Abstract: Diabetes mellitus (DM) with poor glycemic control is often linked to oral manifestations. This study aimed to investigate the association between dental caries (DC) and glycated hemoglobin (HbA1c) among patients with type 2 DM (T2DM). A health center-based cross-sectional study was conducted comprising 91 eligible patients with T2DM (21 males and 70 females) with a mean age (± standard deviation) of 61.49 ± 9.71 years. A structured interview, screening for DM-related factors, and oral examination were performed. Serum HbA1c levels were used as an index for glycemic control. A comparison between patients with controlled T2DM, i.e., HbA1c ≤7.0% (n = 46), and uncontrolled T2DM, i.e., HbA1c >7.0% (n = 45), showed significant differences in mean values of decayed teeth (DT) (P = 0.045); missing teeth (P = 0.002); and decayed, missing, and filled teeth (DMFT) index (P < 0.001). Results of multiple linear regression analysis revealed that the number of DT was significantly correlated with serum HbA1c levels (95% confidence interval [CI] 0.173 to 0.972, P = 0.005). Furthermore, DMFT index values and serum HbA1c levels (95% CI 0.532 to 1.658, P < 0.001) showed a significant association. This study provides substantial evidence on the association between DC indicators and serum HbA1c levels.

Keywords: dental caries; glycated hemoglobin; type 2 diabetes mellitus.

Introduction
Most systemic diseases, including diabetes mellitus (DM), manifest with oral complications. DM comprises a group of chronic metabolic diseases generally characterized by hyperglycemia resulting from defects in
insulin secretion, insulin action, or a combination of both. Type 2 DM (T2DM) is predominantly an insulin secretory defect with insulin resistance and accounts for 90-95% of diabetes cases (1). Chronic metabolic disease involves numerous systemic manifestations associated with long-term damage; dysfunction; and failure of different organs such as eyes, kidneys, nerves, heart, and blood vessels, as well as noticeable oral health complications (1,2). A wide range of oral manifestations has been reported in DM patients, including periodontal diseases, tooth loss, salivary dysfunction, taste impairment, xerostomia, Candida infection, neurosensory disorder, and fluctuations in the prevalence of dental caries (DC) (2,3). Among these manifestations, periodontal diseases such as gingivitis and periodontitis have received much attention, with periodontal diseases being referred to as the “sixth complication of DM” in the early 1990s (4).

DC is one of the most prevalent chronic oral diseases worldwide. Individuals are vulnerable to caries experiences throughout their lifetime, with tooth loss being the ultimate consequence of DC (5). Individuals with T2DM are often obese and consume high-calorie and carbohydrate-containing foods; therefore, these individuals are expected to have a high exposure to cariogenic foods and are likely to develop DC (6). However, the relationship between glycemic control and DC incidence has received less attention, although both diseases are linked to carbohydrate ingestion (7). Some reports have suggested that there is no clear association between T2DM and DC prevalence (8,9). According to Lin et al. (10) diabetes and poor glycemic control may not be significantly associated with DC incidence in adults with T2DM; however, a tendency for more carious lesions was evident. Conversely, other studies have reported a greater history of DC in people with T2DM (11-13).

However, there is insufficient evidence to determine the relationship between glycemic control in patients with DM and DC incidence. Moreover, previous reports have mainly addressed the association between glycemic control and DC in patients with type 1 DM (T1DM) (14-17). Therefore, it is imperative to classify patients who might be at a high risk for DC.

Thus, the primary objective of this study was to distinguish the decayed, missing, and filled teeth (DMFT) index and periodontal health parameters between patients with controlled and uncontrolled T2DM. The secondary objective was to identify the relationship between number of decayed teeth (DT), DMFT index value, and serum glycated hemoglobin (HbA1c) levels in patients with T2DM. The following are the study hypotheses: 1) patients with uncontrolled T2DM have a higher DMFT index value than those with controlled T2DM and 2) the number of DT and DMFT index value are associated with serum HbA1c levels.

Materials and Methods

Study design and participants

A health center-based cross-sectional study was conducted among registered patients of the Mayor Juan R. Sanchez Memorial Health Center. This health center is governed by the municipality of Pateros, Philippines. Inclusion criteria for baseline screening were restricted to the following:

1. Patients pre-diagnosed with T2DM by a professional diabetologist
2. Patients who had been diagnosed as a diabetic for at least 1 year
3. Patients aged >30 years
4. Patients having at least one remaining natural tooth

Patients fulfilling any of the following criteria were not considered for initial screening:

1. Patients with T1DM
2. Patients with severe comorbidities such as myocardial infarction, stroke, severe renal dysfunction, retinopathy, and gangrene requiring hospitalization
3. Patients with dementia or mental illness
4. Pregnant or lactating women
5. Patients who had difficulty in completing surveys or participating during measurements

All participants were residents of Pateros and underwent a comprehensive assessment including an interview, screening for DM-related factors, and oral health assessment from March through April 2017.

Interview

A standardized pre-tested structured questionnaire was used for a face-to-face interview. The questionnaire comprised sociodemographic factors (age, sex, and educational level), general health behaviors (smoking, drinking, exercise habit, and duration of DM), oral hygiene behaviors (tooth brushing and flossing frequency, receiving oral health education, and regular dental visits), and perceived self-oral health. Each question and its corresponding answer options were translated into the Filipino (Tagalog) version from the English version by a professional native translator. Interviews were conducted by trained barangay health workers of Pateros.

Screening for DM-related factors

Participants were instructed to fast overnight before arriving at the Mayor Juan R. Sanchez Memorial Health Center. A health center-based cross-sectional study was conducted among registered patients of the Mayor Juan R. Sanchez Memorial Health Center. This health center is governed by the municipality of Pateros, Philippines. Inclusion criteria for baseline screening were restricted to the following:

1. Patients pre-diagnosed with T2DM by a professional diabetologist
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5. Patients who had difficulty in completing surveys or participating during measurements

All participants were residents of Pateros and underwent a comprehensive assessment including an interview, screening for DM-related factors, and oral health assessment from March through April 2017.
Health Center in the early morning; upon arrival, their blood samples were collected. Serum HbA1c levels were measured using Clover A1c Self’ (Infopia Co., Ltd. Gyeonggi-do, Republic of Korea) to determine the level of glycemic control. As recommended by the American Diabetes Association, glycemic control status was defined according to the HbA1c target of <7.0% (53 mmol/mol) (18). Therefore, patients with HbA1c levels of ≤7.0% were selected as the suboptimal control group for controlled T2DM, whereas those with the levels >7.0% were selected as uncontrolled T2DM group. Fasting blood glucose (FBG) was measured using GluNEO (Infopia Co., Ltd) and was set to ≤130 mg/dL for controlled and >130 mg/dL for uncontrolled T2DM. Body mass index (BMI) was measured using the Body Composition Meter (TANITA, MC-980A, Tokyo, Japan), and the cut-off point was set to ≤23 kg/m². All measurement devices were tested for reliability and validity prior to use.

Screening for oral health
Oral examinations were conducted by a dentist along with a data recorder assistant at the dental clinic of Mayor Juan R. Sanchez Memorial Health Center. DC and periodontal status were diagnosed according to the modified World Health Organization (WHO) oral health survey basic methods (5th ed. Geneva: 2013). Instruments for oral examination comprised plane mouth mirrors, metallic periodontal probes (Community Periodontal Index [CPI] probe) that conform to WHO specifications, tweezers, and gauze. DC was detected without using radiographs, and the numbers of DT, missing teeth (MT), and filled teeth (FT) were counted. DT was defined as a tooth with a decayed lesion on any surface, and FT was defined as filled and crowned teeth. Individual scores of DT + MT + FT were calculated to determine the DMFT index. The DMFT index is considered as a general indicator of an individual lifetime caries experience. For periodontal assessment, the modified CPI was applied; it helped evaluate two periodontal parameters: bleeding on probing (BOP) and periodontal pocket depth (PPD). BOP score was recorded as follows: 0, absence of gingival bleeding; 1, presence of gingival bleeding. PPD was recorded as follows: 0, absence of condition; 1, PPD 4-5 mm; and 2, PPD ≥6 mm. Standard biosafety norms were followed during the examinations.

Statistical analyses
Distribution of sociodemographic factors, lifestyle, and oral health behaviors were compared between the controlled and uncontrolled T2DM groups. Mann-Whitney U test was performed to analyze non-normally distributed continuous variables. If Shapiro-Wilk normality test showed normally distributed continuous variables, Student’s t-test was used. Chi-square test was performed for categorical variables. Comparisons of DC indicators (DT, MT, FT, and DMFT index) and periodontal health parameters (BOP, PPD 4-5 mm, and PPD ≥6 mm) by DM-related factors were performed using Mann-Whitney U test. Stepwise multiple linear regression analyses with Akaike information criterion were adopted to determine the association of illustrative variables (absolute DT and DMFT index values) with DM-related factors, general health behaviors, and oral health behaviors. The variance inflation factor (VIF) included the regression model to assess multicollinearity; however, none of the variables exceeded a VIF >2.0. All statistical analyses were conducted using IBM SPSS Statistics version 25 (IBM, Armonk, NY, USA). Statistical significance was set at P < 0.05.

Ethical aspects
This study was conducted in accordance with the Declaration of Helsinki (1964 World Medical Association General Assembly at Helsinki) and the Ethical Guidelines for Medical Research with Human Subjects (Japan Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare Notice, December 2014, Volume 3). This study was conducted after approval by the ethics review board of the Faculty of Medicine, Tottori University (No. 1608B013). Prior to the health screening, written informed consent was obtained from each participant after explaining the research purpose and consequences together with an assurance of confidentiality. The informed consent documents were also approved by the ethics review boards before the beginning of the study.

Results
Subject characteristics
A total of 145 (114 females and 31 males) patients were included in the initial screening, and 54 patients were excluded from the analysis because they had no naturally remaining teeth (53 patients) or were aged <30 years (1 patient). In total, 91 patients met the eligibility criteria and were included in this study; 21 (23.07%) patients were male and 70 (76.93%) were female with a mean age (± standard deviation) of 61.5 ± 9.7 years (range: 39-92 years).

Distribution of sociodemographic, lifestyle, and oral health behavior factors across T2DM groups are shown in Table 1. Among the eligible participants, the number
of patients with controlled T2DM, i.e., HbA1c ≤7.0%, (n = 46, 50.5%) was nearly equivalent to that of those with uncontrolled T2DM, i.e., HbA1c >7.0%, (n = 45, 49.5%). Moreover, there were no significant differences in age and sex between the two groups. Regarding continuous variables, the duration of DM was significantly different (P = 0.043) between controlled and uncontrolled T2DM groups; however, BMI was not significantly different. Some categorical variables such as educational level, alcohol consumption, and perceived self-oral health status were well balanced between the two groups. However, there were significant differences in smoking status (P = 0.033), frequency of tooth brushing (P = 0.044), frequency of flossing (P = 0.002), lack of oral health education (P < 0.001), and no regular dental visits (P < 0.001) between the controlled and uncontrolled T2DM groups.

**DC indicators and periodontal health parameters by T2DM-related factors**

Table 2 displays the distribution of DC indicators by T2DM-related factors. A significant difference was observed in the mean values of DT (P = 0.045), MT (P = 0.002), and DMFT index (P < 0.001) between controlled and uncontrolled HbA1c groups. Participants were also classified according to FBG levels: FBG ≤130 mg/dL (n

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**Table 1** Subject characteristics by glycemic control (n = 91)

| Variables                           | HbA1c ≤7.0% (n = 46) | HbA1c >7.0% (n = 45) | P       |
|-------------------------------------|----------------------|----------------------|---------|
| Age                                 | 62.98 ± 9.66         | 59.98 ± 9.63         | 0.142   |
| BMI (kg/m²)                         | 25.18 ± 3.19         | 26.50 ± 4.38         | 0.092   |
| Duration of diabetes (years)        | 8.84 ± 11.99         | 9.75 ± 6.87          | 0.043   |
| Sex                                 |                      |                      |         |
| male                                | 11                   | 10                   | 0.848   |
| female                              | 35                   | 35                   |         |
| Education                           |                      |                      |         |
| ≤primary                            | 15                   | 15                   | 0.362   |
| secondary                           | 14                   | 19                   |         |
| ≥college                            | 17                   | 11                   |         |
| Exercise                            |                      |                      |         |
| everyday                            | 26                   | 13                   | 0.015   |
| few times a week                    | 19                   | 27                   |         |
| none                                | 1                    | 5                    |         |
| Smoking                              |                      |                      |         |
| yes                                 | 9                    | 18                   | 0.033   |
| no                                  | 37                   | 27                   |         |
| Alcohol consumption                 |                      |                      |         |
| yes                                 | 4                    | 6                    | 0.398   |
| no                                  | 42                   | 39                   |         |
| Frequency of brushing per day       |                      |                      |         |
| One time                            | 29                   | 36                   | 0.044   |
| Two times                           | 9                    | 8                    |         |
| Three times                         | 8                    | 1                    |         |
| Frequency of flossing per day       |                      |                      |         |
| one time                            | 12                   | 5                    | 0.002   |
| two times                           | 7                    | 4                    |         |
| less than one time                  | 27                   | 36                   |         |
| Received oral health education      |                      |                      | <0.001  |
| yes                                 | 14                   | 4                    |         |
| no                                  | 32                   | 41                   |         |
| Regular dental visit                |                      |                      | <0.001  |
| yes                                 | 21                   | 3                    |         |
| no                                  | 25                   | 42                   |         |
| Perceived self-oral health status   |                      |                      | 0.583   |
| healthy                             | 9                    | 6                    |         |
| moderate                            | 8                    | 11                   |         |
| unhealthy                           | 29                   | 28                   |         |

Continuous variables expressed as (mean ± standard deviation), P by Student’s t-test or Mann-Whitney U-test, categorical variables subjected to chi-square test. HbA1c: glycated hemoglobin; BMI: body mass index.
Table 2: Distribution of dental caries indicators by DM-related factors (n = 91)

| Variables | N (%) | DT | P | MT | P | FT | P | DMFT | P |
|-----------|-------|----|---|----|---|----|---|------|---|
| HbA1c (%) |       |     |   |    |    |    |   |      |   |
| ≤7        | 46 (50.50) | 6 (0-15) | 0.045 | 12.50 (2-29) | 0.002 | 1 (0-6) | 0.990 | 22 (5-32) | <0.001 |
| >7        | 45 (49.50) | 8 (0-18) | 0.977 | 13 (2-26) | 0.012 | 1.5 (0-6) | 0.362 | 23 (11-32) | 0.006 |
| FBG (mg/dL) |     |     |   |    |    |    |   |      |   |
| ≤130      | 41 (45.05) | 6 (0-18) | 0.884 | 13 (2-29) | 0.924 | 1 (0-6) | 0.854 | 23 (13-32) | 0.872 |
| >130      | 50 (54.95) | 7 (0-16) | 10.00 ± 6.94 | 1 (0-6) | 0.012 | 13 (2-29) | 0.990 | 22 (5-32) | <0.001 |
| BMI (kg/m²) |     |     |   |    |    |    |   |      |   |
| ≤23       | 18 (19.78) | 7 (2-18) | 0.325 | 2 (0-7) | 0.242 | 1.5 (0-6) | 0.430 | 26 (12-32) | 0.339 |
| >23       | 73 (80.22) | 7 (0-16) | 15.50 ± 6.94 | 1 (0-6) | 0.012 | 13 (2-29) | 0.990 | 22 (5-32) | <0.001 |
| Duration of DM (years) |     |     |   |    |    |    |   |      |   |
| ≤10       | 61 (67.03) | 6 (0-18) | 0.881 | 15 (2-29) | 0.376 | 1 (0-5) | 0.501 | 26 (12-32) | 0.339 |
| >10       | 30 (32.97) | 7.50 (0-16) | 13.50 (2-28) | 1.5 (0-6) | 0.012 | 13 (2-29) | 0.990 | 22 (5-32) | <0.001 |

Values are expressed as median (range). P by Mann-Whitney U test.

HbA1c: glycated hemoglobin; FBG: fasting blood glucose; BMI: body mass index; DM: diabetes mellitus; DT: decayed teeth; MT: missing teeth; FT: filled teeth; DMFT: decayed, missing and filled teeth; DM: diabetes mellitus.

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Table 3: Distribution of periodontal health parameters by DM-related factors (n = 91)

| Variables | N (%) | BOP | P | PPD 4-5 mm | P | PPD ≥6 mm | P |
|-----------|-------|-----|---|------------|---|-----------|---|
| HbA1c (%) |       |     |   |            |   |           |   |
| ≤7        | 46 (50.50) | 3 (0-11) | 0.325 | 2 (0-7) | 0.242 | 1.5 (0-6) | 0.430 |
| >7        | 45 (49.50) | 3 (0-10) | 0.856 | 2 (0-6) | 0.381 | 1 (0-5) | 0.585 |
| FBG (mg/dL) |     |     |   |            |   |           |   |
| ≤130      | 41 (45.05) | 3.5 (0-11) | 0.856 | 2 (0-6) | 0.381 | 1 (0-5) | 0.585 |
| >130      | 50 (54.95) | 3 (0-10) | 0.856 | 2 (0-6) | 0.381 | 1 (0-5) | 0.585 |
| BMI (kg/m²) |     |     |   |            |   |           |   |
| ≤23       | 18 (19.78) | 2.50 (0-11) | 0.856 | 2 (0-6) | 0.381 | 1 (0-5) | 0.585 |
| >23       | 73 (80.22) | 3 (0-11) | 0.856 | 2 (0-6) | 0.381 | 1 (0-5) | 0.585 |
| Duration of DM (years) |     |     |   |            |   |           |   |
| ≤10       | 61 (67.03) | 3.5 (0-10) | 0.116 | 1.5 (0-6) | 0.333 | 2 (0-6) | 0.105 |
| >10       | 30 (32.97) | 3 (0-8) | 0.116 | 1.5 (0-6) | 0.333 | 2 (0-6) | 0.105 |

Values are expressed as median (range). P by Mann-Whitney U test.

HbA1c: glycated hemoglobin; FBG: fasting blood glucose; BMI: body mass index; BOP: bleeding on probing; PPD: periodontal pocket depth; DM: diabetes mellitus.

Significant differences were also observed in the prevalence of MT (P = 0.012) and DMFT index value (P = 0.006) between the FBG groups. However, DC prevalence according to other DM-related factors, such as BMI and duration of illness, was not significantly different. Moreover, there was no significant difference regarding periodontal health parameters (BOP, PPD 4-5 mm, and PPD ≥6 mm) and DM-related factors (Table 3) between the groups.

A sensitivity analysis was also performed for the HbA1c cut-off value of 8.0% (64 mmol/mol) as an index for poor glycemic control (19). On comparing HbA1c ≤8.0% (n = 61) and HbA1c >8.0% (n = 30) groups, similar results were observed as when using HbA1c 7.0% as the cut-off value for DC indicators (DT, MT, and DMFT index). However, different results were observed for periodontal health parameters (Table 4).

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**Association between the number of DT, DMFT index value, and serum HbA1c levels**

Multiple linear regression analysis revealed that the absolute number of DT was significantly correlated with serum HbA1c levels (adjusted β = 0.283, 95% confidence interval [CI] 0.173 to 0.972, P = 0.005) and education level (adjusted β = 0.175, 95% CI 0.175 to 0.175, P = 0.005) (Table 5). Moreover, serum HbA1c levels significantly predicted the DMFT index value. Significant correlations of DMFT index value were observed with serum HbA1c levels (adjusted β = 0.413, 95% CI 0.532 to 1.658, P < 0.001), regular dental visits (adjusted β = 0.334, 95% CI 1.563 to 7.118, P = 0.003), and receiving oral health education (adjusted β = 0.303, 95% CI 1.553 to 7.920, P = 0.004; Table 6).

**Discussion**

The first objective of the current study was to investigate the feasible high DMFT index value among patients with...
uncontrolled T2DM compare with that among patients with controlled T2DM. This study demonstrated that patients with uncontrolled glycemic levels exhibited higher DT, MT, and DMFT index values than those with controlled glycemic levels. These findings are consistent with those of previous studies reporting that poor glycemic control may influence the DMFT index values (12,14). One study has reported negative consequences on the coronal caries incidence in diabetic patients compared with nondiabetic individuals (20). However, the consequences of DC manifestation among patients with T2DM may depend on the duration of diabetes illness (11). The second objective was to evaluate the association of the number of DT and DMFT index values with serum HbA1c levels. The results obtained confirmed the hypothesis that both DC indicators were significantly associated with HbA1c levels in patients with T2DM after adjusting for confounders in the multiple linear regression model.

The relationship between DC and DM remains controversial. Several epidemiological studies have reported both positive and negative associations between metabolic control and DC prevalence (6,8,9,12,13). However, it must be emphasized that these studies may not be directly comparable with each other due to a number of differences such as sample size, study design, and comprehensive assessment of DC. The present study is consistent with previous studies that have clearly indicated an association between glycemic control of DM, DT, and DMFT index values (12,13). However, this study was a health center-based clinical study, and it may not be appropriate to compare the outcomes to those of other studies due to the differences in study design.

Several explanations may address the observed association between the DC indicators and serum HbA1c levels. First, DC is considered a biofilm-mediated, sugar-driven, multifactorial disease that consequently results in the demineralization and remineralization of dental hard tissues (21). Risk factors for oral consequences, especially DC development, occur through complex interactions over time between high numbers of acid-producing cariogenic microflora, such as mutans streptococci, lactobacilli, and Actinomyces spp., and fermentable carbohydrate, several host factors, inadequate salivary flow, immunological components, and genetic factors (22,23). An important predisposing factor for DC development in patients with DM is poor glycemic control, which leads to impaired salivary gland function. In addition, hyperglycemia combined with impaired salivary gland function and bacterial inva-

### Table 4 Dental caries indicators and periodontal health parameters by glycemic control (n = 91)

| Variables       | HbA1c ≤8.0% (n = 61) | HbA1c >8.0% (n = 30) | P    |
|-----------------|----------------------|----------------------|------|
| DT              | 6.5 (0-16)           | 7 (0-18)             | 0.011|
| MT              | 13 (2-19)            | 18 (5-28)            | 0.035|
| FT              | 1 (0-7)              | 1 (0-6)              | 0.463|
| DMFT            | 23 (5-32)            | 28 (21-32)           | <0.001|
| BOP             | 3 (0-11)             | 2 (0-10)             | 0.445|
| PPD ≥5 mm       | 2 (0-7)              | 1 (0-4)              | 0.223|
| PPD ≥6 mm       | 2 (0-6)              | 0 (0-6)              | 0.668|

Values are expressed as median (range). P by Mann-Whitney U test.

HbA1c: glycated hemoglobin; DT: decayed teeth; MT: missing teeth; FT: Filled teeth; DMFT: decayed, missing and filled teeth; BOP: bleeding on probing; PPD: periodontal pocket depth.

### Table 5 Multiple linear regression analysis for DT

|          | B      | SE     | β      | 95% LCI | 95% UCI | P Value |
|----------|--------|--------|--------|---------|---------|---------|
| HbA1c    | 0.572  | 0.201  | 0.283  | 0.173   | 0.972   | 0.005   |
| Education| -1.130 | 0.536  | -0.210 | -2.195  | -0.064  | 0.038   |

HbA1c: glycated hemoglobin; DT: decayed teeth; B: unstandardized beta; SE: standard error; β: standardized beta; LCI: lower value of reliable interval; UCI: upper value of reliable interval.

### Table 6 Multiple linear regression analysis for DMFT index value

|          | B      | SE     | β      | 95% LCI | 95% UCI | P value |
|----------|--------|--------|--------|---------|---------|---------|
| HbA1c    | 1.095  | 0.283  | 0.413  | 0.532   | 1.658   | <0.001  |
| Regular dental visit | 4.341  | 1.397  | 0.334  | 1.563   | 7.118   | 0.003   |
| Received oral health education | 4.736  | 1.601  | 0.303  | 1.553   | 7.920   | 0.004   |

HbA1c: glycated hemoglobin; DMFT: decayed, missing and filled teeth; B: unstandardized beta; SE: standard error; β: standardized beta; LCI: lower value of reliable interval; UCI: upper value of reliable interval.
sion can lead to decreased enamel mineralization and predispose an individual to excessive enamel attrition and eventual tooth decay (23). Patients with DM mostly limit carbohydrates in their diet; however, the decreased salivary flow and increased blood and salivary glucose concentrations favor oral bacterial growth, resulting in a high DC prevalence in diabetic patients despite their efforts at a low cariogenic diet (24). Second, an association between DC and lifestyle and behavioral factors is clearly implicated. As observed in this study, patients with T2DM may lack appropriate awareness or education regarding oral health, preventive strategies, or proper oral hygiene maintenance. In particular, decreased tooth brushing or flossing frequency and fewer dental visits may increase DC incidence.

Substantial evidence exists to support the role of DM and uncontrolled blood glucose as important risk factors for periodontal diseases. Epidemiological studies have concluded that periodontal impairment is significantly more prevalent and severe in patients with T2DM than in nondiabetics (25,26). However, the present study failed to establish any significant relationship between periodontal parameters (BOP and PPD) and serum HbA1c levels. One potential explanation for this finding is the small sample size of this study. In addition, only BOP and PPD were used as periodontal disease indicators, whereas plaque index, gingival index, attachment loss, and alveolar bone resorption were not used. Moreover, Russell’s periodontal index and papillary bleeding index were not included in the examination, which might have led to an underperformed comprehensive evaluation of periodontal health.

In general, the outcomes of a cross-sectional study cannot be taken as evidence of a causal relationship between high serum HbA1c levels and incidences of high number of DT and high DMFT index value in patients with T2DM. Therefore, several methodological limitations of this study warrant consideration. First, a small sample size may affect the outcomes in the statistical analyses and may also prevent performing analyses using various cut-off values for DM-related factors. Second, the intra-examiner error was not assessed, which is critical for clinical research into such measures of dentition and periodontal parameters. Third, only current smoking and alcohol consumption status were acquired, which may have led to underestimation of the impact of past smoking and drinking on DC and periodontal health. Fourth, root surface caries was not included in the examination, although T2DM is significantly associated with root caries (20). Finally, other potential indicators such as oral hygiene index, microbial counts, salivary function, alveolar bone resorption, daily diet, and medication, which all impact oral health, were not included in the study. Therefore, a future investigation with a larger cohort to evaluate multiple comprehensive confounders may reinforce a better understanding of the relationship between DC and DM.

In conclusion, within the limitations, the present study suggested a considerable association between DC incidence and serum HbA1c levels in patients with T2DM. Consequently, close collaboration among healthcare professionals, dentists, and patients is required for better management of oral health care, particularly in patients with poor glycemic control. In addition, promotion of oral health awareness and encouragement of patients with DM, both to maintain proper oral hygiene and seek oral health advice, may contribute to decreased oral complications and help improve glycemic control in patients with T2DM.

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

References
1. American Diabetes Association (2014) Diagnosis and classification of diabetes mellitus. Diabetes Care 37, 81-90.
2. Ira B Lamster (2012) Diabetes and oral health—current concepts regarding periodontal disease and dental caries. US Endocrinology 8, 93-97.
3. Leite RS, Marlow NM, Fernandes JK (2013) Oral health and type 2 diabetes. Am J Med Sci 345, 271-273.
4. Löe H (1993) Periodontal disease. The sixth complication of diabetes mellitus. Diabetes Care 16, 329-334.
5. Urzua I, Mendoza C, Arteaga O, Rodriguez G, Cabello R, Faleiros S et al. (2012) Dental caries prevalence and tooth loss in chilean adult population: first national dental examination survey. Int J Dent, doi.org/10.1155/2012/810170.
6. Lamster IB, Lalla E, Borgnakke WS, Taylor GW (2008) The relationship between oral health and diabetes mellitus. J Am Dent Assoc 139, 19-24.
7. Malvania EA, Sheth SA, Sharma AS, Mansuri S, Shaikh F, Sahani S et al. (2016) Dental caries prevalence among type II diabetic and nondiabetic adults attending a hospital. J Int Soc Prev Community Dent 6, 232-236.
8. Collin HL, Uusitupa M, Niskanen L, Koivisto AM, Markkanen H, Meurman JH (1998) Caries in patients with non-insulin-dependent diabetes mellitus. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 85, 680-685.
9. Taylor GW, Manz MC, Borgnakke WS (2004) Diabetes, periodontal diseases, dental caries, and tooth loss: a review of the literature. Compend Contin Educ Dent 25, 179-184.
10. Lin BP, Taylor GW, Allen DJ, Ship JA (1999) Dental caries in older adults with diabetes mellitus. Spec Care Dentist 19, 8-14.
11. Sandberg GE, Sundberg HE, Fjellstrom CA, Wikblad KF (2000) Type 2 diabetes and oral health: a comparison between diabetic and non-diabetic subjects. Diabetes Res Clin Pract 50, 27-34.
12. Bakhshandeh S, Murtomaa H, Vehkalahti MM, Mofid R, Suomalainen K (2008) Dental findings in diabetic adults. Caries Res 42, 14-18.
13. Yonekura S, Usui M, Murano S (2017) Association between numbers of decayed teeth and HbA1c in Japanese patients with type 2 diabetes mellitus. Ups J Med Sci 122, 108-113.
14. Miko S, Ambrus SJ, Sahafian S, Dinya E, Albrecht MG (2010) Dental caries and adolescents with type 1 diabetes. Br Dent J, Mar 27, doi: 10.1038/sj.bdj.2010.290.
15. Saes Busato IM, Bittencourt MS, Machado MA, Grégio AM, Azevedo-Alanis LR (2010) Association between metabolic control and oral health in adolescents with type 1 diabetes mellitus. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 109, 51-56.
16. Sampaio N, Mello S, Alves C (2011) Dental caries-associated risk factors and type 1 diabetes mellitus. Pediatr Endocrinol Diabetes Metab 17, 152-157.
17. Akpata ES, Alomari Q, Mojiminiyi OA, Al-Sanae H (2012) Caries experience among children with type 1 diabetes in Kuwait. Pediatr Dent 34, 468-472.
18. American Diabetes Association (2018) Glycemic targets: standards of medical care in diabetes—2018. Diabetes Care 41, S55-64.
19. Ashur ST, Shah SA, Bosseri S, Fah TS, Shamsuddin K (2016) Glycaemic control status among type 2 diabetic patients and the role of their diabetes coping behaviours: a clinic-based study in Tripoli, Libya. Libyan J Med, doi: 10.3402/ljm.v11.31086.
20. Hintao J, Teanpaisan R, Chongsuvivatwong V, Dahlen G, Rattarasarn C (2007) Root surface and coronal caries in adults with type 2 diabetes mellitus. Community Dent Oral Epidemiol 35, 302-309.
21. Pitts NB, Zero DT, Marsh PD, Ekstrand K, Weintraub JA, Ramos-Gomez F et al. (2017) Dental caries. Nat Rev Dis Primers, doi: 10.1038/nrdp.2017.30.
22. Selwitz RH, Ismail AI, Pitts NB (2007) Dental caries. Lancet 365, 51-59.
23. Yeh CK, Harris SE, Mohan S, Horn D, Fajardo R, Chun YHP et al. (2012) Hyperglycemia and xerostomia are key determinants of tooth decay in type 1 diabetic mice. Lab Invest 92, 868-882.
24. Malicka B, Kaczmarek U, Ziętek M (2011) Dental caries in adult patients with type 1 and 2 diabetes mellitus. J Stoma 64, 9-24.
25. Kaur G, Holtfreter B, Rathmann W, Schwahn C, Wallaschofski H, Schipf S et al. (2009) Association between type 1 and type 2 diabetes with periodontal disease and tooth loss. J Clin Periodontol 36, 765-774.
26. Kim EK, Lee SG, Choi YH, Won KC, Moon JS, Merchant AT et al. (2013) Association between diabetes-related factors and clinical periodontal parameters in type-2 diabetes mellitus. BMC Oral Health, doi: 10.1186/1472-6831-13-64.