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ORIGINAL

Association between diabetes-related clinical indicators and oral health behavior among patients with type 2 diabetes

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Abstract : Objective : The aim of this study was to evaluate the association between diabetes-related indicators and oral health behavior among patients with type 2 diabetes. Methods : Seventy-four outpatients were included. We administered a questionnaire and divided the patients into two groups according to oral health behavior and eating habits. We then compared diabetes-related clinical records between the groups and performed logistic regression analysis. Results : Participants who brushed their teeth before bedtime every night had lower BMIs than those who did not. Participants who reported eating slowly and chewing well every day had significantly lower HbA1c than their counterparts. Participants who reported gum bleeding had significantly higher LDL-cholesterol than their counterparts. Binominal logistic regression analysis revealed that BMI < 25 was associated with not brushing teeth before bedtime every night, HbA1c < 7.5 with not eating slowly or chewing well every day, and LDL-cholesterol < 120 with gum bleeding (odds ratio : 0.140, 95% confidence interval : 0.036–0.540 ; OR : 0.085, 95% CI : 0.010–0.736, OR : 0.275, 95% CI : 0.077–0.979, respectively). Conclusions : Our findings suggest that toothbrushing before bedtime every night is associated with reduced risk of obesity and that eating slowly and chewing well are advantageous for glycemic control in patients with type 2 diabetes.
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Keywords **:** *oral health behavior, type 2 diabetes, glycemic control, body mass index, toothbrushing habit*

INTRODUCTION

Diabetes affects disorders of the oral cavity. In particular, periodontal disease and diabetes are closely associated. A number of intervention studies have shown improved glycemic control following periodontal treatment, suggesting that periodontal inflammation is associated with compromised glycemic control (1-3). In a systemic review and meta-analysis on the association between oral hygiene and periodontitis, Lertpimonchai *et al*. concluded that poor oral hygiene increases the risk of periodontitis two- to five-fold compared with good oral hygiene, and that oral care habits, including regular brushing and dental visits, can decrease the risk of periodontitis (4). It is widely recognized that people with diabetes should be advised to practice good oral hygiene to optimize oral health (5, 6).

Onset of type 2 diabetes is affected by lifestyle factors such as overeating, insufficient exercise, and obesity. Eating rapidly without chewing well was recently reported to be a strong risk factor for new-onset diabetes among the Japanese general population (7). Healthy eating behavior, which slows down postprandial hyperglycemia, has gained much attention. Because eating slowly and chewing food well helps to prevent overeating, these habits are emphasized when giving guidance on prevention of obesity. Dental professionals also conventionally recommend thorough chewing because mastication has many desirable effects, such as increased saliva secretion, promotion of self-cleaning actions in the mouth, and activation of the tongue and perioral muscles.

Several recent studies have suggested a possible association between oral health behaviors and metabolic syndrome, including diabetes (5, 8, 9). According to a web-based survey of individuals with (n = 408) and without type-2 diabetes (n = 408) by Ohyama *et al*., a significantly greater percentage of people in an obese group (BMI ≥ 25) than in a non-obese group (BMI < 25) did not brush their teeth before bedtime every night (χ^2 test, $p < 0.001$) (8).

It can be expected that oral health guidance for patients with diabetes might both improve their oral health and help them to develop healthy oral health behaviors and eating habits, leading to prevention of severe diabetes. In this study, we aimed to clarify the association between oral health behavior and diabetes-related clinical indicators among patients with diabetes to obtain evidence to support education of patients with diabetes by dental professionals.

METHODS

The study cohort comprised 74 outpatients with diabetes who were receiving treatment regularly at a medical department specializing in diabetes. Patients who met one or more of the following criteria were excluded : taking insulin, undergoing dialysis, and requiring hospitalization. An oral examination was performed and a structured questionnaire related to oral health behavior (Fig. 1) administered. This structured questionnaire was developed by the Japanese Dental Association as a standard questionnaire for adult dental checkups (10). Diabetes-related clinical data were also obtained from clinical records. Student's *t*-test or the Mann–Whitney U test was used to compare clinical data related to oral health behavior between the two groups as shown in Figure 1 (Items Q1, Q3, Q4, Q5, Q8, Q12, Q15, Q17,

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Q1 Are you warried anything in your mouth? (Yes, No)
Q1-2 If Yes on Q1, what is it? Please check the applicable ones. (1) bite (2) appearance (3) speech (4) bad breath (5) pain (6) other
Q2 How many present teeth do you have? Do you have 20 teeth and more? (Yes, No)
Q3 Can you chew firmly with your back teeth? (both side; one side, not both)
Q4 Do your gum bleed on toothbrushing? (No; sometimes, usually)
Q5 Is your gum swelling? (No; sometimes, usually)
Q6 Are your teeth sensitive to the cold or the hot? (No, sometimes, usually)
Q7 Do you have a primary dentist? (Yes, No)
Q8 Are you sometimes too busy to go to dentist? (No, Yes)
Q9 Are you treated for these diseases? (Diabetes/ Stroke/Heart disease)
Q10 Do your family and/or people around are interested in oral health? (Yes, unclear, No)
Q11 Do you have confidence in your teeth, or have you ever been praised on your teeth? (Yes, unclear, No)
Q12 Do you brush your teeth at your workplace or outside? (every day, sometimes; No)
Q13 Do you have snacks (sweet food and/or drink)? (No, sometimes, every day)
Q14 Do you smoke? (No, Yes)
Q15 Do you brush your teeth before bedtime? (every day; sometimes, No)
Q16 Do you use toothpaste containing fluoride? (Yes, No, unclear)
Q17 Do you use interdental brush or dental floss? (every day, sometimes; No)
Q18 Do you eat slowly and with well chewing during meal? (every day; sometimes, No)
Q19 Have you ever been received tooth brushing instruction at dental office? (Yes, No)
Q20 Do you receive a periodical checkup at dental office more than once a year? (Yes, No)

Figure 1. Questionnaire
Semicolons in parentheses indicate the boundary when divided into two groups for Student's *t*-test or Mann–Whitney U test.

Q18, Q20). Binominal logistic regression analysis was used to identify factors associated with obesity, high glycated hemoglobin (HbA1c), or LDL-cholesterol. Statistical analyses were performed using IBM SPSS 22.0 (IBM, Tokyo, Japan), and statistical significance was set at <0.05. This study was approved by the ethics committee of Kawashima Hospital (No. 0366) and all participants provided written informed consent to inclusion.

RESULTS

Characteristics of study participants and distribution of clinical indicators

The characteristics of the study participants are shown in Table 1. They comprised 48 men and 26 women of mean age 63.7 (standard deviation [SD] 12.4) years, range 34-85 years. The mean duration of diabetes was 8.3 (SD 6.2) years. The distribution of clinical indicators is shown in Table 2. The Shapiro–Wilk test confirmed normal distributions for BMI, LDL-cholesterol, and eGFR. Therefore, Student's *t*-test was used for these variables and the Mann–Whitney U test for the remaining variables.

Table 1. Characteristics of study participants (n = 74)

Age (y)	63.7±12.4
Female	35.1%
Treatment for glycemic control	
Diet and exercise only	8.1%
Diet, exercise and antihyperglycemic agents	91.9%
Administration of antihyperlipidemic agents	52.7%
Administration of antihypertensive agents	56.8%
Exercise habit	32.4%
Smoking habit	27.0%
Frequent alcohol consumption	16.2%

The age distribution of the study participants and types of antihyperglycemic, antihyperlipidemic, and antihypertensive agents prescribed for them are shown in Supplemental Tables 1, 2, 3, and 4, respectively.

Associations between oral health behavior/oral health condition/eating habits, and diabetes-related clinical indicators

Analysis using Student's *t*-test showed that participants who brushed their teeth before bedtime every night had lower BMI and LDL-cholesterol than those who did not brush nightly (Fig. 2). No significant differences in baseline characteristics (age, sex, and administration of antihyperlipidemic agents) were found between the two groups.

Both participants who reported that their gums bled when brushing their teeth and those who reported being too busy to go to the dentist had higher LDL-cholesterol concentrations than their counterparts (Fig. 3). Both of these patient groups were younger than their counterparts ; however, no differences were found between the groups in other baseline attributes such as sex and administration of antihyperlipidemic agents.

Analysis using the Mann–Whitney U test showed that participants who ate slowly and chewed their food well every day had a lower HbA1c than those who did not (Fig. 4). No significant differences in baseline characteristic (age, sex, and administration of antihyperglycemic agents) were found between these two groups.

As for other combinations of oral health behavior/oral health condition/eating habits and diabetes-related clinical indicators, no statistically significant differences were found.

Table 2. Distribution of clinical indicators in study participants

	n	Minimum	Median	Maximum	Mean	SD
Age (y)	74	34	65	85	63.7	12.4
Duration of diabetes (y)	74	0.2	7	35	8.3	6.2
BMI (kg/m^2)[a]	74	17.8	25.0	34.0	25.5	3.4
HbA1c (%)	72	5.4	6.8	11.4	6.9	0.9
Neutral fat	71	37	156	1020	185	139
HDL-cholesterol	71	28	53	112	55	16
LDL-cholesterol[a]	71	53	101	172	104	27
Serum creatinine	73	0.45	0.78	3.31	0.88	0.41
eGFR[a]	73	11	73	120	71	21
Number of present teeth	74	0	25	30	21.9	8.6
Number of decayed teeth	74	0	0	7	0.6	1.2
Number of filled teeth	74	0	8.5	23	9.1	6.2

[a] Normal distribution confirmed using Shapiro–Wilk test.
Abbreviations : BMI, body mass index ; eGFR, estimated glomerular filtration rate ; HbA1c, glycated hemoglobin ; HDL, high-density lipoprotein; LDL, low-density lipoprotein ; SD, standard deviation.

Supplemental Table 1. Age distribution of study participants (n = 74)

Age range	Number	%
30 - 39	2	2.7%
40 - 49	11	14.9%
50 - 59	13	17.6%
60 - 69	21	28.4%
70 - 79	21	28.4%
80 - 89	6	8.1%

Supplemental Table 2. Types of antihyperglycemic agent[a] prescribed for participants

Class	number	%[b]
Biguanides	43	58.1%
Thiazolidinediones	1	1.4%
Sulfonylureas	10	13.5%
Meglitinides	12	16.2%
DPP-4 inhibitors	46	62.2%
α-Glucosidase inhibitors	23	31.1%
SGLT-2 inhibitors	26	35.1%
GLP-1 receptor agonists	11	14.9%

[a] Compounding agent was included in both classes.
[b] Percentage of all study participants

Supplemental Table 3. Types of antihyperlipidemic agent prescribed for participants

Class	number	%[a]
Statins	31	41.9%
Fibrates	6	8.1%
Ezetimibe	2	2.7%

[a] Percentage of all study participants

Supplemental Table 4. Types of antihypertensive agents[a] prescribed for participants

Class	number	%[b]
Calcium channel blockers	27	36.5%
ACE inhibitors	5	6.8%
Angiotensin II receptor blockers	26	35.1%
Diuretics	3	4.1%
β-blockers	3	4.1%

[a] Compounding agent was included in both classes.
[b] Percentage of all study participants

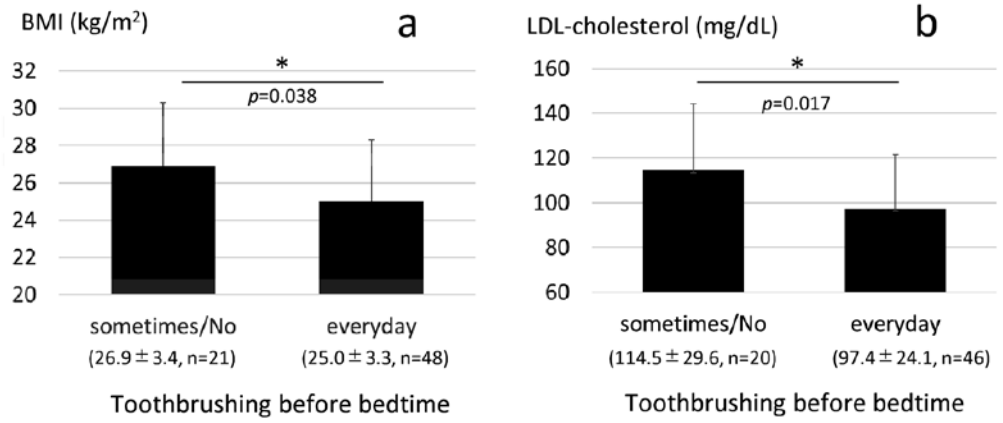

Figure 2. Association between toothbrushing before bedtime and (a) BMI or (b) LDL-cholesterol
* : $p < 0.05$ (Student's t-test)

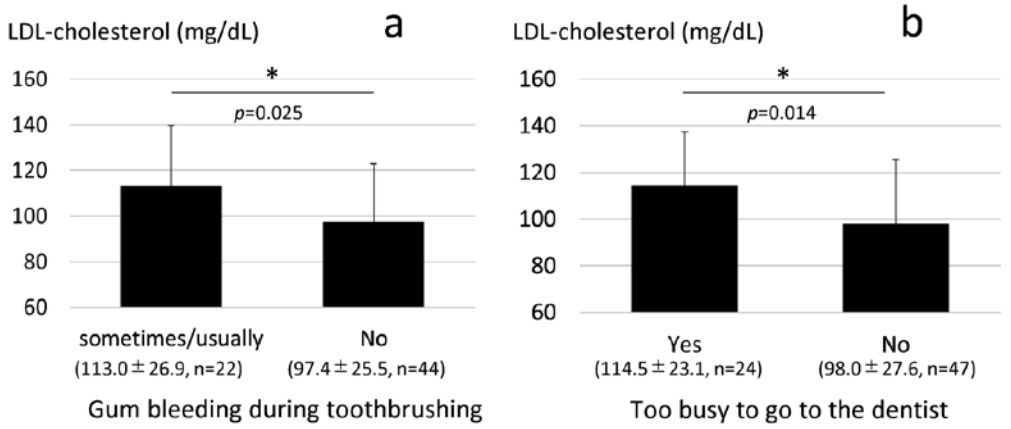

Figure 3. Association between (a) gum bleeding or (b) being too busy to go to the dentist and LDL-cholesterol
* : $p < 0.05$ (Student's t-test)

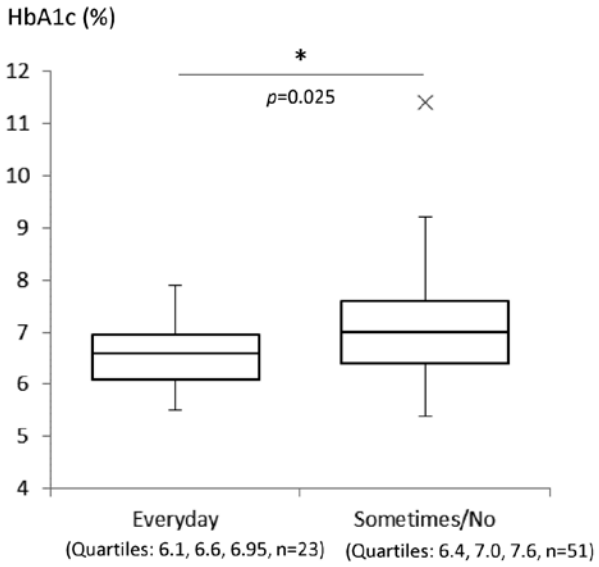

Figure 4. Association between slow eating with chewing well and HbA1c
* : $p < 0.05$ (Mann–Whitney U test)

Factors associated with obesity, high HbA1c or high LDL-cholesterol

We performed binominal logistic regression analysis using BMI < 25, HbA1c < 7.5, or LDL-cholesterol < 120 as the outcome variable and the variables listed in Table 3 as independent variables. The results showed that being in the habit of brushing the teeth before bedtime was associated with BMI < 25, whereas eating slowly and chewing well were associated with HbA1c < 7.5 (Tables 4 and 5). We also found that absence of oral symptoms including bleeding during toothbrushing, was associated with LDL-cholesterol < 120 (Table 6).

Table 3. Variables used in binominal logistic regression analysis

Outcome variable	Independent variables
BMI < 25	Age, sex, duration of diabetes, HbA1c (%), administration of antihyperglycemic agents, perceived oral symptoms (Q1 : No), currently having ≥20 teeth, chewing firmly with molars (Q3 : one side/not both), bleeding gum (Q4 : sometimes/usually), too busy to go to dentist (Q8 : No), toothbrushing before bedtime (Q15 : sometimes/no), eat slowly and chew well (Q18 : sometimes/no), periodical dental checkup (Q20 : No)
HbA1c < 7.5	Age, sex, duration of diabetes, BMI (kg/m^2), administration of antihyperglycemic agents, perceived oral symptoms (Q1 : No), currently having ≥20 teeth, chewing firmly with molars (Q3 : one side/not both), bleeding gums (Q4 : sometimes/usually), too busy to go to dentist (Q8 : No), toothbrushing before bedtime (Q15 : sometimes/no), eat slowly and chew well (Q18 : sometimes/no), periodical dental checkup (Q20 : No)
LDL-cholesterol < 120	Age, sex, duration of diabetes, BMI (kg/m^2), HbA1c (%), administration of antihyperglycemic agents, administration of antihyperlipidemic agents, perceived oral symptoms (Q1 : No), currently having ≥20 teeth, chewing firmly with molars (Q3 : one side/not both), bleeding gums (Q4 : sometimes/usually), too busy to go to dentist (Q8 : No), toothbrushing before bedtime (Q15 : sometimes/no), eat slowly and chew well (Q18 : sometimes/no), periodical dental checkup (Q20 : No)

Independent variables: QX refers to items in the questionnaire shown in Figure 1.ntage of all study participants

Table 4. Odds ratios and 95% confidence intervals for the "BMI < 25" group according to binominal logistic regression analysis[a] (n = 67)

Variable[b]	OR	95%CI	P-value
Age (y)	1.043	0.998–1.091	0.062
Chewing firmly with molars			
one side/not both	3.454	0.941–12.678	0.062
both sides (ref.)			
Toothbrushing before bedtime			
sometimes/no	0.140	0.036–0.540	0.004
every day (ref.)			

[a] : According to stepwise backwards (Wald) method
[b] : Variables used are shown in Table 3.
ref. : reference category

Table 5. Factors associated with "HbA1c < 7.5" according to binominal logistic regression analysis[a] (n = 67)

Variable[b]	OR	95%CI	P-value
Too busy to go to dentist			
No	3.907	0.873–17.485	0.075
Yes (ref.)			
Eating slowly and chewing well			
sometimes/no	0.085	0.010–0.736	0.025
every day (ref.)			
Periodical dental checkup			
No	0.228	0.052–1.004	0.051
Yes (ref.)			

[a] : According to stepwise backwards (Wald) method
[b] : Variables used are shown in Table 3.
ref. : reference category

Table 6. Factors associated with "LDL-cholesterol <120" according to binominal logistic regression analysis[a] (n = 67)

Variable[b]	OR	95%CI	P-value
Administration of antihyperlipidemic agent			
Yes	4.675	1.276–17.131	0.020
No (ref.)			
Perceived oral symptoms			
No	3.680	1.056–12.821	0.041
Yes (ref.)			
Bleeding gums			
sometimes/usually	0.275	0.077–0.979	0.046
No (ref.)			
Eating slowly and chewing well			
sometimes/no	0.244	0.056–1.060	0.060
Every day (ref.)			

[a] : According to stepwise backwards (Wald) method
[b] : Variables used are shown in Table 3.
ref. : reference category

DISCUSSION

Many studies have reported that type 2 diabetes is associated with lifestyle factors such as diet, physical activity, and smoking (11, 12) ; however, only a few have reported a relationship between type 2 diabetes and oral health behavior. Su *et al*. reported that urban residents who rarely brushed their teeth had higher fasting plasma glucose and HbA1c concentrations than those who brushed more than twice daily (13). Kuwabara *et al*. reported an association between low frequency of toothbrushing and high prevalence of diabetes or dyslipidemia (14). These authors stated that a low frequency of toothbrushing leads to periodontal inflammation, which may be a risk factor for diabetes and dyslipidemia ; however, the responsible mechanism remains unclear (14).

Recently, Morita *et al*. reported a significant association between toothbrushing frequency (≥three times/day) and onset of obesity in a 4-year cohort study of individuals who were not obese (BMI <25kg/m^2) at baseline (15). They concluded that people who brushed their teeth frequently (i.e., had good toothbrushing practices) are at low risk of becoming obese. Although we were unable to investigate the frequency of toothbrushing in this study, we identified a relationship between habitual toothbrushing before bedtime and obesity among patients with diabetes. Regular tooth brushing before bedtime is a good practice, being equivalent to brushing three times a day. It is plausible that people who brush their teeth before going to bed each night would tend to have healthy habits, including consuming a healthy diet and avoiding overeating. In fact, our participants who brushed their teeth before bedtime every night had lower LDL-cholesterol concentrations than their counterparts who did not do so.

In this study, we found no significant relationships between non-obese status (BMI <25 kg/m^2) and "age" or "not chewing firmly with both molars" (Table 4) ; however, the P-values were relatively low. It is possible that chewing ability tends to decrease with aging and/or deterioration of occlusal condition of molars, which can lead to malnutrition.

As for glycemic control, it has been suggested that eating slowly and chewing food well leads to good glycemic control. A recent study on a cohort drawn from the general Japanese population reported that eating quickly is a strong risk factor for new-onset diabetes (7). Sakurai *et al*. reported an association between eating speed and incidence of diabetes in a 7-year cohort study (16). In that study, this association was not significant after adjusting for BMI because eating quickly is a risk factor for obesity (16). However, Nagahama *et al*. reported a statistically significant association between eating slowly and hyperglycemia or lipid abnormalities in men, after adjustment for BMI (17).

It has been reported that eating slowly decreases energy intake and suppresses postprandial hyperglycemia (18). Therefore, slow eating with thorough chewing may facilitate good glycemic control.

In this study, we administered a self-report questionnaire survey. Although we confirmed in face-to-face interviews that respondents correctly understood each question, they chose answers to the survey questions on their own, thereby making the responses subjective. One study found that self-reported eating rate is associated with obesity and cardiovascular risk factors (blood pressure, lipid concentrations, HbA1c) (19). That study also identified a significant association between eating rate and HbA1c, after multivariate adjustment, in patients with diabetes receiving insulin therapy (19).

As for lipidemic control, it has been suggested that periodontal conditions such as gum bleeding during toothbrushing may be associated with hyperlipidemia. Recently, Han *et al*. reported an association between LDL-cholesterol concentration and periodontal disease in the over-40 age group after analyzing data from the Korea National Health and Nutrition Examination Survey (20). The present findings are consistent with this.

When offering guidance on oral health, it is important to encourage good eating habits such as eating slowly and chewing well, as well as maintaining good oral hygiene, to prevent dental caries and periodontal disease. The importance of these habits must be more strongly emphasized in patients with diabetes who are at high risk of oral disease and poor glycemic control if they have chronic periodontal inflammation (6).

The government of Japan has focused on prevention of diabetic nephropathy to slow the increase in numbers of patients requiring dialysis (21). That initiative includes clear guidelines for the management of periodontal disease by dental professionals. Additionally, dental professionals can contribute to recommending good habits of oral health, such as slow eating and thorough chewing, in patients with diabetes.

A novel aspect of this study is that we identified factors

concerning oral health behavior and eating habits associated with diabetes-related clinical indicators in patients with diabetes.

The findings of the present study could be used for health promotion in patients with diabetes and could improve medical staff's understanding of comprehensive dental care.

According to the World Health Organization's definition of obesity as BMI ≥30 kg/m², only 2%–3% of the Japanese population are obese (22). However, the Japan Society for the Study of Obesity has proposed that individuals with BMI ≥25 kg/m² should be considered obese (23) and this definition is widely adopted in the field of community health activities and academic research. We therefore defined BMI ≥25 kg/m² as obese in this study.

Treatment goals for people with diabetes should be set individually taking into account such factors as age, presence of complications, and medications. The Japan Diabetes Society suggests higher glycemic control targets for older than younger individuals (24). Given that our study cohort included a wide range of ages, we defined HbA1c < 7.5 as not having poor glycemic control ; this could be a treatment goal for diabetes of all ages.

In this study, we defined LDL-cholesterol < 120 as not having poor lipidemic control because Japan Diabetes Society suggests a control goal of LDL-cholesterol < 120 in diabetes patients without a history of coronary artery disease (24).

We were unable to calculate the required sample size before starting this study because of the lack of previous research on the association between diabetes-related clinical indicators and oral health behavior among diabetes patients. Ohyama *et al*. reported that a significantly greater percentage of obese than non-obese people do not brush their teeth before bedtime every night ; however, they did not compare the mean BMI of their participants. In this study, we used Student's *t*-test to compare the mean BMI between "no habit of toothbrushing before bedtime" and "toothbrushing before bedtime every night". Effect size (Hedges' *g*) was 0.57, when calculated from the sample size, mean, and standard deviation (SD) of BMI in these groups (21, 26.9, 3.4 for no habit of toothbrushing before bedtime and 48, 25.0, 3.3 for toothbrushing before bedtime every night, respectively). The required sample size calculated by a one-sided test using a significance level of 0.05, power level of 0.75, and effect size (Hedges' *g*) of 0.57 was 34 for each group for a total of 68. Therefore, we consider the sample size in this study was appropriate.

Our study had several limitations. First, our findings may not be generalizable outside of Japan because the prevalence of obesity and/or oral health behavior differs considerably between countries (22). Second, although our study cohort included individuals with only a few teeth, we did not evaluate chewing ability or need for toothbrushing objectively. Additionally, in comparisons between the two groups, we did not adjust for baseline characteristics (e.g., age, sex). This was a cross-sectional study. A further study is needed to determine whether there is a causal relationship between oral health behavior and clinical indicators.

CONCLUSIONS

Habitual toothbrushing before bedtime may be associated with a reduced risk of obesity and/or hyperlipidemia. Eating habits, including eating slowly and chewing food well, may facilitate glycemic control. Both toothbrushing before bedtime and chewing well are important components of oral health guidance, meaning that educating diabetes patients about these habits may benefit them.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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