Longitudinal associations of toothbrushing with obesity and hyperglycemia.

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Abstract

Background: Toothbrushing is a health-related lifestyle habit and has been reported to contribute not only to oral health but also to some parameters of general health; however, little research has been conducted to understand the association of the frequency and timing of toothbrushing with the development of comprehensive metabolic abnormalities considering oral health condition. In this study, using longitudinal data, we examined this association in Japanese adults, adjusting for periodontal condition.

Methods: A 5-year longitudinal study was performed with 4,537 participants between 35 and 64 years old who underwent an annual dental examination in both 2003 and 2008. Data about toothbrushing habits and metabolic abnormalities such as obesity, hyperglycemia, diabetes, hypertension, hypertriglyceridemia, and low levels of high-density lipoprotein-cholesterol were analyzed using Poisson regression analysis.

Results: The percentage of participants with a toothbrushing frequency ≤1 time/day was 29.4%, and that for those not brushing their teeth at night was 21.4%. The incidences of obesity and hyperglycemia after 5 years were 5.5% and 28.4%, respectively. A toothbrushing frequency ≤1 time/day was associated with development of obesity [prevalence rate ratio (PRR) = 1.77; 95% confidence interval (CI): 1.12–2.80], after adjusting for periodontal condition and potential risk factors. A significant association between not brushing teeth at night and hyperglycemia (PRR = 1.30; 95% CI: 1.02–1.66) was observed in participants with toothbrushing frequency of 1 time/day. No association was found between toothbrushing habits and other metabolic abnormalities.

Conclusions: This study suggests that toothbrushing habits are associated with the development of obesity and hyperglycemia.
Introduction

In modern affluent societies, unhealthy lifestyle factors are responsible for a large proportion of morbidities and mortalities. For example, smoking, unhealthy dietary habits, lack of regular physical activity, high alcohol consumption, and not maintaining an appropriate body weight have been shown to have an unfavorable influence on cardiovascular disease\textsuperscript{1, 2} as well as diabetes mellitus\textsuperscript{3} and hypertension\textsuperscript{4}. Additionally, metabolic syndrome, a precursor of cardiovascular disease and diabetes mellitus\textsuperscript{5}, is affected by lifestyle factors, including smoking, diet, physical activity, and alcohol consumption habits\textsuperscript{6}.

These lifestyle factors have been shown to be connected to oral health behaviors, such as toothbrushing, as it has been reported that lower toothbrushing frequency correlates with smoking, unhealthier dietary habits, lower physical activity, and higher consumption of alcohol\textsuperscript{7, 8}. Recent studies have shown that low toothbrushing frequency is associated with obesity\textsuperscript{9}, metabolic syndrome\textsuperscript{10}, diabetes mellitus\textsuperscript{11, 12}, and cardiovascular disease\textsuperscript{13}. Furthermore, it has been found that not brushing teeth at night is related to mortality\textsuperscript{14}. These previous studies suggest both the clinical and public health importance of toothbrushing, as toothbrushing leads not only to the prevention of oral disease, but also to a reduced risk of health deterioration. Toothbrushing may be an easily applicable preventive method for overall health deterioration. Additionally, toothbrushing may have the hidden potential to become another factor of improving health deterioration when general lifestyle modification has not been effective.

However, these studies\textsuperscript{10-14} did not simultaneously address oral health condition. Metabolic abnormalities, including obesity, hyperglycemia, dyslipidemia, and high blood pressure, is associated with poor oral health condition, especially periodontal disease\textsuperscript{15}. The association between toothbrushing and metabolic abnormalities may be
influenced not only by lifestyle but also by periodontal condition. We previously reported that low toothbrushing frequency was associated with the onset of metabolic syndrome, defined by ≥3 components of metabolic syndrome, after adjusting for lifestyle factors and periodontal condition. The previous study suggests the possibility that toothbrushing is an independent related factor for the development of metabolic syndrome. However, it remained unclear as to which specific metabolic abnormalities were associated with toothbrushing habits and whether this association differed based on the timing of toothbrushing.

In the present study, we examined whether toothbrushing habits (toothbrushing frequency and toothbrushing at night) was longitudinally associated with the development of metabolic abnormalities in addition to diabetes and hypertension, considering oral health condition in Japanese adults. We hypothesized that toothbrushing was an independent risk factor for developing metabolic abnormalities.

Methods

Study population

This longitudinal study used the medical and dental records of Japanese adults who had undergone workplace health check-ups in 2003 and 2008 at the health examination center of a manufacturing company in Yokohama, Japan. Details of the study design have been described previously.

At baseline, 6,829 individuals received both medical and dental examinations. Participants were included if they fulfilled the following criteria at baseline: (1) were 35 to 64 years old, (2) had 1 or more teeth, and (3) had medical records from 2008. Of the 4,804 participants fulfilling the inclusion criteria, 267 participants with missing data were excluded. Finally, 4,537 participants were analyzed in this study (3643 men and
894 women) (Figure 1).

All participants provided written informed consent for the use of their anonymous data for research. The study design was approved by the Ethics Committee of the Kyushu University Faculty of Dental Sciences, Fukuoka, Japan.

Assessment of toothbrushing and oral health condition

Toothbrushing habits were recorded based on self-reported questionnaires. The frequency of toothbrushing and the time of day when toothbrushing was performed were derived from the following question: ‘How often do you brush your teeth?’ The response options were: ‘once in the morning’; ‘once in the afternoon’; ‘once at night’; ‘two times, in the morning and at night’; ‘two times, in the morning and the afternoon’; ‘two times, in the afternoon and at night’; ‘three times’; and ‘four and more times’. Then, the ‘once in the morning’, ‘once in the afternoon’, and ‘two times in the morning and afternoon’ were combined to create a dichotomous variable to identify the no toothbrushing at night group. Toothbrushing time was also recorded.

Number of teeth, periodontal condition, and oral hygiene status were recorded as indicators of oral health condition at the baseline examination. A periodontal examination was performed on all teeth except the third molars at two sites (mesiobuccal and mid-buccal), following the National Health and Nutrition Examination Survey III method; probing pocket depth (PPD) and clinical attachment level (CAL) were assessed. The percentage of teeth that bled upon probing (%BOP) was also examined. The periodontal examination was described previously in more detail. Oral hygiene status was recorded using the Oral Hygiene Index-Simplified.

Assessment of metabolic abnormalities
The assessment of metabolic abnormalities included the following measurements:

- Fasting glucose, triglyceride, and high-density lipoprotein (HDL) cholesterol concentrations; systolic and diastolic blood pressure; and body mass index (BMI), which was calculated after body weight and height were measured. Metabolic abnormalities were assessed according to the Joint Interim Statement using the criteria for Asians\textsuperscript{20} as follows: obesity was defined as BMI ≥25.0 kg/m\textsuperscript{2} (appropriate cut-off for obesity in Asian individuals\textsuperscript{21}); hyperglycemia was defined as fasting glucose ≥100 mg/dl or current antidiabetic treatment; hypertriglyceridemia was defined as triglycerides ≥150 mg/dl or the use of any lipid-lowering medications; and low HDL cholesterol was defined as <40 mg/dl in males and <50 mg/dl in females. Diabetes was determined by fasting glucose ≥126 mg/dl or current antidiabetic treatment\textsuperscript{22}. The oral glucose tolerance test was not conducted, and therefore, the diagnostic criteria of diabetes used in this study did not correspond with the current diagnostic criteria proposed by the American Diabetes Association. Hypertension was defined by using criteria from the 2017 American College of Cardiology/American Heart Association (ACC/AHA) guidelines and the Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7). In the 2017 ACC/AHA guidelines, hypertension was defined as blood pressure ≥130/80 mmHg or current antihypertensive treatment\textsuperscript{23}, and hypertension in the JNC7 was defined as blood pressure ≥140/90 mmHg or current antihypertensive treatment\textsuperscript{24}.

**Assessment of other variables**

Information about eating habits, smoking, alcohol consumption, physical activity, sleeping hours, and profession was collected by a self-reported questionnaire. Eating habits were assessed using 6 questions, and three answer categories were collapsed into
dichotomous variables as follows: (1) eating a daily snack between meals: yes vs. no; (2) preferred taste of food: salty vs. normal or lightly salted; (3) skipping breakfast: yes vs. no; (4) eating meat and oily food: more vs. normal or lower; (5) eating sweet food: more vs. normal or lower; and (6) eating dinner: eating home-cooked meals vs. eating outside the home or eating take-out food = seldomly eat home-cooked meals. Smoking status was categorized as current smoking or nonsmoker. Alcohol consumption was measured by frequency of alcohol consumption and volume of alcoholic beverages consumed; alcohol consumption was categorized into high consumption (≥30 g ethanol per day for men and ≥20 g ethanol per day for women) or no consumption. Physical activity was assessed by frequency of exercise and was grouped as regular (more than one day per week) or none. Sleeping hours were divided into ≤5 hours, 6 hours, and ≥7 hours. Occupational status was classified into office workers, skilled workers, and other workers.

Statistical analysis

Bivariate tests, including the Mann-Whitney $U$ test, the Kruskal-Wallis test, and the chi-squared test, were performed to describe oral condition and lifestyle factors according to toothbrushing habits. As logistic regression might have overestimated the risk of association in a high incidence of outcomes, a Poisson regression model with robust standard errors was used. The association between toothbrushing habits, including toothbrushing frequency and brushing teeth at night, at baseline (independent variable) and developing each metabolic abnormality (dependent variable) was assessed using Poisson regression analysis. The prevalence rate ratio (PRR) with 95% confidence intervals (95% CIs) based on robust standard errors was calculated. The Poisson regression models included age, sex, mean CAL, number of teeth, BMI, eating habits...
(eating snacks between meals, preferring salty dishes, skipping breakfast, eating meat and oily food, eating sweet foods, and seldomly eating home-cooked meals), smoking, alcohol consumption, physical activity, sleeping hours, and job as covariates. The model with each metabolic abnormality, except obesity, as the dependent variable additionally included the baseline value of each metabolic abnormality as a covariate (e.g., the model for the development of hypertension additionally included systolic blood pressure at baseline). To determine whether brushing teeth at night was associated with metabolic abnormalities regardless of toothbrushing frequency, data stratified by toothbrushing frequency were analyzed. SPSS software (version 25.0 for Windows; IBM SPSS Japan, Tokyo, Japan) was used for data analysis. A two-sided value of $p < 0.05$ was considered statistically significant in all analyses.

**Results**

*Characteristics of the participants*

Age, obesity, and mean values of CAL were different between the analyzed participants and the participants who did not receive a medical examination after the 5-year follow-up period (Table 1). The toothbrushing habits and metabolic conditions were similar between the participants. The prevalence of each metabolic abnormality at baseline was 22.7% for obesity, 29.7% for hyperglycemia, 3.8% for diabetes, 36.7% for hypertension based on the 2017 ACC/AHA guidelines, 10.9% for hypertension based on the JNC7, 25.5% for hypertriglyceridemia, and 9.1% for low HDL cholesterol (Table 1).

*Toothbrushing habits, oral condition and lifestyle factors*

The percentage of participants with a toothbrushing frequency of $\leq 1$ time/day and who did not brushing their teeth at night was 29.4% and 21.4%, respectively. The association
between toothbrushing frequency and brushing teeth at night is shown in Table 2. Of the 1332 participants with a toothbrushing frequency of 1 time/day, 885 brushed their teeth in the morning, 10 in the afternoon, and 437 at night. Participants with a toothbrushing frequency of ≤1 time/day had higher mean values of CAL, more plaque and calculus, higher %BOP, a greater prevalence of current smoking, higher alcohol consumption, lower physical activity, greater preference for salty foods, greater prevalence of skipping breakfast, higher consumption of meat and oily food, lower consumption of home-cooked meals and shorter sleeping hours than those with a toothbrushing frequency of ≥3 times/day (Table 3). The association of not brushing teeth at night with oral condition and lifestyle factors was similar to that of toothbrushing frequency.

Toothbrushing habits and development of metabolic abnormalities

After excluding participants with each metabolic abnormality at baseline, the incidence of the development of each metabolic abnormality was calculated. We analyzed 3,509 participants when examining incidences of obesity, 3,185 for hyperglycemia, 3,378 for hypertriglyceridemia, 4,357 for diabetes, 2,870 for hypertension based on the 2017 ACC/AHA guidelines, 4,043 for hypertension based on the JNC7 guidelines, 3,378 for hypertriglyceridemia, and 4,125 for low HDL cholesterol (Table 4). The incidence of the development of each metabolic abnormality was 5.5% for obesity, 28.4% for hyperglycemia, 2.3% for diabetes, 16.8% for hypertension based on the 2017 ACC/AHA guidelines, 7.9% for hypertension based on the JNC7, 12.8% for hypertriglyceridemia, and 2.7% for low HDL cholesterol (Table 4). Poisson regression models showed that a toothbrushing frequency of ≤1 time/day was positively associated with the development of obesity (PRR 1.77, 95% CI 1.12-2.80) after adjusting for age, sex, number of teeth, mean CAL, BMI, eating snacks
between meals, preferring salty dishes, skipping breakfast, eating meat and oily food, eating sweet food, seldomly eating home-cooked meals, smoking, consuming alcohol, physical activity, sleeping hours, job, and the baseline value of each metabolic abnormality (Table 5). Not brushing teeth at night was significantly associated with the development of obesity (PRR 1.49, 95% CI 1.13-1.96) and hyperglycemia (PRR 1.14, 95% CI 1.00-1.29) (Table 6). When we examined the association between brushing teeth at night and each metabolic abnormality stratified by toothbrushing frequency, participants who had a toothbrushing frequency of 1 time/day and were not brushing at night were more likely to develop hyperglycemia (PRR 1.30, 95% CI 1.02-1.66) than those brushing at night (Table 7). A significant association between brushing at night and obesity was not found (Table 7). Regarding periodontal condition, mean CAL, PPD, calculus, and %BOP were higher in participants who had a toothbrushing frequency of 1 time/day and were not brushing at night than in those who brushed at night (Supplemental Table 1). In participants with toothbrushing frequency of 1 time/day, not brushing at night was not significantly associated with hyperglycemia in the model with %BOP (Supplementary Table 2).

Discussion

We found that a low frequency of toothbrushing was associated with the development of obesity after adjusting for covariates and, furthermore, that not brushing teeth at night in participants with toothbrushing frequency of 1 time/day was associated with hyperglycemia. This longitudinal study reinforced the results of a previous cross-sectional study, which showed the association between a low frequency of toothbrushing and obesity. Moreover, the current study extends the findings of prior longitudinal studies in regard to toothbrushing frequency and health conditions.
by specifying the link between the time of day of toothbrushing and metabolic
abnormalities.

The association between toothbrushing habits and obesity was found, even
though periodontal condition and several lifestyle factors were adjusted for in
multivariate models, suggesting that this association is explained by other related factors.
Our results are similar to a previous study demonstrating a cross-sectional association
between low toothbrushing frequency and obesity after adjusting for lifestyle factors and
periodontal condition [odds ratio (OR) 1.22 of 1 time/day toothbrushing and OR 1.48 of
0 time/day toothbrushing]9. In this study, PRR for obesity with ≤1 time/day toothbrushing
was 1.77, indicating a relatively stronger association than that in the Park et al. study9.
This might be related to unobserved confounders such as diet quality, including total
energy intake, and vegetable and fruit intake.

One possible pathway leading from toothbrushing to obesity may involve
endotoxemia. It has been demonstrated that metabolic endotoxemia induced by
lipopolysaccharides results in an increase in total body fat mass in mice27. The
microbiome of subgingival plaque mainly consists of Gram-negative bacteria that
contain a lipopolysaccharide on the outer membrane28 and subgingival plaque
contributes significantly to endotoxemia. From this perspective, it seems likely that the
accumulation of subgingival plaque caused by poor toothbrushing habits contributes to
endotoxemia and subsequently leads to obesity. Another possible explanation for the
association between toothbrushing and obesity may be related to leptin, which regulates
appetite and energy balance primarily through hypothalamic neurons in the central
nervous system. Oral proprioceptive signals modulate the hypothalamic histamine
neurons, which are concordant with the leptin signaling system29. One study reported
that the serum leptin level within three hours after a meal was changed after
toothbrushing in non-obese young men\textsuperscript{30}. This suggests that mechanical stimulation of the gingiva by toothbrushing may play a role in appetite regulation by influencing leptin, which can control obesity.

The effect of brushing teeth at night on hyperglycemia was observed in participants with toothbrushing frequency of 1 time/day. Not brushing teeth at night in individuals with low frequency of toothbrushing can easily cause poor oral hygiene status, because saliva flow is low while sleeping, and bacterial clearance is reduced, resulting in greater bacterial colonization of oral tissues\textsuperscript{31}. In fact, participants who did not brush their teeth at night had more calculus and higher level of BOP than those who brushed their teeth at night among participants with toothbrushing frequency of 1 time/day (Supplementary Table 1). When we added oral hygiene status to the model, the association between not brushing teeth at night and hyperglycemia was attenuated [PRR 1.29, 95% CI 0.99-1.68 in the model including %BOP (Supplementary Table 2)], suggesting that gingival inflammation may play a role in mediating this association.

However, a significant association between toothbrushing and hyperglycemia remained even in the model adjusted for mean CAL (Tables 6 and 7). CAL reflects a historical accumulation of periodontal destruction, while BOP is a better real-time indicator of inflammation than CAL\textsuperscript{32}. The present study indicates that the intensity of existing gingival inflammation is a mediator between toothbrushing habits and hyperglycemia. It is considered that gingival inflammation caused by poor toothbrushing is linked with increased systemic inflammation/endothelial dysfunction and low adiponectin levels, which in turn may lead to an increased risk of hyperglycemia\textsuperscript{33}. For individuals who had toothbrushing frequency of once a day without brushing teeth at night, increased frequency of toothbrushing may have the hidden potential to reduce a risk of hyperglycemia. In this context, this study showed a lack of a significant association
between toothbrushing habits and diabetes, which was probably due to the low incidence of diabetes (2.3%). A longer follow-up study is necessary to confirm this association.

Although we were not able to clearly explain the direct link between toothbrushing and metabolic abnormalities, one potential pathway may be that the removal of bacterial plaque by toothbrushing decreases chronic low-grade systemic inflammation that can contribute to metabolic abnormalities such as hyperglycemia. An animal experiment showed that subgingival bacteria such as *Porphyromonas gingivalis* induced a change in the bacterial composition of gut microbiota accompanied by increased systemic inflammation, implying that oral pathogens may lead to metabolic abnormalities.

Our results were different from those of Kuwabara *et al.* who found that individuals who did not brush their teeth after every meal had a higher risk of developing diabetes during a 5-year follow-up period than those who brushed their teeth after every meal. However, the study by Kuwabara *et al.* did not consider lifestyle factors such as eating habits, smoking, alcohol consumption, physical activity, and sleeping hours, which contribute to diabetes development. Therefore, their results did not exclude the possibility of residual confounding due to unmeasured factors. Our results regarding hyperglycemia are similar to those reported by Kobayashi *et al.* Their finding of no association between toothbrushing frequency and hyperglycemia was the same as in this study, whereas Kobayashi *et al.* did not evaluate the timing of toothbrushing. More longitudinal studies are required to confirm whether the timing of toothbrushing affects hyperglycemia.

Low frequency of toothbrushing and not brushing teeth at night was inversely associated with eating habits, such as eating snacks between meals and eating more...
sweet foods (Table 2). This finding may be partly because participants are prone to
brushing their teeth after eating a snack or a sweet food to prevent dental caries and
maintain oral hygiene. Regarding metabolic abnormalities, participants who ate snacks
between meals were less likely to have hyperglycemia, hypertriglyceridemia, and
hypertension based on the cross-sectional data (data not shown). It has been reported
that individuals who eat snacks more frequently eat more fruits, vegetables, milk, and
dairy products and less fried food than those with a lower eating frequency35. The
inverse association between eating snacks and metabolic abnormalities may be
explained by diet quality.

This study had several limitations. First, diet quality, such as total energy intake
and vegetable and fruit intake, was not investigated, although eating habits were
included in our study. It has been reported that toothbrushing frequency is positively
associated with intake of vegetables and fruits,36 which contributes to the prevention of
metabolic abnormalities37. We also did not investigate inflammatory parameters, such as
high-sensitivity C-reactive protein, which is considered to be responsible for the link
between gingival and systemic inflammation. These unmeasured potential confounders
may have biased our estimates of the association between toothbrushing habits and
metabolic abnormalities owing to using the data of health check-ups, these variables
that might have been important were not recorded and could not be included in the
model. Future studies are needed to assess these factors. Second, we did not obtain
glucose tolerance test data, which defines diabetes more accurately, since a glucose
tolerance test is more time consuming in the health examination setting and a fasting
blood examination was more practical. Third, we used a partial mouth assessment for
periodontal condition, which did not include an examination of lingual or palatal sites.
Our results potentially underestimate periodontal condition. Finally, the sample
investigated was not representative of the general population because this study included individuals who received workplace health checkups, and the prevalences of obesity and periodontal conditions were different between the analyzed participants and those who dropped out of the follow-up examination. This limitation should be taken into consideration when applying the findings to other populations.

In conclusion, this longitudinal study confirmed that low frequency of toothbrushing was associated with the development of obesity even after adjusting for potential confounders. An association between not brushing teeth at night and hyperglycemia was found in individuals with a toothbrushing frequency of 1 time/day.
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Figure legends

Figure 1.

Flow diagram of the study participants. Of the 4,537 overall participants, we selected 3,509 participants when examining the incidence of obesity during a 5-year period, 3,185 participants for hyperglycemia, 4,357 participants for diabetes, 2,870 participants for hypertension based on ACC/AHA guidelines, 4,043 participants for hypertension based on the JNC7 guidelines, 3,378 participants for hypertriglyceridemia, and 4,125 participants for low HDL.
Table 1. Descriptive statistics comparing analyzed participants with participants who dropped out of the health examination in 2008.

|                      | Analyzed (n = 4537) | Dropped out (n = 1659) | p-value |
|----------------------|---------------------|------------------------|---------|
| Age (years)          | 45.0 ± 8.4          | 46.9 ± 9.2             | <0.001  |
| Sex                  |                     |                        |         |
| Men                  | 3643 (80.3)         | 1203 (72.5)            |         |
| Women                | 894 (19.7)          | 456 (27.5)             |         |
| Obesity              |                     |                        | 0.015   |
| BMI<25.0             | 3509 (77.3)         | 1234 (74.4)            |         |
| BMI≥25.0             | 1028 (22.7)         | 425 (25.6)             |         |
| Fasting glucose*     |                     |                        | 0.518   |
| Normal               | 3185 (70.2)         | 1150 (69.3)            |         |
| Elevated             | 1346 (29.7)         | 506 (30.5)             |         |
| Diabetes*            |                     |                        | 0.102   |
| No                   | 4357 (96.2)         | 1577 (95.1)            |         |
| Yes                  | 174 (3.8)           | 79 (4.8)               |         |
| Hypertension based on the 2017 ACC/AHA guidelines |                     |                        | 0.911   |
| No                   | 2870 (63.3)         | 1052 (63.4)            |         |
| Yes                  | 1667 (36.7)         | 607 (36.6)             |         |
| Hypertension based on the JNC7 guidelines |                     |                        | 0.070   |
| No                   | 4043 (89.1)         | 1451 (87.5)            |         |
| Yes                  | 494 (10.9)          | 208 (12.5)             |         |
| Triglycerides        |                     |                        | 0.743   |
| Normal               | 3378 (74.5)         | 1242 (74.9)            |         |
| Elevated             | 1159 (25.5)         | 417 (25.1)             |         |
| HDL cholesterol      |                     |                        | 0.593   |
| Normal               | 4125 (90.9)         | 1501 (90.5)            |         |
| Reduced              | 412 (9.1)           | 158 (9.5)              |         |
| Toothbrushing frequency |                     |                        | 0.600   |
| ≥3 times             | 844 (18.6)          | 304 (18.3)             |         |
| 2 times              | 2361 (52.0)         | 846 (51.0)             |         |
| ≤1 time              | 1332 (29.4)         | 509 (30.7)             |         |
| Toothbrushing at night |                     |                        | 0.983   |
| Yes                  | 3565 (78.6)         | 1304 (78.6)            |         |
| No                   | 972 (21.4)          | 355 (21.4)             |         |
| Mean CAL             | 2.52 ± 0.72         | 2.57 ± 0.77            | 0.018   |

n (%), mean ± SD.
Chi-square test was performed for categorical variables, and Mann-Whitney U test was performed for continuous variables.
* Excluding individuals with a missing value (n = 6 in analyzed and n =3 in dropped out)
BMI, body mass index; ACC/AHA, American College of Cardiology/American Heart Association; JNC7, Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; HDL, high-density lipoprotein; CAL, clinical attachment level; SD, standard deviation.
Table 2. Association between toothbrushing frequency and toothbrushing at night

| Toothbrushing frequency | ≤1 time (n = 1332) | 2 times (n= 2361) | ≥3 times (n = 844) | p-value |
|-------------------------|--------------------|-------------------|-------------------|---------|
| Toothbrush at night     |                    |                   |                   | <0.001  |
| Yes                     | 437 (32.8)         | 2284 (96.7)       | 844 (100)         |         |
| No                      | 895 (67.2)         | 77 (3.3)          | 0 (0)             |         |

n (%), Chi-square test
Table 3. Oral condition and lifestyle factors according to toothbrushing habits at baseline

| Toothbrushing frequency | ≤1 time (n = 1332) | 2 times (n = 2361) | ≥3 times (n = 844) | p-value | Brushing teeth at night | No (n = 972) | Yes (n = 3565) | p-value |
|------------------------|-------------------|-------------------|-------------------|---------|------------------------|--------------|---------------|---------|
| Age, years, mean (SD)  | 44.9 (8.3)        | 44.9 (8.3)        | 45.8 (8.5)        | 0.02    | 44.5 (8.2)             | 45.2 (8.4)   | 0.022         |
| Men, %                 | 94.5              | 80.6              | 57.1              | <0.001  | 76.1                   | 95.7         | <0.001        |
| CAL, mean (SD)         | 2.55 (0.72)       | 2.52 (0.73)       | 2.46 (0.67)       | 0.015   | 2.57 (0.73)            | 2.50 (0.71)  | 0.005         |
| Dental plaque (debris index simplified), mean (SD) | 0.81 (0.44) | 0.69 (0.39) | 0.58 (0.38) | <0.001 | 0.80 (0.45) | 0.68 (0.40) | <0.001 |
| Calculus (calculus index simplified), mean (SD) | 0.57 (0.51) | 0.45 (0.44) | 0.36 (0.39) | <0.001 | 0.58 (0.52) | 0.44 (0.43) | <0.001 |
| %BOP, mean (SD)        | 24.1 (23.0)       | 19.4 (21.0)       | 17.1 (19.6)       | <0.001  | 23.7 (22.2)            | 19.5 (21.2)  | <0.001        |
| Number of teeth, mean (SD) | 28.0 (2.5) | 27.8 (2.6) | 27.7 (2.4) | 0.049 | 28.0 (2.5) | 27.8 (2.6) | 0.009 |
| Occupational status, % | <0.001            | <0.001            | <0.001            |         | <0.001                 | <0.001       | <0.001        |
| Office workers         | 29.8              | 27.6              | 40.5              | 30.1    | 30.8                   | 32.2         | 32.2          |
| Skilled workers        | 40.5              | 35.2              | 21.1              | 41.4    | 32.2                   | 32.2         | 32.2          |
| Others                 | 29.7              | 37.1              | 38.4              | 28.5    | 37.0                   | 37.0         | 37.0          |
| Current smoking, %     | 38.4              | 24.9              | 11.8              | <0.001  | 40.2                   | 22.7         | <0.001        |
| High alcohol consumption, % | 30.0       | 25.2              | 17.3              | <0.001  | 34.1                   | 22.7         | <0.001        |
| Lack of regular physical activity, % | 70.0 | 64.3 | 53.9 | <0.001 | 70.2 | 62.3 | <0.001 |
| Eats snacks between meals, % | 27.1 | 31.5 | 42.1 | <0.001 | 24.7 | 34.2 | <0.001 |
| Prefers salty dishes, % | 17.5 | 13.0 | 9.5 | <0.001 | 20.4 | 11.9 | <0.001 |
| Skips breakfast, %     | 26.6              | 12.9              | 7.7               | <0.001  | 28.0                   | 12.7         | <0.001        |
| Eats more meat and oily food, % | 21.1 | 15.8 | 10.9 | <0.001 | 23.8 | 14.4 | <0.001 |
| Eats more sweet food, % | 11.8              | 13.0              | 13.5              | <0.001  | 10.7                   | 13.3         | 0.033         |
| Seldom eats home-cooked meals for dinner, % | 27.0 | 19.6 | 13.4 | <0.001 | 28.0 | 18.6 | <0.001 |
| Sleeping hours, %      |                   |                   |                   |         |                       |              |               |
| ≥7 hours               | 32.7              | 33.9              | 36.7              | 32.0    | 34.6                   | 34.6         |               |
| 6 hours                | 44.7              | 46.3              | 46.1              | 44.1    | 46.3                   | 46.3         |               |
| ≤5 hours               | 22.6              | 19.8              | 17.2              | 23.9    | 19.1                   | 19.1         |               |

Chi-square test was used for categorical variables, and Mann-Whitney U test or Kruskal-Wallis test was used for continuous variables.

CAL, clinical attachment level; %BOP, percentage of sites that bled upon probing; SD, standard deviation.
Table 4. Incidence of each metabolic abnormality

| Metabolic Abnormality                                      | Without each metabolic abnormality at baseline | Incidence of each metabolic abnormality |
|-----------------------------------------------------------|------------------------------------------------|----------------------------------------|
| Obesity                                                   | 3509                                           | 5.5%                                   |
| Hyperglycemia                                             | 3185                                           | 28.4%                                  |
| Diabetes                                                  | 4357                                           | 2.3%                                   |
| Hypertension based on the 2017 ACC/AHA guidelines         | 2870                                           | 16.8%                                  |
| Hypertension based on the JNC7 guidelines                 | 4043                                           | 7.9%                                   |
| Hypertriglyceridemia                                      | 3378                                           | 12.8%                                  |
| Low HDL                                                   | 4125                                           | 2.7%                                   |

ACC/AHA, American College of Cardiology/American Heart Association; JNC7, Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.
Table 5. Association between toothbrushing frequency and the development of each metabolic abnormality

| Development of each metabolic abnormality | Crude PRR (95% CI) | Adjusted PRR a (95% CI) |
|------------------------------------------|--------------------|------------------------|
| No | Yes | Model 1 | Model 2 | Model 1 | Model 2 |

**Obesity**

| Toothbrushing frequency, n (%) |  |  |  |  |  |
|--------------------------------|---|---|---|---|---|
| ≥3 times                       | 692 (97.2) | 20 (2.8) | 1 | 1 | 1 |
| 2 times                        | 1757 (94.8) | 96 (5.2) | 1.84 (1.15-2.96) | 1.22 (0.78-1.89) | 1.20 (0.77-1.88) |
| ≤1 time                        | 866 (91.7) | 78 (8.3) | 2.94 (1.82-4.76) | 1.80 (1.14-2.84) | 1.77 (1.12-2.80) |
| CAL, mean (SD)                 | 2.49 (0.72) | 2.58 (0.74) | 1.16 (0.99-1.35) | 1.13 (0.97-1.31) |

**Hyperglycemia**

| Toothbrushing frequency, n (%) |  |  |  |  |  |
|--------------------------------|---|---|---|---|---|
| ≥3 times                       | 495 (77.8) | 141 (22.2) | 1 | 1 | 1 |
| 2 times                        | 1224 (72.0) | 475 (28.0) | 1.26 (1.07-1.49) | 1.03 (0.88-1.21) | 1.04 (0.89-1.21) |
| ≤1 time                        | 561 (66.0) | 289 (34.0) | 1.53 (1.29-1.82) | 1.14 (0.96-1.38) | 1.14 (0.96-1.36) |
| CAL, mean (SD)                 | 2.47 (0.67) | 2.51 (0.72) | 1.05 (0.97-1.14) | 0.98 (0.91-1.06) |

**Diabetes**

| Toothbrushing frequency, n (%) |  |  |  |  |  |
|--------------------------------|---|---|---|---|---|
| ≥3 times                       | 808 (98.7) | 11 (1.3) | 1 | 1 | 1 |
| 2 times                        | 2234 (98.2) | 42 (1.8) | 1.37 (0.71-2.66) | 1.02 (0.56-1.85) | 1.02 (0.56-1.87) |
| ≤1 time                        | 1215 (96.3) | 47 (3.7) | 2.77 (1.45-5.31) | 1.62 (0.91-2.88) | 1.62 (0.91-2.88) |
| CAL, mean (SD)                 | 2.51 (0.70) | 2.71 (1.12) | 1.35 (1.11-1.65) | 1.07 (0.78-1.47) |

**Hypertension based on the 2017 ACC/AHA guidelines**

| Toothbrushing frequency, n (%) |  |  |  |  |  |
|--------------------------------|---|---|---|---|---|
| ≥3 times                       | 502 (87.8) | 70 (12.2) | 1 | 1 | 1 |
| 2 times                        | 1271 (83.5) | 251 (16.5) | 1.35 (1.05-1.72) | 1.14 (0.90-1.45) | 1.14 (0.90-1.45) |
| ≤1 time                        | 616 (79.4) | 160 (20.6) | 1.69 (1.30-2.18) | 1.27 (0.97-1.66) | 1.27 (0.97-1.66) |
| CAL, mean (SD)                 | 2.47 (0.70) | 2.55 (0.75) | 1.13 (1.02-1.25) | 1.03 (0.93-1.15) |

**Hypertension based on the JNC7 guidelines**

| Toothbrushing frequency, n (%) |  |  |  |  |  |
|--------------------------------|---|---|---|---|---|
| ≥3 times                       | 710 (92.6) | 57 (7.4) | 1 | 1 | 1 |
| 2 times                        | 1955 (92.3) | 163 (7.7) | 1.04 (0.78-1.38) | 0.92 (0.70-1.23) | 0.93 (0.70-1.23) |
| ≤1 time                        | 1057 (91.3) | 101 (8.7) | 1.17 (0.86-1.60) | 0.88 (0.64-1.22) | 0.89 (0.64-1.22) |
| CAL, mean (SD)                 | 2.50 (0.71) | 2.62 (0.80) | 1.21 (1.07-1.36) | 1.09 (0.96-1.25) |

**Hypertriglyceridemia**

| Toothbrushing frequency, n (%) |  |  |  |  |  |
|--------------------------------|---|---|---|---|---|
| ≥3 times                       | 644 (91.5) | 60 (8.5) | 1 | 1 | 1 |
| 2 times                        | 1563 (87.2) | 230 (12.8) | 1.51 (1.15-1.97) | 1.12 (0.87-1.45) | 1.12 (0.87-1.45) |
| ≤1 time                        | 738 (83.8) | 143 (16.2) | 1.90 (1.43-2.53) | 1.24 (0.94-1.63) | 1.23 (0.94-1.63) |
Poisson regression models with robust standard error; each metabolic abnormality was the dependent variable and toothbrushing frequency was the independent variable.

The crude model included one independent variable and one dependent variable.

| Toothbrushing frequency, n (%) | ≥3 times | 2 times | ≤1 time | CAL, mean (SD) |
|-------------------------------|----------|---------|---------|----------------|
|                               | 786 (97.6) | 2102 (97.4) | 1143 (96.9) | 2.50 (0.73) |
|                               | 19 (2.4) | 56 (2.6) | 37 (3.1) | 2.51 (0.68) |
|                               | 1 | 1.07 (0.64-1.80) | 1.30 (0.75-2.24) | 1.01 (0.90-1.14) |
|                               | 1 | 1.06 (0.65-1.73) | 1.21 (0.67-2.20) | 1.04 (0.93-1.17) |
|                               | 1 | 1.08 (0.66-1.76) | 1.23 (0.68-2.23) | 1.04 (0.93-1.17) |
|                               | 1 | 1.06 (0.65-1.73) | 1.21 (0.67-2.20) | 1.04 (0.93-1.17) |
|                               | 1 | 1.08 (0.66-1.76) | 1.23 (0.68-2.23) | 1.04 (0.93-1.17) |

Model 1 adjusted for age, sex, number of teeth, BMI, eating snacks between meals, preferring salty dishes, skipping breakfast, eating meat and oily food, eating sweet food, seldomly eating home-cooked meals, smoking, alcohol consumption, physical activity, sleeping hours, job, and baseline value of each metabolic abnormality, and Model 2 additionally included mean CAL.

CAL, clinical attachment level; ACC/AHA, American College of Cardiology/American Heart Association; JNC7, Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; HDL, high-density lipoprotein; PRR, prevalence rate ratio; CI, confidence interval.
Table 6. Association between brushing teeth at night and the development of each metabolic abnormality

| Development of each metabolic abnormality | Crude PRR (95% CI) | Adjusted PRR \( {\text{a}} \) (95% CI) |
|-------------------------------------------|--------------------|--------------------------------------|
| N | Yes | No | | Model 1 | Model 2 | Model 1 | Model 2 |
|-------------------------------------------|--------------------|--------------------------------------|
| **Obesity**                               |                    |                                      |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 2702 (95.2)        | 135 (4.8)                            | 1        | 1        | 1        |
| No                                       | 613 (91.2)         | 59 (8.8)                             | 1.85 (1.37-2.48) | 1.51 (1.14-1.99) | 1.49 (1.13-1.96) |
| CAL, mean (SD)                            | 2.49 (0.72)        | 2.58 (0.74)                          | 1.16 (0.99-1.35) | 1.13 (0.97-1.32) |
| **Hyperglycemia**                         |                    |                                      |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 1898 (73.5)        | 685 (26.5)                           | 1        | 1        | 1        |
| No                                       | 382 (63.5)         | 220 (36.5)                           | 1.38 (1.22-1.56) | 1.14 (1.00-1.29) | 1.14 (1.00-1.29) |
| CAL, mean (SD)                            | 2.47 (0.67)        | 2.51 (0.72)                          | 1.05 (0.97-1.14) | 0.98 (0.91-1.06) |
| **Diabetes**                              |                    |                                      |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 3369 (98.0)        | 68 (2.0)                             | 1        | 1        | 1        |
| No                                       | 888 (96.5)         | 32 (3.5)                             | 1.76 (1.16-2.66) | 1.08 (0.73-1.60) | 1.07 (0.72-1.60) |
| CAL, mean (SD)                            | 2.51 (0.70)        | 2.71 (1.12)                          | 1.35 (1.11-1.65) | 1.09 (0.80-1.48) |
| **Hypertension based on the 2017 ACC/AHA guidelines** | | | | | |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 1960 (84.4)        | 361 (15.6)                           | 1        | 1        | 1        |
| No                                       | 429 (78.1)         | 120 (21.9)                           | 1.41 (1.17-1.69) | 1.16 (0.97-1.40) | 1.16 (0.96-1.39) |
| CAL, mean (SD)                            | 2.47 (0.70)        | 2.55 (0.75)                          | 1.13 (1.02-1.25) | 1.03 (0.92-1.14) |
| **Hypertension based on the JNC7 guidelines** | | | | | |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 2955 (92.4)        | 243 (7.6)                            | 1        | 1        | 1        |
| No                                       | 767 (90.8)         | 78 (9.2)                             | 1.21 (0.95-1.55) | 1.02 (0.80-1.31) | 1.02 (0.80-1.31) |
| CAL, mean (SD)                            | 2.50 (0.71)        | 2.62 (0.80)                          | 1.21 (1.07-1.36) | 1.09 (0.96-1.25) |
| **Hypertriglyceridemia**                  |                    |                                      |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 2424 (88.2)        | 324 (11.8)                           | 1        | 1        | 1        |
| No                                       | 521 (82.7)         | 109 (17.3)                           | 1.47 (1.20-1.79) | 1.08 (0.89-1.31) | 1.08 (0.89-1.31) |
| CAL, mean (SD)                            | 2.50 (0.73)        | 2.51 (0.68)                          | 1.01 (0.90-1.14) | 1.04 (0.93-1.17) |
| **Low HDL**                               |                    |                                      |
| Brushing teeth at night, n (%)            |                    |                                      |
| Yes                                      | 3174 (97.3)        | 89 (2.7)                             | 1        | 1        | 1        |
| No                                       | 839 (97.3)         | 23 (2.7)                             | 0.98 (0.62-1.54) | 0.93 (0.58-1.49) | 0.94 (0.59-1.50) |
| CAL, mean (SD)                            | 2.51 (0.72)        | 2.44 (0.62)                          | 0.88 (0.68-1.13) | 0.87 (0.67-1.12) |

Poisson regression models with robust standard error; each metabolic abnormality was the dependent variable and not brushing teeth at night was the independent variable.

The crude model included one independent variable and one dependent variable.

\( {\text{a}} \) Model 1 adjusted for age, sex, number of teeth, BMI, eating snacks between meals, preferring salty dishes, skipping breakfast, eating meat and oily food, eating sweet food, seldomly eating home-cooked meals,
smoking, alcohol consumption, physical activity, sleeping hours, job, and baseline value of each metabolic abnormality, and Model 2 additionally included mean CAL. 

CAL, clinical attachment level; ACC/AHA, American College of Cardiology/American Heart Association; JNC7, Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; HDL, high-density lipoprotein; PRR, prevalence rate ratio; CI, confidence interval.
Table 7. Association between toothbrushing at night and the development of each metabolic abnormality based on toothbrushing frequency

| Development of each metabolic abnormality | 
|----------------------------------------|
| No | Yes | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|----------------------------------------|
| Model 1 | Model 2 |

**Twice a day toothbrushing**

**Obesity**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 1699 (94.9) | 58 (92.1) | 1.56 (0.66-3.71) | 1.48 (0.66-3.32) |
|                        | 91 (5.1) | 5 (7.9) | 1.05 (0.83-1.32) | 1.03 (0.80-1.32) |
| CAL, mean (SD)         | 2.50 (0.74) | 2.52 (0.71) |

**Hyperglycemia**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 1190 (71.9) | 34 (77.3) | 0.81 (0.47-1.40) | 0.68 (0.39-1.19) |
|                        | 465 (28.1) | 10 (22.7) | 0.99 (0.87-1.15) | 1.00 (0.90-1.11) |
| CAL, mean (SD)         | 2.47 (0.68) | 2.53 (0.78) |

**Diabetes**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 2163 (98.2) | 71 (97.3) | 1.51 (0.37-6.12) | 0.77 (0.19-3.09) |
|                        | 40 (1.8) | 2 (2.7) | 1.39 (1.08-1.79) | 1.38 (1.04-1.83) |
| CAL, mean (SD)         | 2.51 (0.71) | 2.79 (1.47) |

**Hypertension in 2017 ACC/AHA guideline**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 1228 (83.6) | 43 (81.1) | 1.15 (0.65-2.03) | 1.11 (0.66-1.90) |
|                        | 241 (16.4) | 10 (18.9) | 1.14 (1.00-1.29) | 1.07 (0.93-1.24) |
| CAL, mean (SD)         | 2.48 (0.73) | 2.57 (0.74) |

**Hypertension in JNC7**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 1890 (92.3) | 65 (92.9) | 0.93 (0.39-2.18) | 1.09 (0.50-2.38) |
|                        | 158 (7.7) | 5 (7.1) | 1.13 (0.97-1.33) | 1.03 (0.86-1.24) |
| CAL, mean (SD)         | 2.50 (0.74) | 2.58 (0.73) |

**Hypertriglyceridemia**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 1516 (87.2) | 47 (85.5) | 1.14 (0.59-2.19) | 0.85 (0.44-1.61) |
|                        | 222 (12.8) | 8 (14.5) | 0.98 (0.84-1.14) | 1.04 (0.89-1.21) |
| CAL, mean (SD)         | 2.51 (0.75) | 2.49 (0.68) |

**Low HDL**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 2031 (97.4) | 71 (98.6) | 1 | 0.53 (0.07-3.75) |
|                        | 55 (2.6) | 1 (1.4) | 0.70 (0.45-1.09) | |
| CAL, mean (SD)         | 2.51 (0.73) | 2.57 (0.71) |

**Once a day toothbrushing**

**Obesity**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 238 (94.4) | 402 (91.4) | 1.56 (0.86-2.81) | 1.20 (0.66-2.17) |
|                        | 14 (5.6) | 38 (8.6) | 1.39 (1.05-1.84) | 1.12 (0.85-2.12) |
| CAL, mean (SD)         | 2.52 (0.71) | 2.73 (0.74) |

**Hyperglycemia**

| Toothbrushing at night | Yes | No | Crude PRR (95%CI) | Adjusted PRR (95%CI) |
|------------------------|-----|----|-------------------|---------------------|
|                        | 238 (94.4) | 402 (91.4) | 1.56 (0.86-2.81) | 1.20 (0.66-2.17) |
|                        | 14 (5.6) | 38 (8.6) | 1.39 (1.05-1.84) | 1.12 (0.85-2.12) |
| CAL, mean (SD)         | 2.52 (0.71) | 2.73 (0.74) |
|                        | Yes       | No        | PRR                          | CI                          |
|------------------------|-----------|-----------|------------------------------|-----------------------------|
| **Diabetes**           |           |           |                              |                             |
| Toothbrushing at night |           |           |                              |                             |
| Yes                    | 156 (73.9)| 55 (26.1) | 1                            | 1                           |
| No                     | 245 (61.1)| 156 (38.9)| 1.49 (1.15-1.93)             | 1.30 (1.02-1.66)            |
| CAL, mean (SD)         | 2.51 (0.67)| 2.55 (0.66)| 1.05 (0.90-1.23)             | 0.99 (0.84-1.16)            |
| **Hypertension in 2017 ACC/AHA guideline** | | | | |
| Toothbrushing at night |           |           |                              |                             |
| Yes                    | 280 (96.6)| 10 (3.4)  | 1                            | 1                           |
| No                     | 587 (96.2)| 23 (3.8)  | 1.09 (0.53-2.27)             | 0.56 (0.24-1.31)            |
| CAL, mean (SD)         | 2.55 (0.70)| 2.76 (0.85)| 1.42 (0.95-2.12)             | 0.94 (0.63-1.39)            |
| **Hypertension in JNC7** |           |           |                              |                             |
| Toothbrushing at night |           |           |                              |                             |
| Yes                    | 158 (82.3)| 34 (17.7) | 1                            | 1                           |
| No                     | 268 (77.0)| 80 (23.0) | 1.30 (0.91-1.86)             | 1.17 (0.81-1.67)            |
| CAL, mean (SD)         | 2.51 (0.67)| 2.56 (0.79)| 1.09 (0.86-1.39)             | 0.98 (0.77-1.24)            |
| **Hypertriglyceridemia** |           |           |                              |                             |
| Toothbrushing at night |           |           |                              |                             |
| Yes                    | 193 (86.9)| 29 (13.1) | 1                            | 1                           |
| No                     | 356 (84.0)| 68 (16.0) | 1.23 (0.82-1.84)             | 0.87 (0.57-1.33)            |
| CAL, mean (SD)         | 2.52 (0.70)| 2.60 (0.74)| 1.15 (0.90-1.46)             | 0.96 (0.90-1.02)            |
| **Low HDL**            |           |           |                              |                             |
| Toothbrushing at night |           |           |                              |                             |
| Yes                    | 266 (96.7)| 9 (3.3)   | 1                            | 1                           |
| No                     | 549 (97.2)| 16 (2.8)  | 0.87 (0.39-1.93)             | 1.14 (0.48-2.73)            |
| CAL, mean (SD)         | 2.54 (0.70)| 2.40 (0.57)| 0.73 (0.41-1.28)             | 0.71 (0.38-1.34)            |

Poisson regression models with robust standard error; each metabolic abnormalities was the dependent variable and no toothbrushing at night was the independent variable.

The crude model included one independent variable and dependent variable.

a Model 1 adjusted for age, sex, number of teeth, BMI, eating snacks between meals, preferring salty dishes, skipping breakfast, eating meat and oily food, eating sweet food, seldomly eating home-cooked meals, smoking, alcohol consumption, physical activity, sleeping hours, job, and baseline value of each metabolic abnormality, and Model 2 additionally included mean CAL.

CAL, clinical attachment level; HDL, high-density lipoprotein; PRR, prevalence rate ratio; CI, confidence interval.
6,829 participants received medical and dental examination in 2003

Inclusion criteria
35 to 64 years old
Having ≥1 teeth
Having medical records in 2008

4,804 eligible participants

Exclusion criteria
267 had missing data

4,537 participants analyzed

Outcome
- Obesity: 3,509 participants without obesity in 2003 analyzed.
- Hyperglycemia: 3,185 participants without hyperglycemia in 2003 analyzed.
- Diabetes: 4,357 participants without diabetes in 2003 analyzed.
- Hypertension based on the ACC/AHA guidelines: 2,870 participants without hypertension based on this guidelines in 2003 analyzed.
- Hypertension based on the JNC7 guidelines: 4,043 participants without hypertension based on this guidelines in 2003 analyzed.
- Hypertriglyceridemia: 3,378 participants without hypertriglyceridemia in 2003 analyzed.
- Low HDL: 4,125 participants without low HDL in 2003 analyzed.