Received: 18 September 2021 | Revised: 18 January 2022 | Accepted: 27 January 2022

DOI: 10.1111/pedi.13324

COMPLICATIONS

ISPAD WILEY

Caries experience and gingival health in children and adolescents with type 1 diabetes mellitus—A cross-sectional study

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Abstract

Aim: To investigate the oral health of children and adolescents with type 1 diabetes (T1D) and its associations with diabetes-related and lifestyle factors.

Design: Cross-sectional study at a large tertiary hospital pediatric diabetes clinic. Oral examination determined dental caries experience and gingival health. Secondary outcome measures included salivary characteristics, oral hygiene and dietary practices, and diabetes-related factors.

Results: Eighty children and adolescents with T1D participated; mean (SD) age and HbA_{1c} were 13.4(2.6) years and 7.7(0.9)%, respectively. Forty-seven (59%) participants had one or more decayed, missing or filled teeth; 75 (94%) participants had gingivitis. Half (50%) reported ≥3 hypoglycemic episodes necessitating rapid-acting carbohydrate in the previous week. Sixty-two participants (78%) had normal saliva flow, however, 42 (52%) had reduced salivary buffering capacity. Glycemic control (HbA_{1c}) was not associated with caries experience, gingival health or salivary characteristics. Increased frequency of tooth brushing (OR, 0.11; 95%CI 0.01–0.97, $p = 0.05$) and interdental flossing (OR, 0.31; 95%CI 0.12–0.81, $p = 0.02$) were associated with lower caries experience. Interdental flossing (OR, 0.31; 95% CI 0.12–0.80, $p = 0.02$) and good oral hygiene (OR, 0.06; 95% CI 0.01–0.22, $p < 0.001$) were associated with less gingivitis.

Conclusion: Poor oral health is common in children with T1D, regardless of HbA1c. Given potential implications for short- and long-term systemic health, this study demonstrates the need for targeted strategies to improve oral health in children with T1D.

KEYWORDS
children and adolescents, dental caries, gingivitis, oral health, type 1 diabetes

1 | INTRODUCTION

Globally, type 1 diabetes (T1D) affects over one million children and adolescents.[1] A diagnosis of T1D at a young age can pose significant challenges to children and their families and may have serious implications for future overall health, well-being and lifestyle. Oral diseases, particularly periodontal disease, are well-recognized complications of type 2 diabetes in adults.[2] Whilst a bidirectional relationship between

poor glycemic control and periodontal disease has been reported in adults with type 2 diabetes, there is currently insufficient evidence for any such relationship with T1D.[3] However, poor gingival health has been documented in children with T1D, which is associated with increased risk of developing periodontal disease.[4–7] Children with T1D may also be at increased risk of dental caries due to changes in dietary practices, oral hygiene habits and altered salivary properties.[7,8] Few studies have investigated the association between glycemic control and oral health in children with T1D, and results to date are inconsistent.[5,8–14]

The aim of the present study was to investigate the oral health of children and adolescents with T1D and explore possible associations with glycemic control, oral hygiene and lifestyle factors.

2 | MATERIALS AND METHODS

A cross-sectional study of 80 children and adolescents was conducted at a large tertiary pediatric hospital in Melbourne, Australia between April and November 2018. Institutional HREC approval was obtained prior to recruitment (HREC 37099B). Inclusion criteria were: diagnosis of T1D for at least one year, participants aged between 8 and 18 years, ability to speak and understand English and legally provide informed consent. Exclusion criteria included smoking, other systemic illnesses or regular medications (apart from insulin). Recruitment was open to all children and adolescents attending the RCH diabetes clinic who met the eligibility criteria and was independent of any known underlying dental concern or prior attendance at the dental department. Participation was invited through flyers in the outpatient clinic. Additionally, targeted recruited of a convenience sample was also undertaken, whereby eligible participants with upcoming diabetes clinic appointments were contacted consecutively by telephone (in order of their appointment date and time) until available researcher appointments for dental review on that clinic day were filled.

Primary outcomes of interest were the presence or absence of carious lesions and the presence or absence of gingivitis. Secondary outcomes assessed included associations between oral health and potential risk factors; oral hygiene practices, dietary practices, salivary characteristics and glycemic control (HbA_{1c}).

To explore potential associations with glycemic control, recruitment aimed to obtain data from 40 children with HbA_{1c} > 7.5% and a further 40 age- and sex-matched children with HbA_{1c} ≤ 7.5% (dichotomized based on ISPAD target HbA_{1c} at the time of the study[15]). Information on duration since diagnosis of T1D and HbA_{1c} results were obtained from hospital medical records.

The clinical oral examination was conducted by a single trained and calibrated examiner with the patient supine in a dental chair in the outpatient dental clinic. Training was completed using the International Caries Classification and Management System (ICCMS™) e-learning training modules[16] with the aid of an experienced trained examiner (David J. Manton). The intra-examiner kappa score was 0.82, which reflected consistent agreement by the examiner.

Standard validated assessment tools were used. Dental caries lesions were quantified using the international caries detection and assessment system (ICDAS), a validated index for detecting and quantifying carious lesions, restorations and extracted teeth.[17] All teeth were cleaned and dried prior to examination. Where clinically indicated, intraoral bitewing radiographs were taken for detection of proximal caries. The presence of gingival inflammation was measured using the Gingival Index (GI) by Löe and Silness,[18] which was coded as 0, absence of inflammation; 1,mild inflammation; 2, moderate inflammation; 3, severe inflammation. Oral hygiene was measured using the Plaque Index (PI) by Silness and Löe, scored as 0, no plaque (good oral hygiene), 1, a film on the tooth surface observed using the probe (good-to-fair oral hygiene); 2, moderate accumulation of soft deposits (fair oral hygiene); 3, abundance of soft matter (poor oral hygiene).[18] Resting saliva quantity, saliva consistency, resting pH of unstimulated saliva, stimulated saliva flow rate and acid-buffering capacity of stimulated saliva were measured (GC Saliva-Check Buffer, GC Corp., Tokyo, Japan) as any alteration to these salivary properties may predispose an individual to increased risk of caries.[19] Participants were instructed to not brush their teeth or consume any foods or drinks for 1 hour prior to the appointment. All dental examinations were carried out on the same day as their diabetes clinic visit.

Participants and their parents completed a questionnaire to obtain information about oral hygiene and dietary habits. The questionnaire was based on the World Health Organization (WHO) Oral Health Questionnaire for Children[20] (Refer Supplemental Material) with additional questions pertaining to diabetes-related factors such as self-reported frequency of hypoglycemic episodes requiring treatment in the past week (defined as blood glucose level [BGL] <4.0 mmol/L), management of hypoglycemia, along with demographic and socioeconomic factors including maternal education were also obtained. The socio-economic indexes for areas (SEIFA), a product developed by the Australian Bureau of Statistics to rank postal code areas in Australia according to relative socio-economic advantage and disadvantage[21] was recorded for participants. Access to fluoridated reticulated water was determined from the Victorian Department of Health and Human Services website by using participants' residential postcodes.[22]

2.1 | Statistical analyses

Data was analyzed using SPSS® version 25 (IBM, NY, USA) and StataCorp. 2017 (*Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC).

For caries experience, we calculated total number affected by caries (including decayed teeth, missing teeth and filled teeth [DMFT]). In addition, two binary caries outcome variables, reflecting disease severity were derived to indicate presence or absence of dental caries; (1) 'any decay' reflected caries at any stage, including early and advanced lesions (ICDAS >0), missing and filled teeth, and (2) "advanced decay" included children with more obvious lesions only (ICDAS ≥4), missing and filled teeth. This was done to ensure our data

was comparable to previous studies that reported caries outcomes using the WHO DMFT index[23] which only accounts for visibly cavitated lesions. The outcome variable "advanced decay" is approximately the same as the WHO DMFT index.

Glycated hemoglobin (HbA_{1c}) was measured using High Performance Liquid Chromatography Bio-Rad D-10TM Hemoglobin Testing System (Bio-Rad Laboratories Inc., Hercules, CA, USA; non-diabetic reference range 4.5–5.7%). An average HbA_{1c} value of measurements over the previous 12 months was calculated for each individual. Frequency of recorded outcomes of interest are described using proportions (% of cohort); normally distributed data are described as mean (SD). Associations with oral health were assessed both as a binary variable (> and ≤ 7.5% [58 mmol/mol]) and as a continuous variable. The association between caries experience, glycemic control and other variables (e.g., oral hygiene, frequency of brushing, interdental flossing, frequency of consumption of sweetened foods/beverages) were analyzed using simple regression analysis. Exposure data were collapsed due to small numbers in some categories. For the Gingival Index, "Healthy gingivae" and "Mild gingivitis" were combined; for Plaque Index, "fair oral hygiene" and "poor oral hygiene" were combined. Frequency of tooth brushing and interdental flossing were re-categorized as "Daily" and "Less than daily". The p-value for statistical significance was set at <0.05.

3 | RESULTS

One hundred and one of 813 children and adolescents with T1D aged 8-18 years attending our clinic in the study timeframe were directly approached to participate, of whom 21 declined to participate and 80 were recruited. The demographic and diabetes history of study participants is summarized in Table 1. Mean ± SD age of participants was 13.4 ± 2.6 years with 51.3% being 11–14 years. HbA_{1c} values ranged between 6.3% and 11.9% and the overall cohort mean ± SD was 7.7 ± 0.9%. Half (40/80) of the participants reported hypoglycemic episodes at least three or more times-a-week, requiring home management with rapid-acting carbohydrates. More than half of the children 43/76 (56.6%) consumed sweets and candies several times-a-week or more, and 41/78 (52.6%) consumed sweet cakes and biscuits several times-a-week or more. A total of 24/80 (30.0%) parents reported regularly giving additional snacks either before bed or overnight to prevent a hypoglycemic episode from occurring. (based on individual scenarios / BGL parameters). Snacks included a combination of rapid- acting and sustaining CHO-containing foods. All participants reported treating a hypoglycemic event at a BGL < 4.0 mmol/L.

TABLE 1 Demographics and diabetes history of this study population

Demographics	*N* (%)	Mean (SD)
Sex		
Male	40 (50)	
Female	40 (50)	
Age (years)		13.4 [2.6]
SEIFA decile ranking (1–10)	80 (100),	6.0 [3.0]
Low (1–3)	19 (23.8)	
Moderate (4–7)	30 (37.5)	
High (8–10)	31 (38.7)	
Water Fluoridation		
Fluoridated (>0.7 ppm F^-)	70 (90.9)	
Non-fluoridated (<0.3 ppm F^-)	7 (9.1)	
Diabetes History		
HbA_{1c} (%)[a]		7.7 [0.9]
Age at diagnosis of diabetes (years)		6.4 [3.8]
Duration of diabetes (years)		7.4 [3.9]
Insulin regimen		
Multiple daily injections	49 (61.3)	
Insulin pump therapy	31 (38.7)	
Number of hypoglycemic episodes reported in the previous week		
None	8 (10.8)	
1–2	26 (35.1)	
3–5	27 (36.5)	
More than 5	13 (17.6)	
History of previous severe hypoglycemic[b] event ever		
Yes	18 (22.8)	
No	62 (77.2)	

[a]Seventy-seven participants (96.3%) had four HbA1c values recorded within the previous 12 months, which contributed to their individual mean value.
[b]Severe hypoglycemic event defined as an episode of hypoglycemia where there was loss of consciousness, or seizure requiring third party assistance for recovery.

3.1 | Oral health

Over half, 47/80 (58.7%) of the participants experienced dental caries. When early lesions were excluded, 20/80 (25.0%) of participants had advanced carious lesions (Table 2). Bitewing radiographs were taken for nine participants, of whom five had carious lesions extending radiographically into dentine. Caries prevalence across the different age groups were: 8–10 years (9/11, 81.8%), 11–14 years (25/41, 61.0%) and the 15–18 years (13/28, 46.4%) age groups.

Only five (6.3%) children had healthy gingivae, 25/80 (31.2%) children had mild gingivitis, 50/80 (62.5%) participants had moderate gingivitis, and none had severe gingivitis. More than three-quarters (77.5%) had normal to high salivary flow rate, 75.0% had a neutral salivary pH (pH 6.8–7.8) and 48.0% had normal acid buffering capacity. All participants reported brushing their teeth, however, fewer than half (47.5%) brushed twice-a-day, with four (5.0%) children having heavy generalized plaque accumulation (PI score of 3). Only three participants (3.8%) flossed daily.

3.2 | Risk factors for dental caries and gingivitis

There was a strong association between daily tooth brushing and lower caries experience (OR, 0.2; 95% CI 0.01–0.97, $p < 0.05$) (Table 3). Flossing interdentally daily was also associated with a lower caries experience (OR, 0.31; 95% CI 0.12–0.81, $p = 0.02$) and better gingival health (OR, 0.31; 95% CI 0.12–0.80, $p = 0.02$) compared to less frequent interdental flossing; good oral hygiene was associated with better gingival health (OR, 0.06; 95% CI 0.01–0.22, $p < 0.001$) (Table 3). There was no evidence of an association between HbA_{1c} and caries experience or gingival health (Tables 3 and 4). In addition,

TABLE 2 Oral health of the study population

Item	*N* (%)
Caries experience ICDAS-II ANALYSIS	
Including enamel caries, missing teeth due to caries and filled teeth	
Sound (ICDAS = 0)	33 (41.3)
Caries (ICDAS > 0)	47 (58.7)
Excluding enamel surface caries, missing teeth due to caries and filled teeth	
Sound (ICDAS 0–3)	60 (75.0)
Caries (ICDAS >3)	20 (25.0)
Gingival health	
Healthy gingivae (GI score 0)	5 (6.3)
Mild gingivitis (GI score 1)	25 (31.2)
Moderate gingivitis (GI score 2)	50 (62.5)
Severe gingivitis (GI score 3)	0 (0)
Oral hygiene (OH)	
Plaque index	
Good OH (PI score 0–1)	19 (23.8)
Fair OH (PI score 2)	57 (71.2)
Poor OH (PI score 3)	4 (5.0)
Oral hygiene practices	
Do you brush your teeth?	
Yes	80 (100)
No	0 (0.0)
Brushing frequency	
2–3 times per month	1 (1.2)
Once per week	2 (2.5)
2–6 times per week	6 (7.5)
Once per day	33 (41.3)
Twice per day	38 (47.5)
Do you use fluoride toothpaste?	
Yes	75 (93.8)
No	2 (2.5)
Unsure	3 (3.7)
Do you floss between your teeth?	
Yes	29 (36.0)
No	51 (64.0)
Flossing frequency	
Never	48 (60.0)
2–3 times per month	18 (22.5)
Once per week	4 (5.0)
2–6 per week	7 (8.8)
Once per day	1 (1.2)
Twice per day	2 (2.5)

TABLE 3 Simple logistic regression analysis showing the odds of having any caries experience (ICDAS > 0)

Independent variable	Caries present OR (95% CI)	*p* value[b]
Age (years)	0.88 (0.73, 1.05)	0.15
Sex		
Female	1	Ref
Male	1.00 (0.42, 2.41)	0.42
Glycemic control (1%)		
HbA_{1c} % (continuous)	1.42 (0.85, 2.38)	0.18
Glycemic control (categorical)		
HbA_{1c} > 7.5%	1	Ref
HbA_{1c} ≤ 7.5%	0.55 (0.22, 1.33)	0.18
Oral hygiene[a]		
Fair-to-poor (PI 2–3)	1	Ref
Good	0.43 (0.15, 1.25)	0.12
Frequency of brushing[a]		
Brushes less than once a day	1	Ref
Brushes once a day or more	0.11 (0.01, 0.97)	0.046[b]
Flossing daily[a]		
Does not floss daily	1	Ref
Flosses daily	0.31 (0.12, 0.81)	0.02[b]
Consumption of candies		
Several times a week or more	1	Ref
Less than several times a week	0.72 (0.29, 1.80)	0.48
Consumption of sweetened drinks		
Less than several times a week	1	Ref
Several times a week or more	1.32 (0.54, 3.21)	0.55
Saliva pH		
Balanced	1	Ref
Acidic saliva	1.14 (0.41, 3.16)	0.80
Saliva buffering capacity		
Normal	1	Ref
Very low	1.82 (0.75, 4.41)	0.19
Stimulated saliva flow rate (SSFR)		
Normal-to-high	1	Ref
Low	1.36 (0.56, 3.28)	0.49

[b]Statistically significant ($p < 0.05$).
[a]Exposure data were collapsed due to small numbers in some categories. For the Plaque Index, "fair oral hygiene" and "poor oral hygiene" were combined. Frequency of tooth brushing and flossing were re-categorized as "Daily" and "Less than daily".

TABLE 4 Simple logistic regression analysis showing the odds of having poor gingival health

Independent variable	Poor gingival health[b] OR (95% CI)	*p* value[c]
Age (years)	0.88 (0.73, 1.05)	0.15
Sex		
Female	1	Ref
Male	1.00 (0.42, 2.41)	0.42
Glycemic control (1%)		
HbA_{1c} % (continuous)	1.58 (0.88, 2.80)	0.12
Glycemic control (categorical)		
HbA_{1c} > 7.5%	1	Ref
HbA_{1c} ≤ 7.5%	0.65 (0.26, 1.62)	0.36
Oral hygiene[a]		
Fair-to-poor (PI 2–3)	1	Ref
Good	0.06 (0.01, 0.22)	**<0.001c**
Frequency of brushing[a]		
Brushes less than once a day	1	Ref
Brushes once a day or more	0.18 (0.02, 1.53)	0.12
Flossing daily[a]		
Does not floss daily	1	Ref
Flosses daily	0.31 (0.12, 0.80)	**0.02c**

[a]Exposure data were collapsed due to small numbers in some categories. For the Plaque Index, "fair oral hygiene" and "poor oral hygiene" were combined. Frequency of tooth brushing and flossing were re-categorized as "Daily" and "Less than daily".
[b]Poor gingival health is defined by an overall GI score of 2 and 3.
[c]Statistically significant ($p < 0.05$).

no associations between other diabetes-related factors (age at diagnosis, duration since diagnosis, insulin regimen, number of self-reported hypoglycemic episodes) were evident (Table 3), nor was HbA_{1c} associated with saliva flow rate, saliva pH, buffering capacity, consumption of sweet foods and caries experience or dietary practices. Sex of the participants did not influence oral health (OR = 1.00, 95% CI 0.42–2.41, p = 0.42) (Table 3). Higher SEIFA (Decile ranking of 8–10) was, however, associated with lower odds of caries experience ('any decay') (OR, 0.44; 95% CI, 0.22–0.90).

4 | DISCUSSION

This study revealed a concerningly high prevalence of poor oral health in children and adolescents with T1D attending a large tertiary pediatric diabetes clinic. Specifically, we found much higher rates of dental caries (58.7%) and gingivitis (93.7%) than in the Australian National Child Oral Health Survey 2012–2014 (NCOHS), where the prevalence of caries and gingivitis were 41.7% and 21.8%, respectively.[24] However, it is worth noting that the NCOHS did not use the ICDAS-II index and therefore did not include early carious lesions. They used the WHO DMFT index which, although commonly used due to its simplicity and ease of application, only measures more advanced visually cavitated lesions. Thus, it is possible that the lower rates reported by the NCOHS are to some degree explained by exclusion of early, intact enamel lesions. Similarly, most previous studies investigating the oral health of children with T1D have reported caries outcomes using the WHO DMFT index.[8,12–14,25,26] The ICDAS-II index used in our study provides an alternative to WHO DMFT scoring and allows for a more sensitive stratification of lesion diagnosis. The outcome variable "advanced decay" reported here allows for comparison with the WHO DMFT index.

The findings of this study are of major importance for children with T1D as poor oral health and untreated caries adds to their overall treatment burden and can significantly impact their overall quality-of-life.[27] Broader implications for the families and public health resources are also recognized.[28–30]

A recent systematic review identified that modifiable risk markers for periodontal disease (i.e., plaque index, gingival index, bleeding on probing and periodontal pocket depths) were more pronounced in children and adolescents with T1D compared to healthy controls.[9] Thus, if children with T1D have poor oral health, they may be likely to continue to have poor oral health as they transition into adulthood, which can potentially affect diabetes control and overall health. There is evidence from clinical studies to suggest that the release of inflammatory mediators secondary to chronic inflammation of the periodontal tissues causes increased insulin resistance of tissues.[31,32]

Lifestyle and behavioral factors such as oral hygiene practices and frequency of dietary intake of sugars are significant risk factors for dental caries at a population level.[33] The NCOHS reported 49.7% of children brushed their teeth twice a day, which is similar to the data reported in our study (47.5%). In children with T1D, poor oral hygiene has been previously reported as a key determinant for caries development.[26] Given the higher attendant oral health risks in T1D, the low rates of engagement in recommended daily oral hygiene practices[34,35] across our sample is concerning. Whilst the persisting presumption is that oral health in children with T1D is influenced by diabetes-related factors, our study has confirmed that oral hygiene practices influence the oral health of children with T1D as well. A strong association between daily tooth brushing and lower caries experience was evident in our cohort and standard advice at diagnosis of T1D should highlight this finding in future. The use of fluoridated toothpaste in preventing and limiting caries experience is well supported.[35] Therefore, it is encouraging to note that almost all participants (93.8%) in the present study reported using a fluoridated toothpaste regularly. A clinically significant association between interdental flossing and lower caries experience was evident in our cohort, however, the overall rate of regular interdental flossing was low. As with brushing frequency, the benefits of this preventative measure should be emphasized to families.

The majority of previous studies have shown that gingival health is poorer in children with diabetes compared with healthy children.[4,5] A recent Australian study by Jensen and colleagues[10] also explored periodontal health and relationship with glycemic control in youth (n = 77) with T1D. In their cohort, where the median (range) HbA1c

was 8.5% (5.8%–13.3%), 49.0% of participants had early markers of periodontal disease. An association between higher HbA_{1c} and periodontal risk markers was evident.[10] In contrast, in our study, despite a lower median (range) HbA_{1c} of 7.6% (6.3%–11.9%), poor oral health comprising high rates of both caries and gingivitis was observed across the cohort, regardless of glycemic control. The higher rates of gingivitis reported in our study could be because of differences in phenotype measurement; Jensen et al., reported on more advanced gingival disease. Previous studies have reported conflicting data regarding the association between glycemic control and oral health,[8,10–14,25,26,36] possibly due to different inclusion and reporting criteria. In particular, previous studies used different HbA_{1c} cut-off points to determine glycemic control, different sample sizes (with differing numbers of participants within each group) and different indices to measure caries experience; making it challenging to draw direct comparisons between studies. The lack of a consistent association suggests that HbA_{1c} alone may not be a major contributing factor to poor oral health which is multifactorial in nature.

Our study also showed that irrespective of glycemic control, good oral hygiene practices were strongly associated with better gingival health. Thus, the high prevalence of poor oral health may in fact be more generally attributed to known risk factors such as suboptimal oral hygiene practices. The presence of poor oral health across the spectrum of HbA_{1c} encountered in our study also highlights the need to prioritize dental and oral care advice for all children with T1D. This important finding should be included in oral health promotion messages to both children with T1D and their parents, as well as to medical and dental professionals.

Episodes of hypoglycemia are inevitable in children with T1D; however, the potential adverse effects of frequent hypoglycemic treatment with sugary foods or drinks on the dentition cannot be overlooked. Previous Australian population data have shown that 52% of individuals over 2 years-of-age exceeded the recommended upper limit of 10% total energy intake (TEI) consumed from free sugars.[37] It was not possible to compare these findings to our study as we did not determine the free sugar proportion of TEI in our cohort. However, it is worth noting that half of our cohort reported treating hypoglycemic episodes at least three or more times-a-week and almost one-third reported additional night-time feeding to prevent occurrence of a hypoglycemic episode. We did not however obtain information about whether these patients adopted any additional preventive behaviors after night-time feeding. As performing oral hygiene care may not always be feasible at the time of hypoglycemic treatment, it then becomes prudent to educate children and their families on alternative dentally safe strategies for managing hypoglycemic episodes. For instance, it is known that different types of foods have varying levels of retentiveness in the oral cavity, and therefore can influence the rate of clearance from the oral cavity. This in turn can influence the pH of the plaque biofilm which has a significant role to play in the development of dental caries. Hence, there may be some merit in consuming foods that are less sticky or chewy, ensuring adequate consumption of fluoridated water, and if consuming a sugary drink, it is advisable to consume it with a straw to minimize contact between sugars and the tooth surfaces.[38,39] Additionally, focusing on prevention modalities such as using a higher concentration fluoride toothpaste and more regular in-office fluoride varnish applications may also be beneficial.[35]

The present findings need to be considered within the context of our study's limitations and strengths. Our sample size is similar to other cohorts,[11,12,40] yet modest overall. It would have been ideal to have a healthy age-matched control group, but unfortunately this was not possible due to time and funding constraints. In addition, it is possible that our study design may have included unintended selection and/or recall bias due to voluntary recruitment of participants and clinician-administered questionnaire.[41] Additionally, as oral health varies at different dental developmental ages, recruiting participants within accepted dental developmental stages would yield more scientifically robust results in terms of caries experience and gingival health for each specific developmental cohort. Due to the study design, causation cannot be deduced from our findings.

Novel aspects of our study include the fact that unlike all previous studies, aside from assessing caries experience, gingival health, oral hygiene practices and salivary characteristics, we also sought to explore diabetes-related factors beyond HbA_{1c} values, such as self-reported frequency of hypoglycemic episodes requiring treatment in the past week (defined as blood glucose level [BGL] <4.0 mmol/L) and management of hypoglycemia. Our study is also one of the very few diabetes studies that report caries experience using the ICDAS-II index which also reports on early carious lesions and not just advanced visibly cavitated lesions. We also reported caries experience using two outcome variables, which allows for comparison with other studies that use the WHO DMFT index. Additional strengths include having a single trained and calibrated examiner which ensured consistency in the examination process and as the study was conducted at one tertiary diabetes center, participants would have received similar diabetes education and advice from the diabetes clinic.

Given the importance of the topic and the limited literature available, this is a well-defined and well-executed study with important findings that justifies further research into the oral health of this population. Specifically, larger prospective, controlled studies are required to further explore potential causal relationships for poor oral health in children with T1D in comparison to the general population and to confirm or refute the potential impact of dysglycemia and contemporary diabetes care on oral health. Additionally, more in-depth assessment of the dietary patterns and types of food or drinks consumed by children with T1D and their relation to timing of oral hygiene practices is also needed.

In conclusion, our study has demonstrated high rates of caries and poor gingival health in children and adolescents with T1D. These findings were present across the spectrum of HbA_{1c} and those with good glycemic control were not protected. The high caries prevalence and significant associations with suboptimal oral hygiene practices highlight the need for targeted preventative strategies to improve oral health in children with T1D and calls for further research to investigate potential associations between oral hygiene practices, glycemic control and oral health of children with T1D.

ACKNOWLEDGMENTS

The authors would like to thank all the participants, medical and dental personnel who provided assistance during data collection. This study was funded by the Melbourne Dental School and The Royal Children's Hospital Department of Dentistry. Open access publishing facilitated by The University of Melbourne, as part of the Wiley - The University of Melbourne agreement via the Council of Australian University Librarians. Add a correction statement: [Correction added on 1 June 2022 after first online: CAUL funding statement has been added.]

CONFLICTS OF INTEREST

No potential conflicts of interest relevant to this article were reported.

AUTHOR CONTRIBUTIONS

Shangeetha Gunasekaran, Mihiri Silva, Michele A. O'Connell, David J. Manton, Kerrod B. Hallett contributed to the study design, data acquisition and analysis, and interpretation of the results. Shangeetha Gunasekaran prepared the oral health questionnaire. Shangeetha Gunasekaran and Mihiri Silva performed the statistical analysis. Shangeetha Gunasekaran drafted the manuscript. Mihiri Silva, Michele A. O'Connell, David J. Manton, Kerrod B. Hallett contributed to the interpretation of the results and revising of the manuscript. All authors reviewed and edited the manuscript for critical content and approved the submitted version.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/pedi.13324.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. *IDF Diabetes Atlas*. 8th ed. International Diabetes Federation; 2017. https://diabetesatlas.org/atlas/eighth-edition/
2. Löe H. Periodontal disease: the sixth complication of diabetes mellitus. *Diabetes Care*. 1993;16(1):329-334.
3. Sanz M, Ceriello A, Buysschaert M, et al. Scientific evidence on the links between periodontal diseases and diabetes: Consensus report and guidelines of the joint workshop on periodontal diseases and diabetes by the international diabetes federation and the European Federation of Periodontology. *Diabetes Res Clin Pract*. 2018;137:231-241.
4. Al-Khabbaz AK, Al-Shammari KF, Hasan A, Abdul-Rasoul M. Periodontal health of children with type 1 diabetes mellitus in Kuwait: a case-control study. *Med Princ Pract*. 2013;22(2):144-149.
5. Ismail A, McGrath C, Yiu C. Oral health of children with type 1 diabetes mellitus: a systematic review. *Diabetes Res Clin Pract*. 2015;108:369-381.
6. Lalla E, Cheng B, Lal S, et al. Diabetes mellitus promotes periodontal destruction in children. *J Clin Periodontol*. 2007;34(4):294-298.
7. Novotna M, Podzimek S, Broukal Z, Lencova E, Duskova J. Periodontal diseases and dental caries in children with type 1 diabetes mellitus. *Media Inflammation*. 2015;2015:379626. 10.1155/2015/379626
8. Carneiro VL, Fraiz FC, Ferreira FM, Pintarelli TP, Oliveira ACB, da Silva Boguszewski MC. The influence of glycemic control on the oral health of children and adolescents with diabetes mellitus type 1. *Endocrinol Metabol*. 2015;59(6):535-540.
9. Jensen E, Allen G, Bednarz J, Couper J, Peña A. Periodontal risk markers in children and adolescents with type 1 diabetes: a systematic review and meta-analysis. *Diabetes Metab Res Rev*. 2021;37(1):e3368.
10. Jensen ED, Selway CA, Allen G, et al. Early markers of periodontal disease and altered oral microbiota are associated with glycemic control in children with type 1 diabetes. *Pediatr Diabetes*. 2021;22(3):474-481.
11. Coelho ASEC, Carneiro AS, Pereira VF, Paula AP, Macedo AP, Carrilho EVP. Oral health of Portuguese children with type 1 diabetes: a multiparametric evaluation. *J Clinic Pediatr Dentist*. 2018;42(3):231-235.
12. El-Tekeya M, El Tantawi M, Fetouh H, Mowafy E, Abo KN. Caries risk indicators in children with type 1 diabetes mellitus in relation to metabolic control. *Pediatr Dent*. 2011;34(7):510-516.
13. Miko S, Ambrus SJ, Sahafi an S, Dinya E, Tamas G, Albrecht MG. Dental caries and adolescents with type 1 diabetes. *Br Dent J*. 2010;208:E12. doi:10.1038/sj.bdj.2010.290
14. Siudikiene J, Mačiulskienė V, Nyvad B, Tenovuo J, Nedzelskiene I. Dental caries and salivary status in children with type 1 diabetes mellitus, related to the metabolic control of the disease. *Eur J Oral Sci*. 2006;114:8-14.
15. Rewers M, Pillay K, de Beaufort C, et al. Assessment and monitoring of glycemic control in children and adolescents with diabetes. *Pediatr Diabetes*. 2014;2014(15):102-114.
16. ICCMS. International Caries Classification and Management System. https://www.iccms-web.com/content/resources/elearning
17. Ekstrand KR, Gimenez T, Ferreira FR, Mendes FM, Braga MM. The international caries detection and assessment system–ICDAS: a systematic review. *Caries Res*. 2018;52(5):406-419.
18. Löe H. The gingival index, the plaque index, and the retention index systems. *J Periodontol*. 1967;38:38-44.
19. GC Saliva Check Brochure 2008, 2017. http://www.gcaustralasia.com/Upload/product/pdf/97/Brochure-Saliva-Check-BUFFER.pdf
20. World Health Organization. *Oral Health Questionnaire for Children*. World Health Organization; 2013 https://www.who.int/oral_health/publications/pepannex8sohqchildren.pdf?ua=1
21. Australian Bureau of Statistics. *Socio-Economic Indexes For Areas (SEIFA)*. Australian Bureau of Statistics; 2016. https://www.abs.gov.au/ausstats/abs@.nsf/mf/2033.0.55.001
22. Victoria DoH. Is my water fluoridated? https://www.health.vic.gov.au/water/is-my-water-fluoridated
23. Organization WH. Mean number of Decayed, Missing, and Filled Permanent Teeth (mean DMFT) among the 12-year-old age group, https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3812
24. Do LG, Spencer AJ. *Oral Health of Australian Children: the National Child Oral Health Study 2012–14*. University of Adelaide Press; 2016.
25. Siudikiene J, Machiulskiene V, Nyvad B, Tenovuo J, Nedzelskiene I. Dental caries increments and related factors in children with type 1 diabetes mellitus. *Caries Res*. 2008;42(5):354-362.
26. Twetman S, Johansson I, Birkhed D, Nederfors T. Caries incidence in young type 1 diabetes mellitus patients in relation to metabolic

control and caries-associated risk factors. *Caries Res*. 2002;36(1):31-35.
27. Sheiham A. Dental caries affects body weight, growth and quality of life in pre-school children. *Br Dent J*. 2006;201(10):625-626.
28. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the dmft: the human and economic cost of early childhood caries. *J Am Dent Assoc*. 2009;140(6):650-657.
29. Kassebaum N, Bernabé E, Dahiya M, Bhandari B, Murray C, Marcenes W. Global burden of untreated caries: a systematic review and metaregression. *J Dent Res*. 2015;94(5):650-658.
30. Chen Y, Zhang P, Luman ET, Griffin SO, Rolka DB. Incremental dental expenditures associated with diabetes among noninstitutionalized US adults aged≥ 18 years old in 2016–2017. *Diabetes Care*. 2021;44(6):1317-1323.
31. Polak D, Shapira L. An update on the evidence for pathogenic mechanisms that may link periodontitis and diabetes. *J Clin Periodontol*. 2018;45(2):150-166.
32. Preshaw P, Alba A, Herrera D, et al. Periodontitis and diabetes: a two-way relationship. *Diabetologia*. 2012;55(1):21-31.
33. Selwitz RH, Ismail AI, Pitts NB. Dental caries. *The Lancet*. 2007;369(9555):51-59.
34. Dentistry AAoP. Policy on early childhood caries (ECC): classifications, consequences, and preventive strategies. *Pediatr Dent*. 2016;40(6):60-62.
35. Walsh T, Worthington HV, Glenny AM, Marinho VC, Jeroncic A. Fluoride toothpastes of different concentrations for preventing dental caries. *Cochrane Database Syst Rev*. 2019;3:1-40.
36. Siudikienė J, Mačiulskienė V, Dobrovolskienė R, Nedzelskienė I. Oral hygiene in children with type I diabetes mellitus. *Stomatologija*. 2005;7(1):24-27.
37. Statistics ABo. Australian Health Survey: Consumption of added sugars https://www.abs.gov.au/ausstats/abs@.nsf/lookup/4364.0.55.011main+features12011-12
38. O'Sullivan E, Milosevic A, Barry S. Diagnosis, prevention and management of dental erosion: summary of an updated national guideline. *Royal Coll Surg Clinic Guideline*. 2013;1-12. https://www.rcseng.ac.uk/dental-faculties/fds/publications-guidelines/clinical-guidelines/
39. Luke G, Gough H, Beeley J, Geddes D. Human salivary sugar clearance after sugar rinses and intake of foodstuffs. *Caries Res*. 1999;33(2):123-129.
40. Akpata ES, Alomari Q, Mojiminiyi OA, Al-Sanae H. Caries experience among children with type 1 diabetes in Kuwait. *Pediatr Dent*. 2012;34(7):468-472.
41. Alasuutari PBL, Brannen J. *The Handbook of Social Research Methods*. SAGE Publications Ltd; 2008:313-327.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Gunasekaran S, Silva M, O'Connell MA, Manton DJ, Hallett KB. Caries experience and gingival health in children and adolescents with type 1 diabetes mellitus—A cross-sectional study. *Pediatr Diabetes*. 2022;23(4):499-506. doi:10.1111/pedi.13324