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ORIGINAL ARTICLE

Dental caries prevalence among Type 1 diabetes mellitus (T1DM) 6- to 12-year-old children in Riyadh, Kingdom of Saudi Arabia compared to non-diabetic children

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KEYWORDS

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Abstract *Objective:* The aim of this study was to compare the prevalence of dental caries among groups of 6–12-year-old children with and without Type 1 diabetes mellitus (T1DM) in Riyadh, Saudi Arabia, taking into account oral health behaviour, diet, and salivary parameters.

Methods: The study was designed as a comparable study of dental caries experience between T1DM and non-diabetic groups of children. The total sample size of 209 participants consisted of 69 diabetic and 140 non-diabetic children. Oral hygiene, diet and socio-economic status were collected using a pre-tested questionnaire. Caries was recorded in terms of decayed and filled permanent and primary teeth (DFT/dft). Salivary microbial counts and pH levels were recorded using Caries Risk Test (CRT) kit. Student's *t*-test, the chi-squared test, linear regression and one-way analysis of variance were performed P-value of 0.05 considered significant.

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Results: The mean dft scores for the diabetic and non-diabetic groups were 3.32 ± 0.78 and 3.28 ± 0.71 (mean ± SD), respectively ($p = 0.458$). The mean DFT scores for the diabetic and non-diabetic groups were 1.62 ± 0.65 and 1.96 ± 0.65, respectively ($p = 0.681$). Diabetic children visited dentists more often than non-diabetic children did ($p = 0.04$), and had lower consumption of both sweets ($p = 0.003$) and flavoured milk ($p = 0.002$) than the non-diabetic group. Furthermore, analysis showed that the diabetic children had medium oral pH levels (pH = 4.5–5.5), whereas the non-diabetic children tended to have high ($pH \geq 6.0$) oral pH; this difference was statistically significant ($p = 0.01$). In addition, the diabetic group had higher *Lactobacillus* levels than the non-diabetic group ($p = 0.04$).

Conclusion: The difference in caries prevalence between the diabetic and non-diabetic children was not statistically significant. The CRT analysis revealed a higher frequency of "critical" pH values (pH = 4.5–5.5) and higher *Lactobacillus* counts in diabetic children than in non-diabetic children, which indicated a higher caries risk in the former group.

1. Introduction

The upward trend in non-communicable diseases worldwide, specifically in developing countries, is a major public health concern that calls for thorough investigation and appropriate preventive interventions. Diabetes mellitus (DM) and dental caries are widespread non-communicable diseases that impose burdensome costs on governments and individuals. These two diseases share a common risk factor (i.e., sugar consumption), and if their association were better understood, practical interventions could be developed to reduce the burden of both diseases (Sheiham & Watt, 2000). Dental caries is a prevalent chronic disease across all age groups, including children, especially in developing countries. Although the disease is associated with specific bacteria (*Streptococcus mutans* and *Lactobacillus*) that exist as part of the normal flora of the oral cavity, the increased consumption of carbohydrates may have been a significant force behind its wide-reaching global spread (Moye et al., 2014).

DM, on the other hand, is a chronic metabolic disease, characterized by blood-sugar imbalance that has become a global public health concern in recent years due to a drastic increase in its prevalence (Awuti et al., 2012). Saudi Arabia reportedly has the seventh highest prevalence of diabetes of any country worldwide (Al-Rubeaan, 2015). Additionally, a study reported that most of the diabetic Saudi children surveyed were unaware of their condition (Al-Rubeaan, 2015). Type 1 DM (T1DM), also called insulin-dependent diabetes, usually affects children and young adults. A recent systematic review has revealed that the prevalence of T1DM in Saudi Arabia is highest in the city of Riyadh and lowest in the eastern and rural regions of the country (Alotaibi et al., 2017).

Saudi Arabia also ranks highly among the nations of the world in prevalence of dental caries (Al Agili, 2013). Many physical, biological, environmental, behavioural, and lifestyle-associated factors contribute to dental caries. More specifically, high numbers of cariogenic microbes, insufficient salivary flow, inadequate fluoride exposure, poor oral hygiene, incorrect ways of feeding infants, excessive sugar consumption, and low socio-economic status are all primary risk factors for the disease (Fejerskov and Kidd, 2009).

The common risk factor approach (CRFA) indicates that some contributing risk factors are common to many chronic diseases. For example, sugar consumption is a risk factor for both DM and dental caries (Sheiham & Watt, 2000). However, research reports have presented inconsistent findings regarding the association between diabetes and dental caries, with the results of studies differing substantially. Some studies have shown a higher prevalence of caries in subjects with diabetes than in those without (Latti et al., 2018; López et al., 2003), while other studies found either lower (Kirk & Kinirons, 1991; Wyne et al., 2016), or similar caries prevalence in diabetic and non-diabetic subjects (Harrison & Bowen, 1987; Ismail, et al., 2017; Twetman et al., 1989).

The saliva of diabetic patients shows both quantitative and qualitative changes in several parameters (Javed et al., 2009; López et al., 2003; Moreira et al., 2009; Siudikiene et al., 2008; Zalewska et al., 2013) with diabetic adults reportedly having elevated levels of *S. mutans* in their plaque and saliva (Hintao et al., 2007). Inconclusive findings have been reported in the literature, where some studies reported no significant difference in the level of cariogenic bacteria was found in the saliva of diabetic versus non-diabetic children (Harrison & Bowen, 1987; Siudikiene et al., 2008). While a recent study revealed a higher bacterial load in the saliva and dental biofilm of of diabetic study sample (Coelho et al., 2018). Studies have reported that the salivary flow rate of children with T1DM is lower than that of non-diabetic children (Javed et al., 2009; Siudikiene et al., 2008). Although, there was no difference between children with poorly controlled and well-controlled T1DM in terms of salivary flow (Javed et al., 2009). In addition to the decrease in quantity, the saliva of diabetic individuals was characterized by low buffering capacity and pH, higher viscosity, and increased levels of carbohydrates, glucose and total protein (Moreira et al., 2009; Siudikiene et al., 2008).

Studies in Saudi Arabia exploring the relationship between dental caries and T1DM in children have been relatively scarce. Hence, this study could serve as a good model for a baseline study of oral health status in Saudi Arabia. The aim of this study was to compare the prevalence of dental caries among 6- to 12-year-old children with and without T1DM in Riyadh, Saudi Arabia, taking into account oral hygiene and diet.

2. Materials and methods

This research was designed as a comparative study to investigate the prevalence and association between dental caries and T1DM among 6- to 12-year-old children in Saudi Arabia by comparing the risk of caries between samples of diabetic and non-diabetic children. This was achieved by evaluating the numbers of decayed and filled teeth, adjusted for demographic variables, among a sample of diabetic children compared with a sample of schoolchildren matched by age and gender.

2.1. Study sample

At alpha 0.05 with estimated proportional 0.6 and 0.4 and powered 0.86 the total sample size was calculated to be at least 200. The diabetic children were selected from King Khalid University Hospital Pediatric Clinic and King Abdulaziz University Hospital, located in the city of Riyadh. While non-diabetic children were sampled from two public primary schools that were selected randomly from all Riyadh school districts.

Subjects in both groups were excluded from participating if they met any of the following criteria:

1. Active orthodontic treatment.
2. The presence of any systemic disease (other than diabetes).
3. The use of antibiotics within the past month (which might affect the mouth flora).
4. Children who had a meal within an hour before examination were excluded from CRT analysis.
5. Lack of written consent from the parents for their children to participate in the study.

2.2. Ethical review & approval

Letters of approval were sent to the participating schools and healthcare facilities. Approval from the College of Dentistry Research Center (CDRC No. FR0313), approval from the ethical subcommittee of the Institutional Review Board of King Khalid University Hospital (KKUH No. 16-0391-IRB), and informed consent from each subject's parent/guardian were obtained before the commencement of the study.

2.3. Study data

The data for the study were collected using a pre-tested questionnaire, oral examinations, and salivary samples. The questionnaire was filled by parent/guardian and collected a variety of information including socio-demographic factors, oral hygiene practices, dietary habits, dental visits, medical history, type of diabetes and family history. The consent forms and questionnaire were distributed by schoolteachers to be filled out by the parents/-guardians of the participants and collected within a week, just before clinical examination. While consent forms and questionnaire of diabetic children were completed by their parents/guardians just before examination.

2.4. Examiner calibration & inter-examiner reliability

The oral examinations in this study were performed by four examiners (two male and two female dentists) along with four recorders. All examiners were calibrated to a gold-standard examiner according to the WHO Basic Surveys Calibration Protocol for caries detection, coding findings, and recording, which consists of a theoretical training session followed by oral examination of five patients (not part of the study sample) at the College of Dentistry Pediatric Clinic at King Saud University. The inter-examiner kappa statistic was assessed and was found to be 0.873, with a p-value of <0.05.

2.5. Dental caries exam

The selected schools and clinics were informed in advance, prior to the visit of the examiners. Then, the investigators conducted a clinical examination for dental caries utilizing the corresponding WHO diagnostic criteria (WHO, 2013). Because the ages of the children in this study ranged from 6 to 12 years, the subjects were expected to have mixed dentitions; hence, decayed and filled permanent and primary teeth (DFT/dft) instead of decayed, missing, and filled permanent and primary teeth (DMFT/dmft) were used to assess the frequency of caries for the permanent and primary dentitions, respectively. Only the permanent teeth were recorded when both the primary and permanent components of the same tooth/teeth were present.

The examination was carried out using light mounted on the examiner's forehead and a disposable plane mouth mirror (Aesculap AG). The teeth were dried with a cotton roll to remove any plaque or debris where necessary, the surfaces of each tooth were examined. The examiners checked the final form to detect any possible mistakes before dismissing the child for salivary testing.

2.6. CRT salivary testing

The collection of salivary samples was performed utilizing a CRT (Caries Risk Test) kit for testing the microorganism content and buffering capacity of saliva (Ivoclar Vivadent AG, Schaan, Liechtenstein). The test included the following components:

2.6.1. Microbial assessment

Each child chewed on a piece of paraffin wax to stimulate the flow of saliva. The child was asked to sit in an upright, relaxed position, with the head slightly inclined, and to drool saliva from the floor of the mouth into a sterile plastic cup.

2.6.2. CRT buffer test

Using a pipette, a saliva sample was taken, and one drop was placed on each of the three test pads: orange (low pH), green (medium pH), and blue (high pH). The test pads began to change colour immediately, but the final colour was assessed only after two minutes and recorded as the final saliva pH level. The results were categorized into three groups: high pH (i.e., blue), greater than or equal to 6.0, representing low caries risk; intermediate pH (i.e., green), ranging from 4.5 to

5.5, representing critical caries risk; and low pH (i.e., orange), less than or equal to 4.0, representing the highest caries risk.

2.7. Statistical analysis

Once the data was collected and stored in a computer spreadsheet file, they were statistically analysed using SPSS software (IBM SPSS version 20). Descriptive statistics such as frequency, mean and standard deviations were determined. For inferential statistics, a *t*-test ($\alpha = 0.05$) was used to analyse the difference in mean DFT/dft values between groups. The chi-squared test, linear regression, and one-way analysis of variance (ANOVA) were also performed to evaluate the association between diabetes, DFT/dft, and other variables. A p-value below 0.05 was considered statistically significant.

3. Results

The analysed sample consisted of a total of 209 subjects (69 diabetic & 140 non-diabetic); 117 were females and 92 males. The age and gender distribution of the subjects in the diabetic group consisted of 37 (54%) girls and 32 (46%) boys; their average ages were 9.69 ± 1.95 and 10.14 ± 2.17 years (mean ± SD), respectively. The non-diabetic group was composed of 80 (57%) girls and 60 (43%) boys; their mean ages were 9.25 ± 2.00 and 10.35 ± 1.88 years, respectively (Table 1).

The diabetic and non-diabetic groups showed no significant difference in caries experience. Table 2 shows that the mean dft values were 3.32 (±0.78) and 3.28 (±0.71), respectively for the diabetic and non-diabetic children ($p = 0.458$), while the mean DFT values were 1.62 (±0.65) and 1.96 (±0.65), respectively for the diabetic and non-diabetic children ($p = 0.681$).

The data also showed that diabetes had statistically significant associations with the education level of the child's father and the monthly income of the child's household. Paternal education level ($p = 0.003$) and monthly income ($p = 0.002$) were significantly and markedly higher in the diabetic group than in the non-diabetic group. A similar association was also seen with maternal education level, where mothers of diabetic children were more likely to have a higher education than the mothers of non-diabetic children in this study, although this association was not statistically significant ($p = 0.076$), Table 2.

The findings on Table 3 showed non-significant differences between diabetic & non-diabetic children on their brushing habits. But showed that diabetic children were significantly more likely than non-diabetic children to have visited a dentist in the preceding 12 months ($p = 0.04$). The findings also showed associations between non-diabetic status and the frequency of consumption of sweets and flavoured milk. The diabetic group was recorded as having significantly lower consumption of sweets ($p = 0.003$) and flavoured milk ($p = 0.002$) than the non-diabetic group (Table 3).

Table 4 findings showed that higher *Lactobacillus* CRT levels were found among the diabetic children compared to the non-diabetic children ($p = 0.04$).The CRT analysis was conducted on a smaller sample, consisting of 59 (out of 69) diabetic & 135 (out of 140) non-diabetic children, because some subjects were excluded for having eaten a meal just before attending the examination. The CRT testing of the oral flora in the samples indicated that medium oral pH levels (4.5–5.5) were found more among diabetic children than their non-diabetic counterparts, whereas the latter group had high pH (≥6.0) ($p = 0.01$).

4. Discussion

The study aimed at comparing the prevalence of dental caries among groups of 6- to 12-year-old children with and without Type 1 diabetes mellitus in Riyadh, Saudi Arabia. No statistically significant association was found between the prevalence

Table 1 Sample distribution by gender, mean age, and diabetes status.

Subject Distribution by Age, Gender, and Diabetes		Non-diabetic Group N = 140	Diabetic Group N = 69
Girls	Number of Subjects (% of Total)	80 (57%)	37 (54%)
	Mean Age (Std. Deviation)	9.25 (±2.003)	9.69 (±1.952)
Boys	Number of Subjects (% of Total)	60 (43%)	32 (46%)
	Mean Age (Std. Deviation)	10.35 (±1.883)	10.14 (±2.167)

Table 2 Distribution of the study sample by mean dental caries, & some socio-economic indicators.

Variable	Categories	Non-diabetic N = 140	Diabetic N = 69	p-value
Caries (mean (SD) dft Index)		3.28 (0.71)	3.32 (0.78)	0.458
Caries (mean (SD) DFT Index)		1.96 (0.65)	1.62 (0.65)	0.681
Father's Education	Low education (high school or less)	85 (62%)	27 (40%)	0.003
	High education	52 (38%)	40 (60%)	
Mother's Education	Low education (high school or less)	95 (70%)	38 (58%)	0.076
	High education	41 (30%)	27 (42%)	
Monthly Income	10,000 or less	82 (71%)	28 (47%)	0.002
	More than 10,000	34 (29%)	32 (53%)	

Table 3 Associations between the samples' specific oral-health-related behaviours and diabetes status.

Variable	Categories	Non-diabetic	Diabetic	p-value
How frequently does your child brush his/her teeth?	Not daily	58 (50%)	34 (52%)	0.461
	Once or more a day	59 (50%)	32 (48%)	
Does your child use fluoridated toothpaste?	No	29 (21%)	13 (19%)	0.452
	Yes	109 (79%)	55 (81%)	
Does anyone help the child clean his/her teeth?	No	103 (82%)	49 (78%)	0.283
	Yes	22 (18%)	14 (22%)	
Has the child visited a dental clinic in the past 12 months?	No	84 (62%)	33 (48%)	0.040
	Yes	52 (38%)	36 (52%)	
How frequently does your child drink milk?	Never	10 (8%)	10 (15%)	0.089
	Always or Sometimes	119 (92%)	56 (85%)	
How frequently does your child consume sweets?	Never	3 (2%)	9 (14%)	0.003
	Always or Sometimes	126 (98%)	56 (86%)	
How frequently does your child drink flavoured milk, e.g., chocolate milk?	Never	26 (20%)	26 (41%)	0.002
	Always or Sometimes	105 (80%)	38 (59%)	

Table 4 Salivary indicators among the study sample of diabetic & non-diabetic children.

Variable	Categories	Non-diabetic	Diabetic	p-value
Streptococcus Level	Low	13 (10%)	7 (12%)	0.405
	High	122 (90%)	52 (88%)	
Lactobacillus Level	Low	68 (50%)	21 (36%)	0.0400
	High	67 (50%)	38 (64%)	
pH Level	Low (less than 4)	66 (49%)	31 (53%)	0.001
	Medium (4.5–5.5)	34 (25%)	25 (42%)	
	High (greater than 6)	35 (26%)	3 (5%)	

of dental caries and T1DM among 6- to 12-year-old children. The extent of dental caries in the primary teeth was slightly higher in the diabetic group (3.32 ± 0.78) than in the non-diabetic group (3.28 ± 0.71), while caries in the permanent dentition was slightly lower in the diabetic children (1.62 ± 0.65) than in the non-diabetic children (1.96 ± 0.65). These findings contrast with a previous study, which reported a lower rate of caries in the primary teeth and a higher rate in the permanent teeth of diabetic children than in those of healthy control children (Wyne et al., 2016).

These small differences in caries rates between the diabetic and non-diabetic children were not statistically significant. Given the multifactorial nature of dental caries, some factors may increase its risk among diabetic individuals, while others might reduce that risk (Ismail et al., 2015; Novotna et al., 2015).

Our findings are in line with several studies that examined the association between dental caries and T1DM. A systematic review summarizing this relationship found a total of 20 published studies that reported caries experience among children with T1DM, of which 15 were case–control and 5 were longitudinal studies (Ismail et al., 2015). Among the 15 studies that reported caries experience in the permanent dentition (DMFT or DMFS), 8 of them contrasted with our findings: 5 studies found significantly elevated caries experience among children with T1DM compared to healthy control children, while 3 studies reported the opposite. In contrast, the findings of this study were aligned to 7 other studies that reported no difference between the two groups; similarly, among the studies that reported on caries in the primary dentition, none reported a significant difference between children with T1DM and controls.

This study showed that diabetes was more prevalent among children of parents who were more affluent or of higher socio-economic status. A better interpretation may be that parents with higher socio-economic indicators were more likely to have their children's diabetes condition diagnosed, given that a greater percentage (90%) of diabetic children in Saudi Arabia are unaware of their medical condition (Al-Rubeaan, 2015). Socio-economic factors may also explain the increased likelihood of dentist visits during the preceding 12 months among diabetic compared to non-diabetic children.

Diabetic children were less likely than the non-diabetic to be consumers of sweets and flavoured milk, which could be explained by the actions of the diabetic children's parents and their application of stricter dietary controls. A recently published paper attested to the above by indicating a difference in caries risk between children with well-controlled and poorly controlled diabetes (Lai et al., 2017).

The CRT changes associated with diabetes showed that diabetic children were more likely than non-diabetic children to have critical oral pH levels (4.5–5.5) and high *Lactobacillus*

CRT levels. These findings differ from a previous report in which diabetics had reduced *Lactobacillus* levels (Twetman et al., 1989). Although the decreased pH values and increased *Lactobacillus* counts seen in diabetic children are indications of a heightened caries risk, it appears that the participation of diabetic children in healthy behaviours (e.g., diet) might have restored their caries risk to lower levels (Jeong et al., 2006).

A limitation of this study was its comparable cross-sectional design. Stronger evidence of associations could be achieved in future studies utilizing cohort/longitudinal design.

5. Conclusion

No statistically significant differences were found in caries prevalence between diabetic and non-diabetic children in this study, for both the primary and permanent dentitions.

Decreased pH values and elevated *Lactobacillus* counts in diabetic children was noted compared to non-diabetic children, which could indicate a higher caries risk in the former group; nevertheless, the increased probability of healthy behaviours (e.g., diet) among diabetic children may have restored their caries risk to lower levels.

This study could be used as a baseline for future studies, which should attempt to overcome the limitations and explore in greater depth the different risk factors influencing caries risk among T1DM, including socioeconomic status, metabolic control, preferably utilizing longitudinal study designs.

Statement of contributions

All, author and co-authors, contributed in planning and conducting this study, and in revising this manuscript. Al-Badr, Halawany, Al-Jazairy, and Al-Jameel were the examiners of study subjects, but also contributed in writing the manuscript. Alhadlaq, Al-Sharif, Jacob, and Abraham were the recorders during the study, while the first two also performed the CRT laboratory testing. Mr. Al-Maflehi contributed in data setup, statistical analysis and presentation.

Ethical & conflict of interest statement

We confirm that this study was conducted following ethical guidelines; letters of approval were sent to the participating schools and healthcare facilities. Approval from the College of Dentistry Research Center (CDRC No. FR0313), approval from the ethical subcommittee of the Institutional Review Board of King Khalid University Hospital (KKUH No. 16-0391-IRB). Informed consent from each subject's parent/guardian were obtained before commencing the data collection for the study. Furthermore, subjects were de-identified to protect their privacy during data entry and analysis.
Authors also confirm that there are no known conflicts of interest associated with this publication. Although the research received some direct funding from the Dental Caries Research Chair of the King Saud University as well as indirect funding from the College of Dentistry of the same University, the authors believe that such funding would not influence findings.

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