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ORIGINAL RESEARCH

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Factors associated with the development of dental caries among schoolchildren in northwest Mexico

Juan José Villalobos Rodelo[1,2,*], Rosa Alicia García Jau[1], Cynthia Marina Urias Barreras[1], Gloria Elena Guzmán Celaya[1], Martha Viridiana González Jiménez[1], Christopher Ahmed Montes Cruz[1], Valeria Guadalupe Gastélum García[1], Anel Karely Olivas Velázquez[1], Efigenia Moreno Terrazas[1], Aurea Elizabeth Valle Urias[1]

[1]School of Dentistry, Autonomous University of Sinaloa, 80040 Culiacan, SIN, Mexico
[2]Department of Epidemiology, Institute of Social Security and Services for Government Workers, 80000 Culiacan, SIN, Mexico

***Correspondence**
juanvillalobos@uas.edu.mx
(Juan José Villalobos Rodelo)

Abstract

Background: Dental caries represent a multifactorial disease that has been classified as a public health problem of global proportions. Its prevalence and incidence in populations are determined by numerous risk factors. This study sought to determine the factors associated with the development of caries among schoolchildren between 6 and 12 years of age. **Methods**: A sample of 3275 schoolchildren aged 6–12 years was analyzed, using the Decayed, Missing and Filled Primary Teeth (dmft) and the Decayed, Missing and Filled Permanent Teeth (DMFT) Indices to explore the caries experiences of participants in their primary and permanent dentitions. Statistical analyses were performed based on summary and dispersion measures for the quantitative, as well as percentages and frequency rates for the categorical variables. The relationships between variables were estimated using the chi-square test and a logistic regression model. **Results**: The average age of the schoolchildren was 8.5 $\pm$ 1.74 years, and the average dmft and DMFT indices equaled 1.41 $\pm$ 2.10 and 0.34 $\pm$ 1.04, respectively. The Treatment Need Index (TNI) was 81.91%, the Significant Caries Index (SiC) 3.81 and the Care Index 20.29%. Two factors showed a positive association with the presence of caries in the primary dentition: initiating toothbrushing after two years of age (odds ratio—OR = 1.27) and consuming sugar (OR = 1.31). For permanent dentition, the following factors were positively associated: being 10–12 years old (OR = 1.98) and having developed caries during primary dentition (OR = 2.53). Finally, an inverse association was identified between the presence of caries in primary and permanent dentitions and owning household assets, as classified within the second and third socioeconomic terciles (OR = 0.66, 0.63). **Conclusions**: The presence of caries in primary teeth is associated with their presence in permanent teeth, it is crucial that dental professionals promote preventative education from an early age.

Keywords

Dental caries; Risk factors; Schoolchildren; Mexico

1. Introduction

Dental caries rank as the most prevalent oral health disease among school-age children worldwide, posing a significant public health problem [1–3]. According to the global oral health report published by the World Health Organization (WHO) in 2022, oral diseases affect approximately 3.5 billion people around the world. Global estimates indicate that two billion people experience caries in their permanent teeth and 514 million children in their primary teeth [2]. This condition causes dental pain and discomfort, impairs childhood functions including language development and imposes a financial burden on families [4–6]. In children and adolescents, caries constitute a multifactorial disease whose prevalence and incidence in populations are determined by numerous risk factors including age, ethnicity, dietary patterns such as sugar consumption, oral hygiene habits, and socioeconomic level [7–9].

In 2021, a study conducted by the Mexican Ministry of Health obtained a value of 3.69 in the Decayed, Missing and Filled Primary Teeth (dmft) index for girls and boys aged 2–10 years, from a socially marginalized community [7]. Meanwhile, Kolawole *et al.* [8] reported a dmft index of 0.27 for 6–12-year-old schoolchildren from a disadvantaged population in Nigeria, stating that 14.9% of participants suffered from dental caries.

The Mexican study cited above yielded a value of 3.2 in the Decayed, Missing and Filled Permanent Teeth (DMFT) index for children and adolescents aged 6–19 years [7], while the study conducted in Nigeria and a similar research in Saudi Arabia reported DMFT indices of 0.39 and 7.8, respectively [8, 9]. The Mexican study estimated dmft and DMFT indices of 3.36 and 2.97, respectively, in the state of Sinaloa, in northwest Mexico [7]. Additionally, Prada *et al.* [10] reported a global DMFT Index of 4.48 for 6–12-year-old schoolchildren from underprivileged areas of Valencia, in Spain.

Regarding prevalence, the study by the Mexican Ministry of Health analyzed children and adolescents 2–19 years old, yielding rates of 75.4% nationwide and 65.4% in the state of Sinaloa specifically [7]. Similarly, Prada *et al.* [10] found a prevalence of 81.87% in Valencia. Another Mexican study by Casanova and Medina revealed that caries were far more common in primary than in permanent teeth, with a prevalence of 73.6% and a dmft index of 2.85 [11]; a study by Lara-Capi demonstrated that participants from low-income households in Veracruz, Mexico, were 2.21 times as likely to present cavitated caries lesions as those enjoying medium and high socioeconomic levels [12], and a study by Contreras-Bulnes conducted with street children in Toluca, in central Mexico, reported a prevalence of 59.08% in primary teeth, with a dmft of 3.50 [13].

According to Prada *et al.* [10], the presence of cavitated caries is also associated with mothers' educational levels and poor oral hygiene including low brushing frequency. Studies conducted in Chile, Mexico and Saudi Arabia identified more prevalent and severe cases of dental caries among children from low-income families who attended public schools, compared to their counterparts in more favorable settings. These children were raised in contexts calling for preventative measures and adequate restorative care in oral health services [14–17]. Over the last 20 years, the prevalence of caries has decreased in high- and upper-middle-income countries, while increasing in low- and lower-middle-income countries [18].

Various studies have addressed the risk factors affecting dental caries. They show that unhealthy—particularly high-sugar and low-fiber—diets are associated with overweight, obesity, nutrient deficiency and dental caries in children [12, 19, 20]. Furthermore, it has been demonstrated that the interaction between the frequency and quantity of sugar consumption is significantly associated not only with an increase in the experience and prevalence of caries [21], but also with a greater risk of infection [22, 23]. Other determining factors reported include oral hygiene habits, education, the social environment and economic conditions that limit access to health services [24].

The purpose of this study was to identify the risk factors for dental caries such as diet, hygiene practices and the specific sociodemographic variables of a school population in an urban area of northwest Mexico. We anticipated that our findings could provide useful guidelines for conducting longitudinal studies to explore the ways in which these factors are dynamically associated with the prevalence of dental caries over time. This, in turn, would contribute to adapting intervention strategies that fit the needs of specific populations.

2. Material and methods

We conducted a cross-sectional, descriptive study with schoolchildren between the ages of 6 and 12 years, from 28 of the 49 public elementary schools in the city of Culiacan Rosales, the state capital of Sinaloa (N = 14,852). In calculating sample size, we considered the following criteria: a proportion of 73% [25] a precision of 1.5%, a non-response rate of 5% and 95% confidence interval. The calculated sample totaled 3304, and the final sample, 3275 schoolchildren. Authorization to carry out the study was requested from the authorities of the Ministry of Public Education and Culture in Sinaloa, and from the director of each school selected.

Sampling was based on a stratified multistage cluster and simple random probability design. Selection probability for each school was proportional to the total number of students, and the number of schools visited per stratum was proportional to the total number of students in the stratum.

The clusters were comprised of five zones (center, northwest, northeast, southeast and southwest) geographically located in Culiacan. The sites of the 49 schools were distributed as follows: 13 schools (25.87%) in the center, 12 (25.00%) in the southwest, 6 (10.71%) in the southeast, 9 (17.86%) in the northeast and 9 (17.86%) in the northwest of Culiacan.

Our sample of 28 schools (strata) was distributed in proportion to the number of schools in each zone: eight schools were selected from the center, seven from the southwest, three from the southeast, five from the northeast and five from the northwest.

Each school was assigned a sample size of 118 schoolchildren to be examined: 108 from 6–11 and 10–12 years old. Allocation by sex was determined for each school as follows: nine boys and nine girls from the 6–11 age group, and five boys and five girls from the 12-year age group. Selection was random, taking the school enrolment list as our sampling frame.

2.1 Ethical considerations

Pursuant to the International Ethical Guidelines for Biomedical Research Involving Human Subjects, established by the Council for International Organizations of Medical Sciences (CIOMS) [23], we requested that the parents/guardians of the selected schoolchildren sign a letter of written consent based on the principles of autonomy, confidentiality and privacy. Permission to conduct the study activities was requested from the Ministry of Public Education and Culture in Sinaloa and from the authorities of each participating school.

2.2 Selection criteria

Inclusion criteria encompassed male and female schoolchildren 6–12 years old enrolled in the selected public schools, whose parents/guardians signed the required informed-consent letter to participate in the study.

The exclusion criteria pertained to schoolchildren with a disease in their oral cavity and/or fixed orthodontic appliances. Diseases included chickenpox, scarlet fever, herpetic stomatitis and mumps.

The elimination criteria comprised schoolchildren who answered <80% of the items on the survey questionnaire and/or intentionally provided illegible or false responses.

We used the Significant Caries Index (SiC) designed by Bratthall [26] to identify the part of the population most affected by the disease. For this purpose, we calculated the DMFT index for the third of individuals who presented the highest values for caries. Also calculated were the Care Index (CI) [27] and the Treatment Need Index (TNI) [28]. The following variables were analyzed:

Dependent variables: the dmft and DMFT indices were estimated according to the average number of teeth with caries, fillings or indicated extractions in the primary dentition and the average number of teeth with caries, fillings or missing as a result of decay in the permanent dentition of participants. The prevalence of caries was estimated based on the dmft and DMFT indices >0.

We defined the presence of caries operationally as recommended by the WHO in 1997 [29]: "a lesion in a pit or fissure, or a smooth tooth surface exhibiting an unmistakable cavity, undermined enamel or a perceptibly softened floor or wall".

The independent variables analyzed were sociodemographic characteristics such as sex (male or female), age (between 6 and 12 years), the number of family members (2–4 or 5–10), the age at which toothbrushing was initiated (before two years or after two years), consumption of chocolates, sweets, pastries and cookies (never, hardly ever, sometimes or daily), Social Security coverage (yes or no), the educational level of mothers and fathers (middle school or high school and above), and having attended a dental consultation within the last year (for preventative or other reasons).

To determine the socioeconomic levels of participants, we considered proxy variables indicative of differences in their socioeconomic conditions, namely possessions (household assets, automobile and access to the internet) and monthly household living expenses (ranging from 0–1559 Mexican currency—MXN to >14,055 MXN). To construct the analytical indicators, we transformed the categorical into numerical variables and, on this basis, generated terciles, with the first representing the lowest and the last the highest socioeconomic levels.

2.3 Data collection

Prior to initiating the study, training was provided to research personnel in the assessment of the index for the numbers of decayed teeth, teeth missing due to caries, and filled teeth for primary teeth (dmft) and permanent teeth (DMFT) (WHO, 1997) [29]. The diagnostic examinations were carried out by five social service interns from the Faculty of Dentistry of the Autonomous University of Sinaloa; they underwent training in the management of oral health surveys (WHO 1997) [29] and participated in a pilot test as an examiner calibration measure to ensure standardized processes (Kappa test: 0.85 and percent agreement: 92%). The pilot test and diagnostics were implemented at the selected school facilities. Sociodemographic data were collected by means of a questionnaire derived from validated instruments used in previous studies. The parent/guardian of each student was administered the questionnaire after signing an informed consent letter detailing the dental examination procedure that would be performed on the child. The examinations allowed for diagnosing the oral health status and identifying the dmft and DMFT indices (dependent variables) of each child. They were systematically implemented with natural light and employing the visual-tactile method with the aid of a mirror, a No. 5 dental plane and the community periodontal index (CPI) probe.

2.4 Statistical analysis

To create the database, collect information and perform statistical analyses, we used Statistical Package for Social Sciences, Version 26, software (SPSS, Inc., Chicago, IL, USA). For quantitative variables, we prepared descriptive statistics as a basis for calculating the mean and dispersion measures; for categorical variables, we used frequency rates and percentages.

The SiC was obtained by calculating the means of the DMFT and dmft indices for the third of the students most affected by caries. The Care Index was calculated based on the following formula:

$$CI = \frac{filled\ teeth}{DMF} \times (100\%)$$

The TNI was calculated as follows:

$$TNI = \frac{decayed\ teeth}{decayed\ teeth + filled\ teeth} \times (100\%)$$

We applied the Kruskal Wallis and Chi-square tests to establish the relationship of the dependent variables: participants' experiences of caries in their primary (dmft) and permanent (DMFT) dentition, as well as the presence and severity of the caries (dmft and DMFT >0, ≥3 and ≥6), with their age. To analyze the relevance of sex in this association, we used the Mann Whitney and Chi-square tests.

The Chi-square test and crude odds ratios (ORs) were estimated for the bivariate analysis of probable risk factors, using 95% confidence interval and a $p < 0.05$ significance level.

To adjust the multivariate logistic regression model for the dependent variables, prevalence of caries in primary and permanent dentitions with possible risk factors, we selected variables with a $p < 0.25$ significance level in the bivariate analysis. The final model was developed using the Hosmer-Lemeshow Goodness-of-Fit Test.

3. Results

The study was carried out in 28 of 49 public elementary schools in Culiacan. Of the calculated sample (3304 participants), the final response rate reached 99.12% (the 0.88% loss was attributable to our elimination criteria and the refusal of some parents to participate in the study). Our final sample thus totaled 3275 schoolchildren.

Table 1 illustrates the sociodemographic characteristics of the study population. The participants were evenly distributed by sex (50.6% female *vs.* 48.4% male) and their ages averaged

TABLE 1. Sociodemographic characteristics of the study population.

Variable	Mean ± SD	Range
Age (yr):		
Schoolchildren	8.55 ± 1.74	6–12
Fathers	38.87 ± 6.87	22–72
Mothers	35.97 ± 6.28	20–65
Number of family members	3.44 ± 1.27	2–10
Variable	Frequency	Percentage
Sex of schoolchildren:		
Female	1656	50.6
Male	1619	49.4
Number of family members:		
2 to 4	2730	83.9
5 to 10	522	16.1
Age at initiation of toothbrushing (yr):		
Before two	1933	59.4
After two	1320	40.6
Consumption of chocolates, sweets, pastries and cookies:		
Never	34	1.0
Hardly ever	703	21.6
Sometimes	1811	55.5
Daily	715	21.9
Social Security coverage:		
No	534	16.3
Yes	2741	83.7
Age of schoolchildren (yr):		
6 to 9	2150	65.6
10 to 12	1125	34.4
Mothers' educational level:		
Middle school	1458	45.0
High school and above	1781	55.0
Fathers' educational level:		
Middle school	711	24.1
High school and above	2238	75.9
Had attended a dental consultation within the last year:		
For preventative purposes	2712	82.8
For other purposes	563	17.2
Socioeconomic level (ownership of household assets):		
1st tercile (low)	1234	37.8
2nd tercile (medium)	944	28.9
3rd tercile (high)	1090	33.3
Household income:		
1st tercile (low)	789	25.0
2nd tercile (medium)	1475	46.7
3rd tercile (high)	895	28.3

SD: Standard deviation.

8.5 (standard deviation—SD ± 1.74 years). For the purposes of the binary statistical analysis, we dichotomized the age variable into two groups: 6–9 years (65.6%) and 10–12 years (34.4%). Regarding the participants' families, 83.9% of the students belonged to households consisting of 2–4 members; the average age of the fathers slightly exceeded that of the mothers (38.87 *vs.* 35.97), with the former reporting high-school studies and above, a higher educational level (75.9%) than that of the mothers (55.0%). Regarding Social Security insurance, 16.3% of the families had no coverage and 17.2% had attended at least one preventative dental appointment within the last year. In assessing the socioeconomic indicators based on ownership of household assets, we found that 37.38% of the families fell into the first, or lowest, tercile, while 33.3% occupied the third or highest, tercile. Finally, as regards their monthly household living expenses, 28.3% of the families lay in the third and 25% in the first tercile.

3.1 Clinical variables

The SiC reporting the population most affected by caries equaled 3.81, the CI for primary dentition 20.29% and the TNI 81.91%.

For permanent dentition, the CI was 12.02%, the TNI 87.89% and the SiC 1.02. Table 2 shows the experience and prevalence of caries in primary dentition. The dmft reported was 1.41 ± 2.10, with rates of 1.46 for male and 1.36 for female students. The prevalence of caries (dmft >0) in primary dentition, which reached, 46.9%, was identified in 48.1% of male and 45.8% of female ($p = 0.206$) students.

3.2 Permanent dentition

As illustrated in Table 2, the DMFT was 0.34, SD ± 1.04, with a higher average for male than for female (0.35 *vs.* 0.33) students. The prevalence of caries (DMFT >0) came to 14.7%, with higher rates for male than for female students (15.5% *vs.* 13.9%, respectively) ($p = 0.191$).

This table also summarizes the experience, prevalence and severity of caries in the primary and permanent dentitions of the schoolchildren analyzed, by age group and sex. We observed significant differences between age groups ($p < 0.0001$) as regards the presence of caries in the two dentitions. The non-parametric trend test revealed a negative relationship regarding the correlation between dmft and age: as age increased, the dmft index decreased ($p = 0.010$) and the DMFT index decreased as participants became older ($p = 0.010$). We found no statistically significant differences between male and female students regarding the severity of caries in their primary and permanent dentitions ($p = 0.796$ and 0.099, respectively).

Table 3 illustrates the results from the bivariate analysis of the factors associated with the presence of caries in primary and permanent dentition. These data revealed that being 10–12 years old was negatively associated with the presence of caries in primary dentition (OR = 0.52, $p < 0.001$).

The following variables associated with the presence of caries in primary dentition were statistically significant ($p < 0.05$): initiating toothbrushing after age two (OR = 1.29; 95% CI, 1.11–1.49); consuming chocolates, sweets, pastries and cookies sometimes/daily *vs.* never/hardly ever (OR = 1.24; 95% CI, 1.04–1.47); lacking Social Security coverage (OR = 1.27; 95% CI, 1.05–1.54); mothers having attained only middle-school education (OR = 1.37; 95% CI, 1.19–1.59); fathers having attained only middle-school education (OR =

TABLE 2. Distribution of experience, prevalence and severity of caries by age and sex in the study population.

	$\bar{x}$ ± dmft SD (n)	$\bar{x}$ ± DMFT SD (n)	% dmft >0	% DMFT >0	% dmft ≥3	% DMFT ≥3	% dmft ≥6	% DMFT ≥6
Age (yr)								
6	1.78 ± 2.58 (525)	0.19 ± 1.18 (485)	47.2	6.0	28.2	2.1	11.0	1.2
7	1.70 ± 2.37 (547)	0.21 ± 0.75 (544)	48.8	9.9	27.8	3.3	9.5	0.0
8	1.58 ± 2.02 (532)	0.29 ± 0.79 (533)	54.7	15.2	25.9	4.9	5.8	0.0
9	1.45 ± 1.82 (532)	0.36 ± 1.01 (539)	55.5	16.3	21.8	5.2	4.5	0.4
10	1.04 ± 1.69 (483)	0.48 ± 1.20 (546)	40.4	19.4	16.8	9.0	3.1	0.7
11	0.71 ± 1.57 (387)	0.46 ± 1.11 (533)	31.3	19.9	8.3	7.3	1.3	0.8
12	0.83 ± 2.34 (29)	0.76 ± 1.79 (46)	24.1	21.7	6.9	13.0	3.4	6.5
Total	1.41 ± 2.10 (3035)	0.34 ± 1.04 (3226)	46.9	14.7	22.0	5.5	6.1	0.6
p value	<0.001† *−0.132, $p = 0.010$	<0.001† *0.138, $p = 0.010$	<0.001‡	<0.001	<0.001	<0.001	<0.001	<0.001
Sex of school-children:								
Male	1.46 ± 2.12 (1506)	0.35 ± 1.10 (1599)	48.1	15.5	23.2	5.2	6.2	0.8
Female	1.36 ± 2.07 (1529)	0.33 ± 0.98 (1627)	45.8	13.9	20.9	5.7	6.0	0.4
p value	0.150¶	0.272¶	0.206‡	0.191‡	0.136‡	0.511‡	0.796‡	0.099‡

*DMFT index: average number of decayed, missing and filled permanent teeth; dmft index: average number of decayed, extracted and filled primary teeth; SD: standard deviation. †Kruskall-Wallis; *non-parametric trends; ‡χ^2; and ¶Mann-Whitney.*

TABLE 3. Bivariate analysis of the factors associated with the presence of caries in primary and permanent dentition.

Primary dentition			Permanent dentition	
Variables	Crude OR (95% CI)	*p* value	Crude OR (95% CI)	*p* value
Sex of schoolchildren:				
Male	*		*	
Female	0.91 (0.79–1.05)	0.206	0.78 (0.72–1.06)	0.191
Age of schoolchildren (yr):				
6 to 9	*		*	
10 to 12	0.52 (0.44–0.61)	<0.001	1.80 (1.48–2.19)	<0.001
Number of family members:				
2 to 4	*		*	
5 to 10	1.18 (0.98–1.44)	0.079	1.18 (0.91–1.52)	0.199
Age at initiation of toothbrushing (yr):				
Before two	*			
After two	1.29 (1.11–1.49)	0.001	1.15 (0.94–1.40)	0.151
Consumption of chocolates, sweets, pastries and cookies:				
Never/hardly ever	*		*	
Sometimes/daily	1.24 (1.04–1.47)	0.013	1.18 (0.92–1.50)	0.179
Social Security coverage:				
Yes	*		*	
No	1.27 (1.05–1.54)	0.013	1.12 (0.86–1.44)	0.382
Mothers' educational level:				
High school and above	*		*	
Middle school	1.37(1.19–1.59)	<0.001	1.03 (0.85–1.26)	0.722
Fathers' educational level:				
High school and above	*		*	
Middle school	1.35 (1.13–1.61)	0.001	1.34 (1.06–1.69)	0.012
Having attended a dental consultation within the last year:				
For preventative purposes	*		*	
For other purposes	0.64 (0.53–0.78)	<0.001	0.80 (0.61–1.05)	0.113
Socioeconomic level based on ownership of household assets:				
1st tercile (low)	*		*	
2nd tercile (medium)	0.74 (0.63–0.87)	<0.001	0.67(0.53–0.84)	0.001
3rd tercile (high)	0.76 (0.65–0.89)	0.001	0.99 (0.80–1.22)	0.930
Monthly household living expenses:				
1st tercile (low)	*			
2nd tercile (medium)	0.99 (0.85–1.14)	0.915	0.94 (0.77–1.15)	0.596
3rd tercile (high)	0.68 (0.48–0.80)	<0.001	0.95 (0.76–1.19)	0.702
Caries in primary dentition (dmft >0):				
Absent			*	
Present			2.33 (1.88–2.90)	<0.001

*OR: odds ratio; CI: confidence interval; *: Reference category; dmft: numbers of decayed teeth, teeth missing due to caries, and filled teeth for primary teeth.*

1.35; 95% CI, 1.13–1.61); having attended a preventative consultation within the last year (OR = 0.64; 95% CI, 0.53–0.78); owning household assets for those belonging to families in the second (OR = 0.74; 95% CI, 0.63–0.87) and third (OR = 0.76; 95% CI, 0.65–0.89) terciles; and monthly household living expenses for those in the third tercile (OR = 0.68; 95% CI, 0.48–0.80).

Regarding variables linked to the presence of caries in permanent dentition with values of $p < 0.05$, we found that age (OR = 1.80; 95% CI, 1.48–2.19); fathers having attained only middle-school education (OR = 1.35; 95% CI, 1.13–1.61); ownership of household assets for those in the second tercile (OR = 0.67; 95% CI, 0.53–0.84); and the development of caries in primary dentition (OR = 2.33; 95% CI, 1.88–2.90) were all positively associated.

3.3 Multivariate model

After combining the sociodemographic and clinical variables in a multivariate logistic regression model, only five variables exerted an effect on the caries variable during primary dentition, with three affecting permanent dentition ($p < 0.05$).

Compared to the younger schoolchildren, those aged 10 to 12 years had a lower probability (OR = 0.53; 95% CI, 0.44–0.63) of having presented caries in their primary dentition. Initiating toothbrushing later than two years of age increased the likelihood (OR = 1.27; 95% CI, 1.09–1.48) of developing caries in primary dentition; in addition, the consumption of chocolates, sweets, pastries and cookies showed a positive association (OR = 1.30; 95% CI, 1.17–1.45). Conversely, growing up in a family where parents possessed household assets lowered the odds of presenting caries in primary dentition, especially for those in terciles 2 (OR = 0.63; 95% CI, 0.52–0.76) and 3 (OR = 0.68; 95% CI, 0.56–0.81). Similarly, the association proved negative (OR = 0.66; 95% CI, 0.51–0.85) for schoolchildren who came from families with high monthly household living expenses (third tercile).

The final model for the presence of caries in permanent dentition (the dependent variable in our study) showed that being 10–12 years old (OR = 1.98; 95% CI, 1.58–2.47), along with the presence of caries in primary dentition (OR = 2.53, 95% CI, 2.03–3.17), increased the likelihood of developing caries. Owning household assets (for families in tercile 2) proved to be a protective factor against the development of caries in the children (OR = 0.66; 95% CI, 0.51–0.85). Table 4 presents the final model of the multivariate analysis.

4. Discussion

This study identified key factors that predispose individuals to developing caries in primary and permanent dentition. In a previous study conducted in Mexico, Villalobos *et al.* [30] found that schoolchildren who presented caries during their primary dentition were nearly three times as likely (OR = 2.93) to experience caries in their permanent dentition as those who did not. Similarly, our study indicated that the presence of caries in the primary dentition was associated with developing caries in the permanent dentition (adjusted OR = 2.53, $p < 0.001$).

Regarding age, the present study, which analyzed schoolchildren aged 6–12 years, found that older children (ages 10 to 12) were less likely to have had caries in their primary dentition (adjusted OR = 0.53, $p < 0.001$), but were more likely to have caries in their permanent dentition (adjusted OR = 1.98, $p < 0.001$). This association between older children and the presence of caries in permanent dentition has been described in the Mexican population [16, 30].

In Romania, a greater prevalence of caries was observed among schoolchildren who drank soft drinks and chewed sugary gum [31], while in Saudi Arabia, caries prevalence was also correlated with sugar consumption ($p < 0.05$) [9]. Furthermore, in Taiwan, schoolchildren who frequently consumed sugar-rich beverages faced a significantly higher risk of developing caries than those who rarely consumed such beverages ($p = 0.017$) [31].

The preceding results are in line with the findings of our study, which indicated that the consumption of chocolates, sweets, pastries and cookies was associated with a higher risk of developing caries in primary dentition. Accordingly, Al-Ansari [32] has proposed that dentists encourage reducing the intake of ultra-processed food and sugary drinks, as well as adopting a balanced and healthy diet.

As regards toothbrushing, Prada [10] reported that, among schoolchildren aged 6–12 years in Spain, a significant association was observed between the presence of caries and brushing frequency, as well as between brushing frequency and having attended dental consultations: those who had been to the dentist brushed their teeth more often compared to those who had not. In Ecuador, Fernández *et al.* [33] correlated the number of brushes per day with the DMFT index in 12-year-old schoolchildren, and found an inverse correlation, with the SiC yielding a value of $p = 0.029$. We found that initiating toothbrushing after two years of age was a risk factor for developing caries in both primary and permanent dentition.

As to the reasons motivating 12-year-old schoolchildren in Romania to attend a dental consultation in the previous 12 months, Sfeatcu *et al.* [18] reported that 43.1% cited dental pain as an indication of a dental emergency. Furthermore, Alshammary *et al.* [9] reported that, among schoolchildren in Saudi Arabia, 45.1% visited clinics because they had experienced dental pain, while only 15.3% went for a checkup. Our study highlights the importance of preventative consultations as a protective factor against developing caries in primary (OR = 0.64, $p < 0.001$) and permanent (OR = 0.80, $p = 0.11$) dentition.

The above-mentioned study in Saudi Arabia noted that the educational level of parents correlated with the prevalence of caries in schoolchildren [9]. Díaz *et al.* [34] conducted a study in Colombia in order to describe the interaction of the prevalence and severity of caries in schoolchildren with family factors. They found a statistically significant correlation between fathers dropping out of middle school and the development of caries in their children ($p = 0.04$). Similarly, our study found that a low educational level (through middle school) on the part of mothers was positively associated with the presence of caries in the primary dentition of their children, as well as in their permanent dentition during adulthood. Likewise,

TABLE 4. Final model representing the multivariate analysis of the independent variables for prevalence of caries in primary and permanent dentition.

Presence of caries in primary dentition (dmft >0)		
Variable	Adjusted *OR (95% CI)	*p* value
Age of schoolchildren (yr):		
6 to 9	*	
10 to 12	0.53 (0.44–0.63)	<0.001
Age at initiation of toothbrushing (yr):		
Before two	*	
After two	1.27 (1.09–1.48)	0.002
Consumption of chocolates, sweets, pastries and cookies:		
Never/hardly ever	*	
Sometimes/daily	1.30 (1.17–1.45)	<0.001
Ownership of household assets:		
1st tercile (low)	*	
2nd tercile (medium)	0.63 (0.52–0.76)	<0.001
3rd tercile (high)	0.68 (0.56–0.81)	<0.001
Monthly household living expenses:		
1st tercile (low)	*	
3rd tercile (high)	0.75 (0.63–0.90)	0.002
Presence of caries in permanent dentition (DMFT >0)		
Age of schoolchildren (yr):		
6 to 9	*	
10 to 12	1.98 (1.58–2.47)	<0.001
Presence of caries in primary dentition (dmft >0):		
Absent	*	
Present	2.53 (2.03–3.17)	<0.001
Ownership of household assets:		
1st tercile	*	
2nd tercile	0.66 (0.51–0.85)	<0.001

*Reference value: adjusted OR value of the result of the logistic regression analysis; primary dentition: R^2 Nagelkerke = 0.064, Hosmer-Lemeshow χ^2 (8) = 8.93, p = 0.348; permanent dentition: R^2 Nagelkerke = 0.065, Hosmer-Lemeshow χ^2 (8) = 11.56, p = 0.17. *OR: odds ratio; CI: confidence interval; DMFT: numbers of decayed teeth, teeth missing due to caries, and filled teeth for permanent teeth; *: Reference category; dmft: numbers of decayed teeth, teeth missing due to caries, and filled teeth for primary teeth.*

a low level of education on the part of fathers constituted a risk factor for caries in the primary and permanent dentitions of their children. Along these lines, Minervini *et al.* [35] reported that, in Italy, both parents having a low educational level could negatively affect the oral health status of their children. For the authors, a clear relationship existed between the educational level of parents and their ability to prevent their children from engaging in unhealthy behavior.

In addition to the above, Casanova *et al.* [11] reported that 6–13-year-old Mexican children of low socioeconomic level were more likely to develop caries than those enjoying medium and high socioeconomic levels (OR = 1.38). Our study also found that a high socioeconomic position, as determined by ownership of household assets, was a protective factor against developing caries in primary (adjusted OR = 0.68, $p < 0.001$) and permanent (adjusted OR = 0.66, $p < 0.001$) dentition.

In Australia, a high family income correlated with fewer caries among schoolchildren, regardless of dentition or educational level [36]. We found that higher monthly household living expenses constituted a protective factor for caries in primary dentition (adjusted OR = 0.75, $p = 0.002$), while not having Social Security coverage was associated with caries in both dentitions (OR = 1.27, $p = 0.01$; OR = 1.12, $p = 0.38$).

This study had several important limitations. The first was a possible self-reporting bias which could have affected the validity of our results. The second pertained to the use of a cross-sectional survey. This method is characterized as being temporally ambiguous as a result of the exposure-effect association,

making it impossible to establish causality. Additionally, the population sample was drawn from a single city in the state of Sinaloa, which might have affected the generalizability of the results. Nonetheless, the evidence provided can be useful in designing oral health initiatives for other urban schoolchildren comparable to those in our sample. Finally, the use of the WHO criteria did not consider caries in their early stages, possibly resulting in an underestimation of their prevalence. The study also had several strengths. These included the flexibility to explore associations between multiple exposures and effects, considering the demographic, socioeconomic and clinical variables of a representative population sample in the locality analyzed. This contributed to generating useful data for the planning and management of health services.

5. Conclusions

The presence of caries in primary teeth is positively associated with the presence of caries in permanent teeth, with preventative dental consultation representing a protective factor for caries in both dentitions. To reduce the development of caries at both stages of dental development, it is essential that dental professionals promote preventative education regarding correct oral hygiene, healthy nutrition, and dental check-ups from an early age.

AVAILABILITY OF DATA AND MATERIALS

The data analyzed in this study are available upon request. Please write to the corresponding author.

AUTHOR CONTRIBUTIONS

JJVR and RAGJ—designed the study. CMUB, MVGJ, CAMC, GEGC and JJVR—conducted the study. RAGJ, VGGG and AKOV—provided support and advice in oral epidemiology. CAMC, JJVR and CMUB—contributed to data collection and analysis. CMUB, AEVU and EMT—wrote the manuscript. All authors made editorial revisions to the manuscript. All authors have read and agreed to the published version of the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in conformity with the Declaration of Helsinki, and was ethically approved by the Research Project Coordination Department at the Autonomous University of the State of Sinaloa (601-ASC107658). Participant assent was obtained from the schoolchildren and written informed consent from their parents/guardians for participation in the study. All were assured that the information gathered would be treated in a confidential manner.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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