Effect of Periodontitis and Toothbrushing Frequency on Obesity Onset: A Cohort Study

Toyoko Morita, Yoji Yamazaki, Misae Seto, Takashi Yamamoto, Kumiko Nakai, Hideki Tanaka, Manami Ozaki, Masao Maeno, Takayuki Kawato

Background: The interplay between obesity and periodontitis has been widely examined. While obesity was reported as a risk factor for periodontitis, the inverse relationship is still little explored. Therefore, we aimed to determine whether periodontitis and toothbrushing frequency affect the onset of obesity.

Material/Methods: This cohort study included 1619 employees of a business enterprise headquartered in Tokyo, who in 2002 and 2006 underwent prescribed annual health checks, both general and dental-specific, and who were not obese in 2002 (body mass index <25). The response variable was obesity (or absence) at 4 years, while the explanatory variables were presence/absence of periodontal pockets and toothbrushing frequency in 2002; their relationships were examined by multiple logistic regression analysis.

Results: Subjects with periodontal pockets ≥4 mm showed a significantly higher odds ratio (OR) for onset of obesity at 4 years than those without periodontal pockets [OR: 1.59, 95% CI (confidence interval): 1.08–2.35, p<0.05]. Similarly, subjects who brushed their teeth ≥3 times/day had a significantly lower obesity OR than those who brushed ≤1 time/day (OR: 0.49, 95% CI: 0.28–0.85, p<0.01).

Conclusions: The presence of periodontal pockets and toothbrushing frequency are significantly associated with the onset of obesity. Periodontal pockets ≥4 mm are associated with increased risk of obesity, while frequent toothbrushing (≥3 times/day) appears to reduce the risk of obesity.

MeSH Keywords: Chronic Periodontitis • Cohort Studies • Obesity, Abdominal • Toothbrushing

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/917356
**Background**

Obesity is a worldwide health problem and is not specific to developed nations [1]. In 2014, the World Health Organization (WHO) estimated the worldwide population of obese adults at roughly 600 million and forecast a further increase due to increased intake of high-calorie foods and sedentary lifestyles [2]. Obesity is a major risk factor for many diseases that markedly reduce the quality of life, such as type 2 diabetes, dyslipidemia, hypertension, arteriosclerosis, cardiovascular and cerebrovascular diseases, and sleep-disordered breathing [1]. These diseases are highly prevalent in middle-aged adults, who comprise the majority of the working population [3,4]. Therefore, prevention of obesity is also important from a socioeconomic perspective.

Periodontitis is a chronic inflammatory disease that is known to negatively affect the systemic health status. The relationship between obesity and periodontal disease has been examined in several cross-sectional studies [5–8] and was reported in their systematic reviews and meta-analyses [9–11]. In addition, several cohort studies have shown that obesity actually affects the onset of periodontal disease [12–15]. However, few epidemiological studies have determined the effects of periodontal disease on the development of obesity; the only such study on this topic followed children from childhood to adolescence [12]. However, as both periodontal disease and obesity become more prevalent with age [3,6], there is also a clear need to evaluate this impact in adults.

Toothbrushing is the most basic method to prevent periodontal disease [16]. A systematic review and meta-analyses reported that good oral hygiene as measured by the amount of plaque accumulation and good oral healthcare habits as evident by toothbrushing frequency or visits to a dental hygienist/dentist decreased the risk of periodontitis [17]. Toothbrushing practices have recently been reported to affect the onset of diabetes mellitus and dyslipidemia [18], as well as metabolic syndrome [19]. Despite the fact that obesity is the main cause of metabolic syndrome [20], very few studies have examined the possible relationship between toothbrushing practices and obesity. Apart from a cross-sectional study using the results of the Korea National Health and Nutrition Examination Survey [21], assessing the relationship between toothbrushing frequency and obesity, there have been few longitudinal studies.

We have previously reported that periodontitis increases the risk of developing metabolic syndrome in a longitudinal cohort study from which we excluded not only obese individuals, but also individuals with hypertension, hyperglycemia, or dyslipidemia [22]. Therefore, in the present study, we examined whether periodontitis and toothbrushing frequency affect the development of obesity in non-obese individuals, including those with hypertension, hyperglycemia, or dyslipidemia.

**Material and Methods**

**Study population**

The present study was conducted with the approval of the Nihon University School of Dentistry Institutional Review Board (approval number: 2007-7). After the study aim and protocol were fully explained, the participants provided informed consent.

Initially, the study population comprised 2373 employees of a business headquartered in Tokyo who, in 2002, underwent prescribed annual health checks, both general and dental-specific, conducted voluntarily by a health insurance association. Although 99.9% of employees underwent the general health check, only 82.8% underwent the dental health check; thus, only those were considered. The analysis set was then narrowed down to those employees who also underwent both health checks in 2006 (2078 employees), and who were not obese in 2002 [final set of 1619 employees: 1286 men and 333 women; mean age of 39.7 years (age range, 20–56 years)]. In this study, obesity was defined as body mass index (BMI) ≥25 [20]. Figure 1 shows the flow chart for the selection of the study population.

**Periodontitis examination**

Periodontitis was evaluated and classified according to the World Health Organization’s Community Periodontal Index (CPI) [23]. With the oversight of a dentist, a dental hygienist examined 10 index teeth in the 6 sextants; the highest CPI code attributed to that sample was recorded as the subject’s CPI. Based on the results obtained in the initial examination in 2002, the subjects were divided into 2 subgroups: CPI 0–2 (absence of periodontal pockets) and CPI 3–4 (presence of periodontal pockets ≥4 mm).
**General examination**

BMI was calculated from each individual’s height and body weight. Blood pressure was measured in a seated position with an automated sphygmomanometer. Blood was collected from a vein in the arm, with the subjects having fasted from 9 p.m. the previous night, and the levels of triglycerides, HDL cholesterol, and fasting blood glucose were determined. Hypertension was defined as systolic blood pressure ≥130 mmHg and/or a diastolic blood pressure ≥85 mmHg. Dyslipidemia was defined as a triglyceride level ≥150 mg/dL and/or an HDL cholesterol level ≤40 mg/dL. A fasting blood glucose ≥110 mg/dL was defined as hyperglycemia.

**Self-administered questionnaire**

Toothbrushing and other aspects of lifestyle were examined with a self-administered questionnaire during annual general health checks. Toothbrushing practices were examined in terms of daily frequency (i.e., how many times the subjects brushed their teeth daily). Accordingly, the subjects were divided into subgroups of once or less daily (≤1 time/day), twice daily (2 times/day), or 3 or more times daily (≥3 times/day). Smoking habits and ability to maintain a healthy body weight were examined with the following respective questions, “Do you smoke?” and “Are you making an effort to maintain a healthy body weight?”; the subjects were then divided based on their “yes” or “no” answers.

**Statistical analysis**

Subjects’ baseline characteristics were compared using Pearson’s χ² test based on presence/absence of periodontal pockets and daily toothbrushing frequency. The relationships of obesity at 4 years with presence/absence of periodontal pockets and daily toothbrushing frequency at baseline and/or 4 years were analyzed using forced entry multiple logistic regression (adjusted for hypertension, dyslipidemia, hyperglycemia, smoking habits, ability to maintain a healthy body weight, age, and sex) to determine the odds ratio (OR) and the 95% confidence interval (CI). Statistical analyses were performed using JMP (ver. 13.0; SAS Institute, Tokyo, Japan) with the level of statistical significance set at <5% (p<0.05).

**Results**

**Subjects’ baseline characteristics**

At baseline, in 2002, hypertension, dyslipidemia, and hyperglycemia were present in 25.3% (n=410), 16.0% (n=260), and 4.6% (n=75), respectively, of the 1619 non-obese subjects included in this study; all of the above conditions were significantly more prevalent among subjects with periodontal pockets than among those without them. A total of 36.1% (n=584) of subjects responded that they smoke and 28.5% (n=461) responded that they do not make efforts to maintain a healthy body weight. Smoking was significantly more common among subjects with periodontal pockets than among subjects without, but the presence of periodontal pockets was not significantly different between subjects who maintained a healthy body weight and those who did not (Table 1).

Daily toothbrushing frequency was once or less for 9.1% of subjects (n=147), twice for 39.2% (n=635), and 3 or more times for 51.7% (n=837). These percentages of toothbrushing frequencies significantly differed according to the presence or absence of periodontal pockets (Table 1).

Compared to subjects without periodontal pockets, the group of subjects with periodontal pockets included significantly higher percentages of men and people aged ≥40 years (Table 1). In comparisons involving daily toothbrushing frequency, significant differences were observed for all items studied (Table 2).

**Effects of periodontal pockets presence and toothbrushing frequency at baseline on obesity onset**

At baseline, in 2002, none of the 1619 subjects were obese; 4 years later in 2006, 140 subjects (corresponding to 8.6%) had developed obesity (BMI ≥25). None of the subjects had a BMI ≥30 in 2006. The group of subjects with periodontal pockets (CPI 3–4) showed a significantly higher OR for onset of obesity at 4 years than the group of subjects without periodontal pockets (CPI 0–2) (1.59, 95% CI: 1.08–2.35, p<0.05) (Table 3).

For the group of subjects who brushed their teeth ≥3 times/day or who brushed 2 times/day, the ORs for onset of obesity at 4 years were 0.49 (95% CI: 0.28–0.85, p<0.01) or 0.62 (95% CI: 0.37–1.06, p=0.08), respectively, in relation to the group of subjects who brushed ≤1 time/day. Thus, the OR was significantly lower for subjects with toothbrushing frequency ≥3 times/day (Table 3).

Participants who made an effort to maintain a healthy body weight showed significantly lower OR (0.44, 95% CI: 0.30–0.62, p<0.01) for onset of obesity at 4 years than the group who did not. The ORs for onset of obesity were significantly lower in females than in males (0.48, 95% CI: 0.26–0.89, p<0.05). There was no significant difference in the OR for onset of obesity relative to hypertension, dyslipidemia, hyperglycemia, smoking, and age at baseline (Table 3).

**Changes in the presence of periodontal pockets at baseline and at 4 years and its effects on obesity onset**

Among the 1190 subjects without periodontal pockets at baseline, 1006 subjects (84.5%) remained without periodontal
pockets at 4 years and 184 (15.5%) developed periodontal pockets. Among the 429 subjects with periodontal pockets at baseline, 216 (50.3%) still had periodontal pockets, and 213 (49.7%) were without periodontal pockets. The group with periodontal pockets at both baseline and 4 years had a significantly higher OR for the onset of obesity at 4 years than the group without periodontal pockets at both baseline and 4 years (2.22, 95% CI: 1.34–3.68, p<0.01) (Table 4).

Discussion

In this cohort study, we showed that periodontitis and toothbrushing frequency may have an effect on the onset of obesity. This study can increase our knowledge of the events related to development of obesity, and improve our understanding of how dental health care may influence this clinical condition.

One of the most widely used indices of obesity is BMI. While the WHO defines obesity as BMI ≥30, in this study, as all the participants were Japanese, a BMI ≥25 was considered obese.

Table 1. Characteristics of study population in relation to the presence of periodontal pockets at baseline.

| Variables                        | Without pockets (n=1,190) | With pockets (n=429) | P value |
|----------------------------------|---------------------------|----------------------|---------|
|                                  | N  | %   | N  | %   |        |
| Hypertension                     |    |      |    |      |        |
| No                               | 932| 78.3 | 277| 64.6 | <0.001 |
| Yes                              | 258| 21.7 | 152| 35.4 |        |
| Dyslipidemia                     |    |      |    |      |        |
| No                               | 1,027| 86.3 | 332| 77.4 | <0.001 |
| Yes                              | 163| 13.7 | 97 | 22.6 |        |
| Hyperglycemia                    |    |      |    |      |        |
| No                               | 1,152| 96.8 | 392| 91.4 | <0.001 |
| Yes                              | 38 | 3.2  | 37 | 8.6  |        |
| Smoking habit                    |    |      |    |      |        |
| No                               | 809| 68.0 | 226| 52.7 | <0.001 |
| Yes                              | 381| 32.0 | 203| 47.3 |        |
| Making an effort to maintain a healthy body weight | |      |    |      |        |
| No                               | 344| 28.9 | 117| 27.3 | 0.520 |
| Yes                              | 846| 71.1 | 312| 72.7 |        |
| Age                              |    |      |    |      |        |
| <40 year                         | 745| 62.6 | 135| 31.5 | <0.001 |
| ≥40 year                         | 445| 37.4 | 294| 68.5 |        |
| Gender                           |    |      |    |      |        |
| Male                             | 898| 75.5 | 388| 90.4 | <0.001 |
| Female                           | 292| 24.5 | 41 | 9.6  |        |
| Toothbrushing frequency          |    |      |    |      |        |
| ≤1 time/day                      | 88 | 7.4  | 59 | 13.8 |        |
| 2 times/day                      | 435| 36.6 | 200| 46.6 | <0.001 |
| ≥3 times/day                     | 667| 56.1 | 170| 39.6 |        |
as per the guidelines of the Japan Society for the Study of
Obesity, which is based on studies that have reported that BMI
³ 25 in the Japanese population are associated with increased
prevalence of glucose intolerance, dyslipidemia, and hyperten-
sion [20,24]. The incidence of obesity in 4 years of follow-up
was 8.6% and there was no subject with BMI ³ 30 by the end
of the study period. The mean age of the participants was 40
years and consisted mostly of men. This incidence was largely
consistent with that reported in previous studies [25,26]. In fact,
in the Japan Public Health Center Study, a multipurpose cohort
study, the incidence of obesity (BMI ³ 25) in a 10-year follow-
up period was 12.5%, 9.1%, and 7% among men aged 40–44,
50–54, and 60–64 years, respectively; the prevalence of obe-
sity decreased with age and was slightly lower among women
than among men [25]. Additionally, a large-scale study among
Japanese reported that from age 50 years onwards, the preva-
ience of obesity decreased among men but increased among
women; consequently, from age 60 years onwards, obesity be-
comes more prevalent among women [26].

Previous studies have found a relationship between obesity
and periodontal disease [9–11]. Li et al. [12], who studied a
group of subjects aged 12–18 years, reported that obesity at
age 15 years was associated with periodontal diseases at age
18 years; however, there was no significant association between
periodontal diseases at age 12 or 15 years and obesity at age
15 or 18 years. Nonetheless, in previous studies that we con-
ducted with subjects negative for all indicators of metabolic
syndrome, including obesity [22,27], we observed a signifi-
cant association between the cumulative duration of having

| Table 2. Characteristics of study population in relation to the frequencies of toothbrushing at baseline. |
|-------------------------------------------------|
| Variables                                        |
|        | The frequencies of toothbrushing | P value |
|        | ≤1 time/day (n=147) | 2 times/day (n=635) | ≥3 times/day (n=837) |
|        | N | % | N | % | N | % |
| Hypertension                                    |   |   |   |   |   |   |
| No                                              | 95 | 64.6 | 462 | 72.8 | 652 | 77.9 | 0.001 |
| Yes                                             | 52 | 35.4 | 173 | 27.2 | 185 | 22.1 |   |
| Dyslipidemia                                    |   |   |   |   |   |   |
| No                                              | 107 | 72.8 | 511 | 80.5 | 741 | 88.5 | <0.001 |
| Yes                                             | 40 | 27.2 | 124 | 19.5 | 96 | 11.5 |   |
| Hyperglycemia                                   |   |   |   |   |   |   |
| No                                              | 129 | 87.8 | 597 | 94 | 818 | 97.7 | <0.001 |
| Yes                                             | 18 | 12.2 | 38 | 6 | 19 | 2.3 |   |
| Smoking habit                                   |   |   |   |   |   |   |
| No                                              | 68 | 46.3 | 353 | 55.6 | 614 | 73.4 | <0.001 |
| Yes                                             | 79 | 53.7 | 282 | 44.1 | 223 | 26.6 |   |
| Making an effort to maintain a healthy body weight |   |   |   |   |   |   |
| No                                              | 57 | 38.8 | 187 | 29.5 | 217 | 25.9 | 0.005 |
| Yes                                             | 90 | 61.2 | 448 | 70.6 | 620 | 74.1 |   |
| Age                                             |   |   |   |   |   |   |
| <40year                                         | 50 | 34.0 | 341 | 54.7 | 489 | 58.4 | <0.001 |
| ≥40year                                         | 97 | 66.0 | 294 | 46.3 | 348 | 41.6 |   |
| Gender                                          |   |   |   |   |   |   |
| Male                                            | 144 | 98.0 | 574 | 90.4 | 568 | 67.9 | <0.001 |
| Female                                          | 3 | 2.0 | 61 | 9.6 | 269 | 32.1 |   |

This work is licensed under Creative Common Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0)
periodontal disease and obesity 9 years later [22], although a significant association between periodontal disease at baseline and onset of obesity in a 4-year follow-up period was not observed [27]. In the present study, we examined subjects who were not obese at baseline (although the baseline blood pressure, blood glucose, and lipid values exceeded the reference values in some subjects), and we observed a significant association between periodontitis (having periodontal pockets) at

| Condition in 2002                  | Number of subjects in 2006 (n, %) | Adjusted OR (95%CI) |
|------------------------------------|----------------------------------|---------------------|
|                                    | Non-obesity (n=1,479, 91.4%)      | Obesity (n=140, 8.6%)|
| Periodontal pockets                |                                   |                     |
| Without pocket                     | 1,103 (92.7)                      | 87 (7.3)            | 1                     |
| With pocket                        | 376 (87.6)                        | 53 (12.4)           | 1.59 (1.08–2.35)*     |
| Toothbrushing frequency            |                                   |                     |
| ≤1 time/day                        | 123 (83.7)                        | 24 (16.3)           | 1                     |
| 2 times/day                        | 574 (90.4)                        | 61 (9.6)            | 0.62 (0.37–1.06)      |
| ≥3 times/day                       | 782 (93.4)                        | 55 (6.6)            | 0.49 (0.28–0.85)**    |
| Hypertension                       |                                   |                     |
| No                                 | 1,114 (92.1)                      | 95 (7.9)            | 1                     |
| Yes                                | 365 (89.0)                        | 45 (11.0)           | 1.18 (0.79–1.77)      |
| Dyslipidemia                        |                                   |                     |
| No                                 | 1,250 (92.0)                      | 109 (8.0)           | 1                     |
| Yes                                | 279 (88.1)                        | 31 (11.9)           | 1.22 (0.78–1.91)      |
| Hyperglycemia                      |                                   |                     |
| No                                 | 1,411 (91.4)                      | 133 (8.6)           | 1                     |
| Yes                                | 68 (90.7)                         | 7 (9.3)             | 0.75 (0.32–1.73)      |
| Smoking habit                      |                                   |                     |
| No                                 | 947 (91.5)                        | 88 (8.5)            | 1                     |
| Yes                                | 532 (91.1)                        | 52 (8.9)            | 0.76 (0.52–1.12)      |
| Making an effort to maintain a healthy body weight |             |                     |
| No                                 | 396 (85.9)                        | 65 (14.1)           | 1                     |
| Yes                                | 1,083 (93.5)                      | 75 (6.5)            | 0.44 (0.30–0.62)**    |
| Age                                |                                   |                     |
| <40year                            | 812 (92.3)                        | 68 (7.7)            | 1                     |
| ≥40year                            | 667 (90.3)                        | 72 (9.7)            | 1.01 (0.68–1.48)      |
| Gender                             |                                   |                     |
| Male                               | 1,159 (90.1)                      | 127 (9.9)           | 1                     |
| Female                             | 320 (96.1)                        | 13 (3.9)            | 0.48 (0.26–0.89)*     |

* p<0.05; ** p<0.01. Confounders: hypertension, dyslipidemia, hyperglycemia, smoking habit, making an effort to maintain a healthy body weight, age, and gender. OR – odds ratio; CI – confidence interval.
baseline and the onset of obesity after 4 years, when adjustments for confounders including hypertension, dyslipidemia, hyperglycemia, smoking status, ability to maintain a healthy body weight, age, and sex were made. These findings suggest that periodontitis in adulthood increases the risk of future obesity. To determine the change in the status of periodontitis after 4 years, we divided the subjects into 4 groups based on the presence of periodontal pockets at baseline and/or 4 years later, and investigated its association with the onset of obesity. The multiple logistic analysis revealed that the group of participants with periodontal pockets at both the baseline and 4 years later showed a significantly higher OR (2.22, p<0.01) for onset of obesity than in the group of subjects without periodontal pockets at both the baseline and 4 years later. These results suggest that periodontitis as a risk factor for obesity is a modifiable factor, and the risk of obesity may be elevated in people with untreated periodontitis. Still, multiple logistic regression analysis did not show an association of baseline hypertension, hyperglycemia, or dyslipidemia with the onset of obesity in the 4-year follow-up period.

In contrast, we observed an inverse relationship between toothbrushing frequency at baseline and the onset of obesity 4 years later: subjects with a high toothbrushing frequency (i.e., good toothbrushing practice) were considered to have a low risk of becoming obese. Other studies have also reported a relationship between these parameters, including a cross-sectional study using the results of the Korea National Health and Nutrition Examination Survey [21]. However, to the best of our knowledge, our study is the first longitudinal study to evaluate toothbrushing frequency, age, and gender. OR – odds ratio; CI – confidence interval.

Exercise and dietary habits are major determinants of obesity and can affect its onset as confounding factors [1]; however, we adjusted for lifestyle habits related to caloric intake and expenditure, which were determined by asking subjects whether they were maintaining a healthy body weight in the multiple logistic regression analysis. This analysis revealed that there is a significant association between the onset of obesity and a positive response to the question, “Are you making an effort to maintain a healthy body weight?” (Table 3). Even when dividing subjects into 4 groups based on the answer to this question at baseline and 4 years later (“yes” at both baseline and 4 years, “yes” at baseline only, “yes” at 4 years only, and “no” at both times), multiple logistic analysis still indicated that the group who answered “yes” at both times and the group who answered “yes” at 4 years only had significantly lower ORs (0.14 for yes at both times and 0.27 for yes at 4 years only, respectively).

Table 4. Relationship between obesity in 2006 and the change in periodontal pockets.

| Condition in 2002 and 2006 | Number of subjects in 2006 (n, %) | Adjusted OR (95%CI) |
|---------------------------|---------------------------------|---------------------|
|                           | Non-obesity | Obesity |                           |                           |
| Periodontal pockets       | (n=1,479, 91.4%) | (n=140, 8.6%) |                           |                           |
| Without pocket at both times | 934 (92.8) | 72 (7.2) | 1                           |                           |
| With pocket only in 2002  | 169 (91.9) | 15 (8.1) | 0.95 (0.52–1.75)          |                           |
| With pocket only in 2002  | 166 (90.7) | 20 (9.3) | 1.12 (0.65–1.95)          |                           |
| With pocket at both times | 180 (84.5) | 33 (15.5) | 2.22 (1.34–3.68)**        |                           |

** p<0.01. Confounders: hypertension, dyslipidemia, hyperglycemia, smoking habit, making an effort to maintain a healthy body weight, toothbrushing frequency, age, and gender.
The present study has some limitations. We used BMI, but obesity can be assessed in several other ways, such as waist and hip circumferences, and subcutaneous fat thickness [3,12]. These indicators aid in estimating central obesity, which is more closely linked to metabolic syndrome than BMI is [20]. Moreover, we evaluated periodontitis based on CPI, which only evaluates index teeth and can potentially underestimate the degree of periodontitis. The question about smoking in this study also did not clarify the duration or the frequency of smoking. These limitations were mainly because we used the results of regular medical health checkups, which are designed and conducted specifically to help working adults to manage their health. Therefore, further understanding of the causal relationship between periodontitis/toothbrushing frequency and the onset of obesity may require not only cohort studies, using methods that enable a greater characterization of subjects’ obesity lifestyle, and periodontitis status, but also interventional studies.

Conclusions

The presence/absence of periodontal pockets and toothbrushing frequency were found to be significantly associated with the onset of obesity. Our findings suggest that periodontal pockets $\geq$4 mm might increase the risk of obesity, while frequent toothbrushing might reduce its risk.

Conflicts of interest

None.

References:

1. Kopelman PG: Obesity as a medical problem. Nature, 2000; 404(6778): 635–43
2. NCD Risk Factor Collaboration (NCD-RisC): Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19–2 million participants. Lancet, 2016; 387: 1377–96
3. Hu H, Nakagawa T, Okazaki H et al: Cumulative risk of type 2 diabetes in a working population: The Japan Epidemiology Collaboration on Occupational Health Study. J Epidemiol, 2018; 28(11): 465–69
4. Veronesi G, Borchini R, Landsbergis P et al: Cardiovascular disease prevention at the workplace: Assessing the prognostic value of lifestyle risk factors and job-related conditions. Int J Public Health, 2018; 63(6): 723–32
5. Saito T, Shimazaki Y, Koga T et al: Relationship between upper body obesity and periodontitis. J Dent Res, 2001; 80(7): 1631–36
6. Wood N, Johnson RB, Streckfus CF: Comparison of body composition and periodontal disease using nutritional assessment techniques. Third National Health and Nutrition Examination Survey (NHANES III). J Clin Periodontol, 2003; 30(4): 321–27
7. Saxlin T, Ylisstalo P, Suominen-Talajae L et al: Association between periodontal infection and obesity: results of the Health 2000 survey. J Clin Periodontol, 2011; 38(3): 236–42
8. Kim EJ, Jin BH, Bae KH: Periodontitis and obesity: A study of the Fourth Korean National Health and Nutrition Examination Survey. J Periodontol, 2011; 82(4): 533–42
9. Chaffee BW, Weston SJ: Association between chronic periodontal disease and obesity: A systematic review and meta-analysis. J Periodontol, 2010; 81(12): 1708–24
10. Martinez-Herrera M, Silvestre-Rangil J, Silvestre FJ: Association between obesity and periodontal disease. A systematic review of epidemiological studies and controlled clinical trials. Med Oral Patol Oral Cir Bucal, 2017; 22(6): e708–15
11. Nascimento GG, Leite FR, Correa MB et al: Does periodontal treatment have an effect on clinical and immunological parameters of periodontal disease in obese subjects? A systematic review and meta-analysis. Clin Oral Investig, 2016; 20(4): 639–47
12. Li WW, Wong HM, McGrath CP: Longitudinal association between obesity and periodontal diseases among secondary school students in Hong Kong: A prospective cohort study. BMC Oral Health, 2018; 18(1): 189
13. Morita T, Okamoto Y, Yoshii S et al: Five-year incidence of periodontal disease is related to body mass index. J Dent Res, 2011; 90(2): 199–202
14. Jimenez M, Hu FB, Marino M et al: Prospective associations between measures of adiposity and periodontal disease. Obesity (Silver Spring), 2012; 20(8): 1718–25
15. Gorman A, Kaye EE, Apovian C et al: Overweight and obesity predict time to periodontal disease progression in men. J Clin Periodontol, 2012; 39(2): 107–14
16. van der Weijden F, Slot DE: Oral hygiene in the prevention of periodontal diseases: The evidence. Periodontol 2000, 2011; 55(1): 104–23
17. Lehtimokkahal A, Rattanasi S, Arj-Ong Vallibhakara S et al: The association between oral hygiene and periodontitis: A systematic review and meta-analysis. Int Dent J, 2017; 67: 352–43
18. Kuwabara M, Motoki Y, Sato H et al: Low frequency of toothbrushing practices is an independent risk factor for diabetes mellitus in male and dyslipidemia in female: A large-scale, 5-year cohort study in Japan. J Cardiol, 2017; 70(2): 107–12
19. Tanaka A, Takeuchi K, Furuta M et al: Relationship of toothbrushing to metabolic syndrome in middle-aged adults. J Clin Periodontol, 2018; 45(5): 538–47
20. Matsuzawa Y: Metabolic syndrome – Definition and diagnostic criteria in Japan. J Atheroscler Thromb, 2005; 12(6): 301
21. Park JB, Nam GE, Han K et al: Obesity in relation to oral health behaviors: An analysis of the Korea National Health and Nutrition Examination Survey 2008–2010. Exp Ther Med, 2016; 12(5): 3093–100
22. Morita T, Yamazaki Y, Fujihara C et al: Association between the duration of periodontitis and increased cardiometabolic risk factors: A 9-year cohort study. Metab Syndr Relat Disord, 2016; 14(10): 475–82
23. Anamo I, Barnes D, Beagrie G et al: Development of the World Health Organization (WHO) community periodontal index of treatment needs (CPTIN). Int Dent J, 1982; 32(5): 281–91
24. Aizawa Y, Kamimura N, Watanabe H et al: Cardiovascular risk factors are really linked in the metabolic syndrome: this phenomenon suggests clustering rather than coincidence. Int J Cardiol, 2006; 109(2): 213–18
25. Matsushita Y, Takahashi Y, Mizoue T et al: Overweight and obesity trends among Japanese adults: A 10-year follow-up of the JPHC Study. Int J Obes, 2008; 32(12): 1861–67
26. Kuzuya M, Ando F, Iguchi A, Shimokata H: Age-specific change of prevalence of metabolic syndrome: longitudinal observation of large Japanese cohort. Atherosclerosis, 2007; 191(2): 305–12
27. Morita T, Yamazaki Y, Mita A et al: A cohort study on the association between periodontal disease and the development of metabolic syndrome. J Periodontol, 2010; 81(4): 512–19
28. Theilade E, Wright WH, Jensen SB, Löe H: Experimental gingivitis in man. II. A longitudinal clinical bacteriological investigation. J Periodont Res, 1966; 1: 1–13
29. Yamazaki Y, Morita T, Fujiharu C et al: The association between oral health behavior and development of periodontal pocket – A cohort analysis using data from Japanese adults with routine dental checkups in occupational settings. J Dent Health, 2018; 68(1): 21–27 [in Japanese]
30. Saito T, Murakami M, Shimazaki Y et al: Association between alveolar bone loss and elevated serum C-reactive protein in Japanese men. J Periodontol, 2003; 74(12): 1741–46
31. Loos BG, Craandijk J, Hoek FJ et al: Elevation of systemic markers related to cardiovascular diseases in the peripheral blood of periodontitis patients. J Periodontol, 2000; 71(10): 1528–34
32. Nishimura F, Soga Y, Iwamoto Y et al: Periodontal disease as part of the insulin resistance syndrome in diabetic patients. J Int Acad Periodontol, 2005; 7(1): 16–20
33. Slade GD, Ghezzi EM, Heiss G et al: Relationship between periodontal disease and C-reactive protein among adults in the Atherosclerosis Risk in Communities study. Arch Intern Med, 2003; 163(10): 1172–79
34. Nakai K, Tanaka H, Yamanaka K et al: Effects of C-reactive protein on the expression of matrix metalloproteinases and their inhibitors via Fc receptors on 3T3-L1 adipocytes. Int J Med Sci, 2017; 14(5): 484–93
35. Tanaka H, Nakai K, Murakami F et al: Ligature-induced periodontitis increased insulin resistance and triglyceride levels in Wistar rats. J Hard Tissue Biol, 2017; 26(3): 261–67