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ORIGINAL RESEARCH

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Correlation between metabolic control and dental caries status in children with type 1 diabetes mellitus

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Abstract

Background: Type 1 diabetes mellitus (T1DM) is the most common form of diabetes in children and adolescents, and its incidence and prevalence are rising worldwide. The disease has a profound impact on lifestyle, and the oral cavity is among the most frequently affected organs. Evidence from previous research suggests a complex association between TIDM and dental caries, yet the influence of metabolic control on oral health remains insufficiently defined. This study aimed to assess caries status in the permanent dentition of children and adolescents with T1DM and to determine whether poor metabolic control, measured by glycated hemoglobin (HbA1c), is associated with oral health outcomes. **Methods**: A cross-sectional study was conducted at the Dental Clinic of the University of Salamanca (Spain) between 2020 and 2025. The study included 300 children aged 6–12 years with T1DM, divided into two groups according to the International Society for Paediatric and Adolescent Diabetes (ISPAD) criteria: 150 with good metabolic control (HbA1c $<$7%) and 150 with poor metabolic control (HbA1c $>$7%). Oral health was evaluated using the Decayed, Missing, and Filled Teeth index (DMFT) for permanent teeth. **Results**: The mean age of participants was 9.14 $\pm$ 1.92 years; 53.3% were boys and 46.7% were girls. The DMFT index ranged from 0 to 6, with a mean of 2.74 $\pm$ 1.81. Neither age nor sex significantly influenced DMFT values. Children with good metabolic control had a lower mean DMFT score (2.41 $\pm$ 1.76) compared with those with poor control (3.08 $\pm$ 1.80), and this difference was statistically significant ($p < 0.01$). **Conclusions**: Poor metabolic control (HbA1c $>$7%) was associated with a higher burden of dental caries in children with T1DM.

Keywords

Children; Dental caries; Type 1 diabetes mellitus; Metabolic control; Oral health

1. Introduction

Type 1 diabetes mellitus (T1DM) is the most frequent and prevalent form of diabetes in the pediatric population. It is characterized by chronic hyperglycemia caused by an absolute deficiency of insulin secretion, and this condition develops when the pancreas fails to produce sufficient insulin, leading to complete insulin dependence [1–4]. The etiology of T1DM is heterogeneous and involves a combination of genetic and environmental factors [3, 4]. Currently, type 1 diabetes, also referred to as insulin-dependent diabetes, cannot be prevented [5]. Its symptoms may appear suddenly, with considerable variability at initial presentation in children. The most common manifestations include polyuria with nocturia, polydipsia, and weight loss [6].

The incidence of T1DM varies geographically and has been rising steadily in recent years, particularly in Europe [7]. In Spain, a notable increase in incidence has been reported compared with earlier decades [8, 9]. Among children under 15 years of age, the mean incidence is estimated at 15 cases per 100,000, although substantial regional variations exist [8]. T1DM accounts for more than 90% of diabetes cases in childhood and adolescence, and the incidence rate in Spain is higher than that in neighboring countries such as Portugal, France, and Italy [8].

The primary goal of treatment in children with T1DM is to achieve optimal metabolic control. Insulin therapy is essential to maintain plasma glucose levels within the target range, as poor metabolic control predisposes patients to chronic microvascular and macrovascular complications [10, 11]. Current insulin therapy guidelines are being refined to more closely mimic physiological patterns, with approaches such as continuous subcutaneous insulin infusion demonstrating promising results [12]. Glycemic targets should be individualized to remain as close to normal values as possible while minimizing the risk of recurrent hypoglycemia. In 2018, the International Society for Paediatric and Adolescent Diabetes (ISPAD) recommended

a glycated hemoglobin (HbA1c) goal of <7% [13]. Despite advances in therapy, maintaining long-term metabolic control in pediatric patients remains challenging, emphasizing the need for individualized, multidisciplinary strategies to support optimal management throughout the patient's lifetime [6].

Children with T1DM often exhibit poorer oral health outcomes, which are closely related to the level of metabolic control [14–16]. However, the epidemiological association between T1DM and dental caries in the pediatric population remains controversial. Some studies have reported a significantly higher prevalence of caries in children with diabetes [3, 16, 17], whereas others have found lower rates [18, 19] or no statistically significant differences compared with healthy controls [20–24]. More recent investigations have documented an increased incidence of caries in both permanent and primary dentition among children with T1DM [3, 25–27]. Beyond caries, diabetes mellitus is also considered a predisposing factor for periodontal disease, due to vascular alterations and changes in the oral microbiota [27–29]. Poor metabolic control in children with diabetes has been linked to worsening gingival health [21, 30]. These findings highlight the importance of regular dental examinations and optimal glycemic control to preserve oral health in this population. Oral health in adulthood is strongly influenced by oral health during childhood. Early and regular dental examinations not only support long-term oral health, but also reduce the risk of anxiety and fear related to dental visits, thereby improving adherence to dental care later in life [31–34]. Preventive dental protocols and timely appointments during childhood are therefore essential. It is particularly important that children with T1DM receive dental examinations as early as possible to mitigate future oral health problems [33].

It is important to emphasize that early and regular visits to the pediatric dentist can reduce stress and dental fear later in life [34, 35]. Anxiety and fear of dental treatment in children often lead to poor cooperation, which may negatively affect treatment outcomes and, in some cases, leave certain dental pathologies untreated. Despite the recognized importance of oral health in this population, studies specifically analyzing the correlation between metabolic control and oral health in children with T1DM remain limited. The available evidence suggests that poor metabolic control (HbA1c >7%) is associated with increased caries incidence, reduced salivary flow, and inflammatory changes in periodontal tissues [36–38]. However, most published studies have focused on the influence of diabetes on pediatric oral health without stratifying outcomes according to metabolic control [14, 15, 21, 39–43].

The present study was designed to evaluate whether metabolic control, measured by HbA1c, is associated with caries experience in the permanent dentition of children with T1DM. The null hypothesis was that poor metabolic control does not influence caries status in this population.

2. Materials and methods

2.1 Study design

This cross-sectional study was conducted at the Dental Clinic of the University of Salamanca (Salamanca, Spain) between 2020 and 2025. The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [44]. All clinical procedures were performed following the ethical principles of the Declaration of Helsinki. Before enrollment, the objectives, study protocol, potential benefits, and possible risks were explained to the participants and their parents or legal guardians. Participation was voluntary, and written informed consent was obtained from each child and their guardian. Ethical approval was granted by the Research Ethics Committee of the University of Salamanca (protocol number 1100).

For the sample size calculation, a minimum of 128 participants per group was required to achieve a 95% confidence interval, a statistical power of at least 80%, and a mean effect size. The calculation was performed using G*Power software (version 3.1.9.7, Heinrich-Heine-Universitaï Dusseldorf, Dusseldorf, NRW, Germany). Participants were consecutively recruited from patients attending the Dental Clinic between 2020 and 2025 who met the study's inclusion criteria. The final sample consisted of 300 children, divided into two groups of 150 each according to metabolic control, based on the criteria of the International Society for Paediatric and Adolescent Diabetes (ISPAD) [13]. Glycated hemoglobin (HbA1c) levels were measured for all participants to determine metabolic status: children with HbA1c <7% were classified as having adequate metabolic control, while those with HbA1c >7% were classified as having poor metabolic control (Fig. 1).

The inclusion criteria were: (i) children aged 6–12 years, and (ii) a confirmed diagnosis of T1DM for at least two years prior to enrollment. Exclusion criteria were: (i) the presence of systemic diseases other than T1DM, (ii) ongoing treatment with systemic medications, and (iii) significant physical or psychological conditions that could interfere with oral examinations.

2.2 Outcome variables

The number of carious teeth, missing teeth, and filled teeth in the permanent dentition was evaluated using the Decayed, Missing, and Filled Teeth (DMFT) index. This index quantifies oral health by recording the number of permanent carious teeth (D), missing teeth (M), and filled teeth (F) for each participant [45]. The DMFT index was calculated individually for every child included in the study. Caries were assessed according to the diagnostic criteria established by the European Academy of Paediatric Dentistry (EAPD) in 2016 [46], ensuring standardized and reproducible evaluation. All clinical examinations were performed in accordance with the criteria of the World Health Organization (WHO) [47]. A systematic visual-tactile examination was conducted for each participant, and when additional confirmation was necessary, radiographic imaging (*i.e.*, X-rays) was obtained to ensure diagnostic accuracy.

2.3 Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics (version 28, Released 2024; IBM Corp., Armonk, NY, USA). Continuous variables were described using standard measures of central tendency (mean and median) and vari-

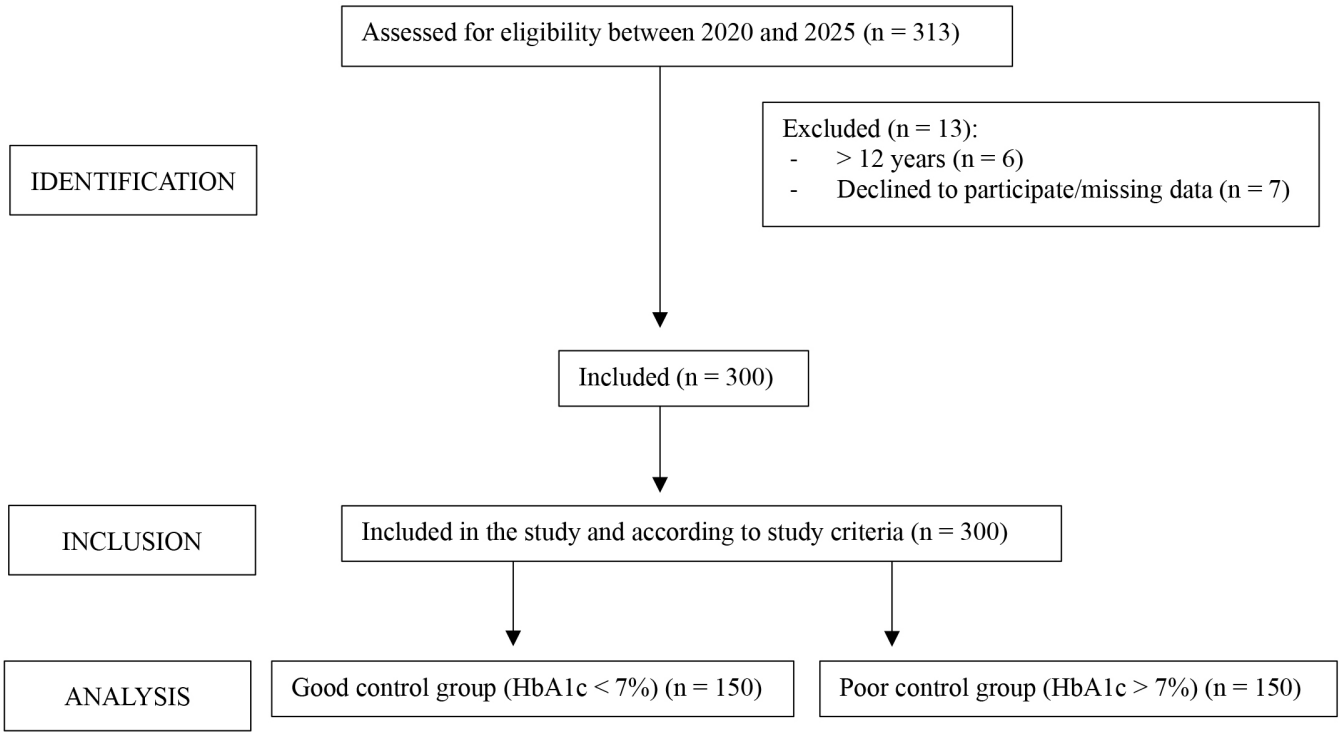

FIGURE 1. STROBE flow chart. HbA1c: glycated hemoglobin.

ability (observed range and standard deviation). To compare means across different groups, a one-way analysis of variance (ANOVA) was applied, while additional comparisons were conducted using the Student's *t*-test for continuous variables and the chi-square test for categorical variables. The distribution of the data was assessed with the Kolmogorov-Smirnov test, and descriptive shape indices, such as skewness and kurtosis, were also examined to further evaluate normality. Effect size was calculated to express the magnitude of the observed differences between groups, with eta squared used as the metric for this analysis. In all statistical tests, a *p*-value of < 0.05 was considered statistically significant.

3. Results

3.1 Baseline characteristics of the participants

A total of 300 children treated at the University of Salamanca Dental Clinic were included in this study. The participants were aged between 6 and 12 years, with a median age of 9 years and a mean age of 9.14 $\pm$ 1.92 years. The distribution of participants by age and sex was homogeneous, and no statistically significant differences were found ($p > 0.05$). Age was analyzed using the Student's *t*-test, while sex was evaluated using the chi-square test. With respect to sex, the sample included 160 boys and 140 girls, indicating a slightly higher proportion of male participants.

3.2 Descriptive analysis of the DMFT index

The number of carious teeth ranged from 0 to 5, with a mean of 1.57 $\pm$ 1.24 and a median of 1.50. A total of 22% of the participants (n = 66) presented without any carious teeth. The number of missing teeth ranged from 0 to 1, with a mean of 0.22 $\pm$ 0.41 and a median of 0, as 78% of the participants (n = 234) did not present with any missing teeth. The number of fillings varied between 0 and 3, with a mean of 0.95 $\pm$ 0.82 and a median of 1.00; 33.7% of the participants (n = 101) had no fillings. Among the three components of the DMFT index, carious teeth showed the highest mean value, whereas missing teeth showed the lowest mean value. Finally, analysis of the overall DMFT index revealed a range from 0 to 6, with a mean of 2.74 $\pm$ 1.81 and a median of 2.00, and 11% of the participants (n = 33) had a DMFT score of 0 (Table 1).

When the DMFT variables were analyzed by sex and age group (Table 2), some variability was observed across categories. The mean number of carious teeth, missing teeth, and the overall DMFT index were higher in boys than in girls; however, these differences were not statistically significant. Similarly, no significant associations were found between age and DMFT variables, indicating that neither sex nor age exerted a significant influence on caries status in this sample.

3.3 Analysis of the variables of the DMFT index by metabolic control

A statistically significant association was found between metabolic control and most variables of the DMFT index, except for missing teeth. Children with poor metabolic control consistently exhibited higher mean values for carious teeth ($p < 0.01$), filled teeth ($p < 0.05$), and the overall DMFT index ($p < 0.01$).

For carious teeth, participants with poor metabolic control had a higher mean value (1.79 $\pm$ 1.30) compared with those with adequate metabolic control (1.35 $\pm$ 1.14). The prevalence of carious teeth was also greater in this group, with 82.7%

TABLE 1. Exploratory and descriptive analysis of the DMFT index variables.

Variable	Mean	Median	Minimum	Maximum	SD	Asymmetry	Curtois	Kolmogorov-Smirnov test *p*-value
Carious teeth	1.57	1.50	0	5	1.24	0.67	0.10	<0.001
Missing teeth	0.22	0.00	0	1	0.41	1.36	−0.16	<0.001
Fillings	0.95	1.00	0	3	0.82	0.31	−0.89	<0.001
DMFT index	2.74	2.00	0	6	1.81	0.27	−0.95	<0.001

DMFT: Decayed, Missing, and Filled Teeth; SD: standard deviation.

TABLE 2. DMFT index variables (mean ± SD) segmented by sex and age of the participants.

Variables	Sex	Age (yr)							Total
		6	7	8	9	10	11	12	
Carious teeth									
	Boy	1.45 (±1.23)	1.21 (±1.05)	1.72 (±1.21)	1.42 (±1.46)	1.83 (±1.50)	1.77 (±1.14)	1.67 (±1.32)	1.60 (±1.29)
	Girl	1.47 (±0.74)	1.32 (±1.11)	1.33 (±1.13)	1.57 (±1.16)	1.14 (±1.46)	1.83 (±1.24)	1.90 (±1.34)	1.54 (±1.19)
	Total	1.46 (±1.04)	1.27 (±1.07)	1.53 (±1.17)	1.48 (±1.33)	1.57 (±1.50)	1.80 (±1.18)	1.79 (±1.32)	1.57 (±1.24)
Missing teeth									
	Boy	0.24 (±0.44)	0.14 (±0.36)	0.32 (±0.48)	0.29 (±0.46)	0.22 (±0.42)	0.27 (±0.45)	0.24 (±0.44)	0.26 (±0.44)
	Girl	0.27 (±0.46)	0.21 (±0.42)	0.21 (±0.42)	0.22 (±0.42)	0.14 (±0.36)	0.13 (±0.34)	0.10 (±0.30)	0.18 (±0.38)
	Total	0.26 (±0.44)	0.18 (±0.39)	0.27 (±0.45)	0.26 (±0.44)	0.19 (±0.40)	0.20 (±0.40)	0.17 (±0.38)	0.22 (±0.42)
Fillings									
	Boy	0.65 (±0.67)	0.64 (±0.84)	1.16 (±0.94)	0.74 (±0.73)	0.91 (±0.85)	1.12 (±0.71)	1.05 (±0.92)	0.91 (±0.82)
	Girl	1.13 (±0.64)	0.68 (±0.75)	1.00 (±0.88)	1.26 (±0.69)	0.57 (±0.65)	1.21 (±0.93)	0.95 (±0.86)	1.00 (±0.81)
	Total	0.86 (±0.69)	0.67 (±0.78)	1.08 (±0.91)	0.96 (±0.75)	0.78 (±0.79)	1.17 (±0.82)	1.00 (±0.88)	0.95 (±0.82)
DMFT index									
	Boy	2.35 (±1.69)	2.00 (±1.75)	3.20 (±1.92)	2.45 (±1.88)	2.96 (±2.14)	3.15 (±1.59)	2.95 (±1.86)	2.77 (±1.85)
	Girl	2.87 (±1.12)	2.21 (±1.65)	2.54 (±1.74)	3.04 (±1.80)	1.86 (±1.88)	3.17 (±1.88)	2.95 (±1.91)	2.71 (±1.76)
	Total	2.57 (±1.48)	2.12 (±1.67)	2.88 (±1.84)	2.70 (±1.85)	2.54 (±2.09)	3.16 (±1.72)	2.95 (±1.86)	2.74 (±1.81)

DMFT: Decayed, Missing, and Filled Teeth.

of participants affected, versus 73.3% in the adequately controlled group.

In regard to filled teeth, the mean value was higher in the poor control group (1.05 ± 0.80) compared with the adequate control group (0.86 ± 0.82). Moreover, 74% of children with poor metabolic control had at least one filling, in contrast to 58.7% in the adequately controlled group.

In contrast, for the missing teeth component of the DMFT index, no significant difference was observed between groups. The proportion of patients presenting with missing permanent teeth was 24% in the poor metabolic control group and 20% in the adequate control group.

Overall, children with poor metabolic control demonstrated significantly higher DMFT scores than those with good metabolic control (3.08 *vs.* 2.41, $p < 0.01$), confirming the association between inadequate glycaemic control and a greater burden of dental caries (Table 3).

TABLE 3. Comparison of DMFT index variables according to metabolic control in children with type 1 diabetes (HbA1c <7% *vs.* HbA1c >7%).

Variables	Good control group (HbA1c <7%) (n = 150)		Poor control group (HbA1c >7%) (n = 150)		*p*-value	Size of the effect
	Mean	SD	Mean	SD		
Carious teeth	1.35	±1.14	1.79	±1.30	0.002**	0.032
Missing teeth	0.20	±0.40	0.24	±0.43	0.405	0.002
Fillings	0.86	±0.82	1.05	±0.80	0.048*	0.013
DMFT index	2.41	±1.76	3.08	±1.80	0.001**	0.035

*SD: Standard deviation; DMFT: Decayed, Missing, and Filled Teeth; HbA1c: glycated hemoglobin. *: significant ($p < 0.05$); **: significant ($p < 0.01$).*

4. Discussion

This study investigated whether children with T1DM and poor metabolic control present a worse caries status compared with children with T1DM and adequate metabolic control, using glycated haemoglobin (HbA1c) as the reference indicator.

Diabetes is a chronic metabolic disease associated with a wide range of systemic and oral manifestations [21, 48]. In the oral cavity, reductions in salivary flow and increases in salivary glucose concentration have been documented [19, 48]. Dental caries remains the most prevalent chronic disease in childhood [49, 50], although its prevalence has declined over the last decade in Spain and in other countries [51, 52]. Identifying children at increased risk of caries continues to be a major objective of paediatric dentistry and public health, given the impact of the disease on children's physical and psychological well-being, as well as the increased likelihood of caries persisting into adulthood.

In the present study, children with poor metabolic control (HbA1c >7%) exhibited a significantly higher incidence of caries, a greater number of fillings, and higher overall DMFT scores compared with those who maintained adequate metabolic control (HbA1c <7%). These findings are consistent with previous reports. For example, Wang *et al.* [26] conducted a systematic review in 2019 evaluating the prevalence of caries in children and adolescents with T1DM, and found that individuals with well-controlled diabetes had a significantly lower prevalence of caries than those with poor metabolic control.

In 2022, Ferizi *et al.* [36] conducted a study similar to the present investigation, although with some notable methodological differences. Their study defined adequate metabolic control as HbA1c <7.5%, included a sample of 80 children, and did not specifically analyze patients attending their first dental visit. Despite these differences, their findings were consistent with ours: children with poor metabolic control (HbA1c >7.5%) had significantly higher DMFT scores in permanent dentition (7.91 ± 3.94) compared with those with adequate control (4.74 ± 1.80, $p < 0.01$). Similarly, in 2020, Pachoński *et al.* [37] evaluated 50 children aged 10–18 years and reported a higher DMFT index in poorly controlled patients (HbA1c >7.5%) (5.80 ± 3.75) compared with well-controlled patients (3.44 ± 3.37). Notably, in that study, the number of filled teeth exceeded the number of carious teeth in both groups, which contrasts with our findings, where the number of carious teeth was greater than the number of filled teeth. Vidya *et al.* [38] also investigated the relationship between metabolic control and dental status in children with T1DM aged 8–16 years, using the American Diabetes Association guidelines to classify metabolic control. Their results demonstrated statistically significant differences in the DMFT components (decayed, missing, and filled teeth) between well- and poorly controlled groups ($p < 0.05$) in permanent dentition, but no significant differences in primary dentition [38]. Furthermore, they assessed gingival health and reported significantly higher gingival index scores ($p < 0.01$) among children with poor metabolic control (HbA1c >7%) compared with those with good control.

The possible influence of diabetes on dental malocclusions and alterations in child patients has also been studied. For example, in 2022, Banyai *et al.* [53] described that the prevalence of orofacial skeletal anomalies was significantly greater ($p < 0.05$) in patients with diabetes in comparison with patients without diabetes. However, the limitations of this analysis should be noted, as the findings may reflect a statistically significant correlation rather than a clinically meaningful association [53].

Nageeb *et al.* [20] conducted a study evaluating the oral health status of diabetic children with adequate metabolic control (HbA1c <7.5%, n = 18) and poor metabolic control (HbA1c >7.5%, n = 22). The authors used the Oral Hygiene Index Simplified (OHIS), the Caries Assessment Spectrum and Treatment (CAST), and microbiological profiling of the oral cavity. They reported that diabetes itself did not significantly increase the risk of dental caries, although the microbiological profile differed between children with adequate versus poor metabolic control [20].

A recent systematic review and meta-analysis reported similar findings regarding the oral microbiota profile of children with T1DM, showing differences according to metabolic control [17]. According to current literature, studies comparing the oral microbiota of children with and without T1DM consistently demonstrate that diabetic patients exhibit significant differences in both quality and quantity of their oral microbiota [54].

It is also essential to emphasize the importance of early and preventive dental care in children and adolescents. Adult patients with T1DM have been reported to show higher rates of

tooth loss and an increased prevalence of periodontal disease compared with healthy patients. Therefore, this observation supports the notion that paediatric patients with T1DM may be at higher risk of developing dental problems in adulthood [55].

The importance of proper metabolic control in adolescent patients with T1DM has also been highlighted. Adolescence is a stage of life involving psychosocial and behavioural changes that may reduce compliance with diabetes treatment, leading to poor glycaemic control. This makes monitoring adolescent patients particularly important, as inadequate metabolic control not only worsens systemic health outcomes, but may also adversely affect oral health [56].

4.1 Strengths of this study

The main strength of this study is that it analyzed the influence of metabolic control in paediatric patients with T1DM, using HbA1c levels according to the criteria established by the ISPAD. To our knowledge, this is the first study of its kind conducted in Spain. Finally, the sample size in this study was relatively larger than that reported in comparable studies from other regions, thereby strengthening the robustness of the findings.

4.2 Limitations and future scope

This study also has several limitations. First, only the caries status of the permanent dentition was evaluated, while the condition of the temporary dentition and the gingival health of the participants were not assessed. Second, the methodology was based on ISPAD recommendations, which set the HbA1c threshold for adequate metabolic control at 7%. Third, this study did not consider the influence of other potentially relevant factors, such as children's dietary habits and oral hygiene practices. Despite these limitations, the findings provide a valuable overview of the caries status in paediatric patients with T1DM and its association with metabolic control. From a clinical perspective, periodic dental check-ups and strict glucose monitoring should be recommended for children with T1DM, underscoring the need for close cooperation among paediatric dentists, paediatric specialists, and parents/caretakers. Furthermore, dentists should be aware of and evaluate potential oral signs and symptoms in children with poorly controlled diabetes. Previous studies have also highlighted the importance of monitoring the microbial load of the oral cavity, as this may help prevent oral complications related to diabetes. Overall, this study highlights the value of implementing specific preventive and therapeutic strategies to improve the oral health status of children with T1DM, with particular emphasis on those with poor metabolic control.

5. Conclusions

This study indicates that children with poorly controlled T1DM (HbA1c $>7\%$) present higher mean values for carious teeth and dental fillings compared with those who maintain adequate metabolic control. These results highlight the importance of glycaemic regulation not only for systemic health, but also for oral health. Accordingly, it is essential to encourage parents to understand the impact of diabetes control on their children's oral health and to reinforce the need for preventive dental care as part of comprehensive diabetes management.

ABBREVIATIONS

ANOVA, one-way analysis of variance; CAST, Caries Assessment Spectrum and Treatment; DMFT, Decayed, Missing, and Filled Teeth index; EAPD, European Academy of Paediatric Dentistry; HbA1c, glycated hemoglobin; ISPAD, International Society for Paediatric and Adolescent Diabetes; OHIS, Oral Hygiene Index Simplified; SD, Standard Deviation; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; T1DM, Type 1 diabetes mellitus; WHO, World Health Organization.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

AC, CPT, RMGG, LOYB, GGL and CGP—designed the research study. AC, CPT, RMGG, LOYB, GGL, BE, CSGD and CGP—performed the research. AC, BE, CSGD and CGP—analyzed the data. All authors wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The protocol for this study was approved by the Research Ethics Committee of the University of Salamanca, Spain (protocol number: 1100). The present study obtained written informed consent to participate was obtained from the parents or legal guardians of participants. The study was conducted in accordance with the Declaration of Helsinki, as well as the guidelines of the STROBE guide for the conduct of observational studies.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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