2008) Influence of residual pockets on progression of periodontitis and tooth loss: results after 11 years of maintenance. J Clin Periodontol 35, 685-695.

9. Oliveira Costa F, Miranda Cota LO, Pereira Lages EJ, Medeiros Lorentz TC, Soares Dutra Oliveira AM, Dutra Oliveira PA et al. (2011) Progression of periodontitis in a sample of regular and irregular compliers under maintenance therapy: a 3-year follow-up study. J Periodontol 82, 1279-1287.

10. Costa FO, Miranda Cota LO, Pereira Lages EJ, Soares Dutra Oliveira AM, Dutra Oliveira PA, Cyrino RM et al. (2013) Progression of periodontitis and tooth loss associated with glycemic control in individuals undergoing periodontal maintenance therapy: a 5-year follow-up study. J Periodontol 84, 595-605.

11. Nibali L, Sun C, Akcali A, Meng X, Tu YK, Donos N (2017) A retrospective study on periodontal disease progression in private practice. J Clin Periodontol 44, 290-297.

12. Graetz C, Plaumann A, Schlattmann P, Kahl M, Springer C, Salzer S et al. (2017) Long-term tooth retention in chronic periodontitis—results after 18 years of a conservative periodontal treatment regimen in a university setting. J Clin Periodontol 44, 169-177.

13. Vargas CM, Burt VL, Gillum RF, Pamuk ER (1997) Validity of self-reported hypertension in the National Health and Nutrition Examination Survey III, 1988-1991. Prev Med 26, 678-685.

14. Ngo DL, Marshall LM, Howard RN, Woodward JA, Southwick K, Hedberg K (2003) Agreement between self-reported information and medical claims data on diagnosed diabetes in Oregon’s Medicaid population. J Public Health Manag Pract 9, 542-544.

15. Wada K, Tamakoshi K, Tsunekawa T, Otsuka R, Zhang H, Murata C et al. (2005) Validity of self-reported height and weight in a Japanese workplace population. Int J Obes (Lond) 29, 1093-1099.

16. Machtie EE, Christersson LA, Grossi SG, Dunford R, Zambon JJ, Genco RJ (1992) Clinical criteria for the definition of “established periodontitis”. J Periodontol 63, 206-214.

17. Tonetti MS, Claibey N (2005) Advances in the progression of periodontitis and proposal of definitions of a periodontitis case and disease progression for use in risk factor research. Group C consensus report of the 5th European Workshop in Periodontology. J Clin Periodontol 32 Suppl 6, 210-213.

18. Haffajee AD, Socransky SS, Goodson JM (1983) Clinical parameters as predictors of destructive periodontal disease activity. J Clin Periodontol 10, 257-265.

19. Barros AJ, Hirakata VN (2003) Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. BMC Med Res Methodol 3, 21.

20. Chrysantheopoulos NA, Chrysantheopoulos PA (2016) Association between indices of clinically-defined periodontitis and self-reported history of systemic medical conditions. Journal of investigative and clinical dentistry 7, 27-36.

21. Umeizudike KA, Ayanbadejo PO, Onajole AT, Umeizudike TI, Alade GO (2016) Periodontal status and its association with self-reported hypertension in non-medical staff in a university teaching hospital in Nigeria. Odontostomatol Trop 39, 47-55.

22. Lamster IB, Cheng B, Burkett S, Lalla E (2014) Periodontal findings in individuals with newly identified pre-diabetes or diabetes mellitus. J Clin Periodontol 41, 1055-1060.

23. Engström S, Gahnberg L, Hogberg H, Svardsudd K (2007) Association between high blood pressure and deep periodontal pockets: a nested case-referent study. Ups J Med Sci 112, 95-103.

24. Hegde V, Dhurandhar NV (2013) Microbes and obesity—interrelationship between infection, adipose tissue and the immune system. Clin Microbiol Infect 19, 314-320.

25. Casanova L, Hughes FJ, Preshaw PM (2014) Diabetes and periodontal disease: a two-way relationship. Br Dent J 217, 433-437.

26. Taylor JJ, Preshaw PM, Lalla E (2013) A review of the evidence for pathogenic mechanisms that may link periodontitis and diabetes. J Clin Periodontol 40 Suppl 14, S113-134.

27. Leong XF, Ng CY, Badiah B, Das S (2014) Association between hypertension and periodontitis: possible mechanisms. ScientificWorldJournal 2014, 768237.

28. Higashi Y, Goto C, Jitsuiki D, Umemura T, Nishioka K, Hidaka T et al. (2008) Periodontal infection is associated with endothelial dysfunction in healthy subjects and hypertensive patients. Hypertension 51, 446-453.

29. Morita M, Horiuchi M, Inumura T, Nishioka K, Hitada T et al. (2008) Periodontal infection is associated with endothelial dysfunction in healthy subjects and hypertensive patients. Hypertension 51, 446-453.

30. Fentoglu O, Oz G, Tasdelen P, Uskun E, Aykac Y, Bozkurt FY (2009) Periodontal status in subjects with hyperlipidemia. J Periodontol 80, 267-273.

31. Syrjälä AM, Kneckt MC, Knuuttila ML (1999) Dental hygiene and HbA1c level among diabetic patients. J Clin Periodontol 26, 616-621.

32. Grundy SM (2012) Pre-diabetes, metabolic syndrome, and cardiovascular risk. J Am Coll Cardiol 59, 635-643.