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ORIGINAL ARTICLE

Dental caries, tooth eruption timing and obesity: a longitudinal study in a group of Mexican schoolchildren

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Abstract

Objectives. To identify the possible association between dental caries and body mass index (BMI) and to explore the effect of BMI on tooth eruption in a cohort of elementary schoolchildren. ***Material and methods.*** A 4-year longitudinal study was completed. A total of 110 children from a public elementary school, located in a middle-income area of Mexico City, entered the study; of these, 88 completed the 4-year follow-up period. Dental caries assessments were carried out using the WHO criteria for decayed, missing and filled primary and permanent teeth indices (dmft and DMFT, respectively) and surface indices (dmfs and DMFS, respectively). BMI was used to classify the children's obesity status, according to the Centers for Disease Control 2000 reference charts. ***Results.*** At 7 years of age, 29.6% of the children were in the overweight or at risk of being overweight categories and, by 11 years of age, this proportion had risen to 45.5%. The mean dmft for children aged 7 years was 2.70 and, for children aged 11 years, the DMFT was 0.54. Children in the higher BMI categories had more erupted teeth than the other children ($p < 0.001$). A lower dmfs index was detected in the overweight children, compared with children with a lower BMI ($p < 0.001$). ***Conclusions.*** The overweight children had more erupted teeth and a lower caries index. The complex relationships between body composition and oral health should be considered in pediatric patients.

Key Words: *Body mass index, childhood obesity, mixed dentition, tooth decay*

Introduction

Childhood obesity is a significant public health problem [1]. Obesity is a risk factor for cardiovascular, respiratory and skeletal diseases and other health problems [2,3]. In addition, a large proportion of obese children will become obese adults [4]. Among countries with the highest prevalences of overweight children and childhood obesity, Mexico ranks second, behind only the USA [5]. A high body fat content affects hormonal metabolism and growth; there is evidence indicating that obese children have accelerated linear growth [6]. It is also possible that the hormonal changes produced by obesity could modify tooth eruption. Some cross-sectional studies have shown that heavier children have more erupted teeth than children with a healthy body mass index (BMI) [7,8]. There is a scarcity of information regarding tooth eruption and obesity.

More attention has been paid to the possible association between obesity and dental caries. As Marshall et al. [9] suggested, the lack of biological plausibility indicates that there is not a causal relationship between dental caries and obesity, but its association may be related to a third variable as diseases share a relationship with food consumption. The dental caries process depends, among other factors, on the presence of a tooth-surface biofilm; ingestion of food, particularly sugars, plays a key role in the development and aggressiveness of oral bacteria harbored in this biofilm [10,11]. Sugars are widely available in the Mexican diet, particularly in snacks, soft drinks and desserts [12], and these types of food have a high cariogenic capacity [11,13].

Obesity is the result of an imbalance between energy expenditure and caloric intake that results in excess fat accumulation. In Mexico, 54.8% of the total caloric intake comes from carbohydrates (including cereals, sugars and refined carbohydrates) [12], of which sugar-sweetened beverages provide about 21% of the total caloric intake [14]. Carbonated soft drinks

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have been suggested to be a key contributor to the epidemic of overweight and obesity people [15].

Information regarding the association between obesity and dental caries is inconclusive. Several cross-sectional studies have shown a positive association between obesity and dental caries [16–18]. However, data from the National Health and Nutrition Examination Survey (NHANES) 1999–02, carried out in 2- to 17-year-old participants, identified an association in the opposite direction: overweight children had lower levels of dental caries than children in the normal BMI category [19]. Most of the studies relating BMI and dental caries have been conducted in developed countries. The dietary pattern varies from one society to another, and this affects body composition and the dental caries process. The need for longitudinal studies has been highlighted, given that this type of study design allows for the identification of the exposure and event in a time sequence and may contribute to elucidating the characteristics of the relationship between these two diseases [20].

The aim of the present study was to identify the possible association between dental caries and BMI and to explore the effect of this anthropometric indicator on tooth eruption in a cohort of elementary schoolchildren.

Material and methods

Subjects

A 4-year longitudinal study was conducted. Elementary schoolchildren from a public (federally funded) school in the southern part of Mexico City were selected. The school is located in a middle-income area of the city. Based on their places of residence, the children were classified into one of two socioeconomic (SE) categories: middle and middle–low. This was achieved by applying the SE classification developed by the National Institute of Geography and Informatics. This classification considered information regarding social security, education, employment and quality of housing. For Mexico City, the classification is available at the neighborhood level.

The sample size calculation was completed for the mean number of teeth erupted using $\alpha = 0.05$, $\beta = 0.20$ and a total variance of 4.5. The variance was obtained from data from previous studies [21]. For these calculations, the number of repeat measurements by child, the duration of the study, and between- and within-subject variability were considered [22]. The effect size selected was two teeth. Under these specifications, the total sample size required was 81 children. Based on a potential attrition rate of 25% and a refusal rate of 20%, the sample size was increased to 135. Therefore, 135 children's parents were informed about the study and asked to sign the consent form before any procedure was carried out on the children. We obtained permission from 110 parents to allow their children to participate in the study. The inclusion criterion was to be a registered student in the first grade. No exclusion criteria were applied. A total of 110 children were allowed to participate in the study. No data were collected from the 25 children whose parents did not give consent. Participating parents were informed periodically of the results of the clinical examination of their children and advised about the institutions that could provide dental and medical services for their community. This study was approved by the Research Commission at the Autonomous Metropolitan University—Xochimilco.

Dental examination

The dental caries indices were calculated as the sum of decayed, missing and filled teeth and surfaces for primary teeth (dmft and dmfs, respectively) and as the sum of decayed, missing and filled teeth and surfaces for the permanent dentition (DMFT and DMFS, respectively), using criteria recommended by the World Health Organization (WHO) [23]. Radiographs were not obtained. The oral examinations were conducted under natural light, using a WHO probe and plain mirrors. One trained dentist, with experience in epidemiological surveys, carried out all dental examinations, and these examinations were repeated annually by the same dentist (kappa = 0.88–0.92). To avoid observer bias, the children were evaluated by the oral examiner without access to previous dental records or the results of the anthropometric measurements. The numbers of deciduous and permanent teeth present were recorded annually. According to the WHO criteria, a tooth was considered erupted if any part of its enamel could be touched by the tip of the WHO probe.

Anthropometric measurements

The children's weight and height were also measured annually, and the BMI was calculated. A standardized protocol was followed to perform the anthropometric measurements [24]. These measurements were carried out by one trained nutritionist, who was previously trained in anthropometric measurements in children. The reliability of measurements in each year of the study was quite solid. The intraclass correlation coefficient (ICC) was 0.89–0.93 for height and 0.87–0.95 for weight. The same nutritionist performed all anthropometric measurements in each year of the study. The participants were weighed in light clothing without shoes. Height was measured using a stadiometer (Seca, Hamburg, Germany), and a standard clinical scale (Seca) was used to weigh the children. The Epi Info 2000 software package was used for the annual anthropometric evaluation, considering height, weight and BMI, and the sex-specific 2000 Centers for Disease Control (CDC) standards were applied to obtain the percentile values of the height for age, the weight for age and BMI for age. "Overweight" was defined as a BMI for age at or above the sex-specific 95th percentile; "risk of overweight" was defined as a BMI for age at or above the sex-specific 85th percentile, but less than the 95th percentile; children with a BMI for age at or above the sex-specific 50th percentile and less than the 85th percentile were classified as "normal". Children with a BMI for age below the sex-specific 50th percentile but above the 5th percentile were classified as "thin," and children with a BMI under the age- and sex-specific 5th percentile were classified as "underweight" [25].

Statistics

Mean standard deviations (SDs) and proportions for the main variables by year of follow-up were calculated. The average BMI percentile was computed considering the trajectory over time of the children during the follow-up period. ANOVA was used to estimate differences in means of selected variables at the beginning of the study. To analyze the data on tooth eruption, dental caries and BMI over time, mixed models with a random intercept and random slope were constructed to estimate the cross-sectional and longitudinal effects. The longitudinal effect captures the changes in the response variable over time, and the cross-sectional effect identifies differences between groups of subjects related to selected covariates at a given point in time [22]. The mixed model to estimate the BMI effects on tooth eruption was adjusted by age at the beginning of the study and sex. The mixed model to estimate the BMI effects on dental caries experience was adjusted by age at the beginning of the study, sex, SE status and the baseline number of primary teeth present. The BMI was also used as a random slope. The STATA 10 (StataCorp LP, College Station, TX) statistical software package was used for the data analysis.

Results

A total of 110 children began the study. At the end of the 4 years of follow-up, 88 children remained in the cohort (20% drop-out rate). The main reason for dropping out was changing the school of attendance. The mean values of the baseline caries indices, teeth erupted and BMI of the children lost during the follow-up period were similar to those for the children who remained in the cohort ($p > 0.05$).

Table I. Means of anthropometric measurements at the baseline observation and at each year of follow-up in the schoolchildren studied. Mean values are shown, with SDs in parentheses.

	Anthropometric measurement		
Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
7	122.28 (5.56)	25.71 (6.08)	17.03 (2.93)
8	128.55 (5.59)	29.56 (6.69)	17.73 (2.94)
9	133.49 (5.83)	33.07 (7.44)	18.39 (3.08)
10	139.11 (6.30)	37.60 (8.55)	19.26 (3.32)
11	144.45 (6.82)	42.60 (9.86)	20.22 (3.61)

A total of 440 observations were recorded from the 88 children who completed the 4 years of follow-up. Half of the participants were girls. The mean age of the children at the beginning of the study was 7.1 years (SD 0.32 years), and at the end of the study period it was 11.0 years (SD 0.32 years). No difference in baseline age was detected between boys (7.07 years; SD 0.31 years) and girls (7.09 years; 0.32 years) ($p = 0.75$). With regard to their SE levels, 55.7% of the children were in the middle–low category, and 44.3% were in a better SE category, the latter encompassing the middle SE group. The mean stature of the children in each year of the follow-up, from 7 to 11 years old, is presented in Table I. Regarding height for age, only one child (a girl) (1.14%) had low stature and remained in this condition during the follow-up period. The mean weight and BMI of the children in each year of follow-up, from 7 to 11 years old, are presented in Table I. No children were detected in the underweight category during the follow-up.

According to the average BMI percentile, 25% (22 children) of the children were thin, 45.5% (40 children) were classified as normal, 12.5% (11 children) were in the risk-of-overweight category and 17.0% (15 children) were in the overweight category. A higher average BMI percentile was associated with higher stature: in the lowest BMI category, the mean stature was 129.6 cm (SD 5.6 cm), and in the normal category, the mean was 133.7 cm (SD 5.2 cm). In the risk-of-overweight category, the mean was 134.2 cm (SD 5.0 cm), and in the overweight group it was 138.7 cm (SD 5.0 cm) ($p < 0.001$). The mean BMI percentile was 61.92th (SD 30.6th) at baseline and 70.96th (SD 26.6th) at the final observation. Figure 1 depicts the children's BMI percentile distribution for the first and last measurements. The percentage of children in the 85th or higher BMI percentile increased from 29.6% at 7 years to 45.5% at 11 years of age. The mixed model showed that the BMI percentile increased with age ($\beta = 2.3$, $p < 0.001$). No differences in the BMI percentile were detected between boys and girls over time ($p = 0.22$), and no significant difference was found between BMI and the children's SE status ($p = 0.22$). In terms of the average BMI percentile, the students in the middle SE group had an average BMI

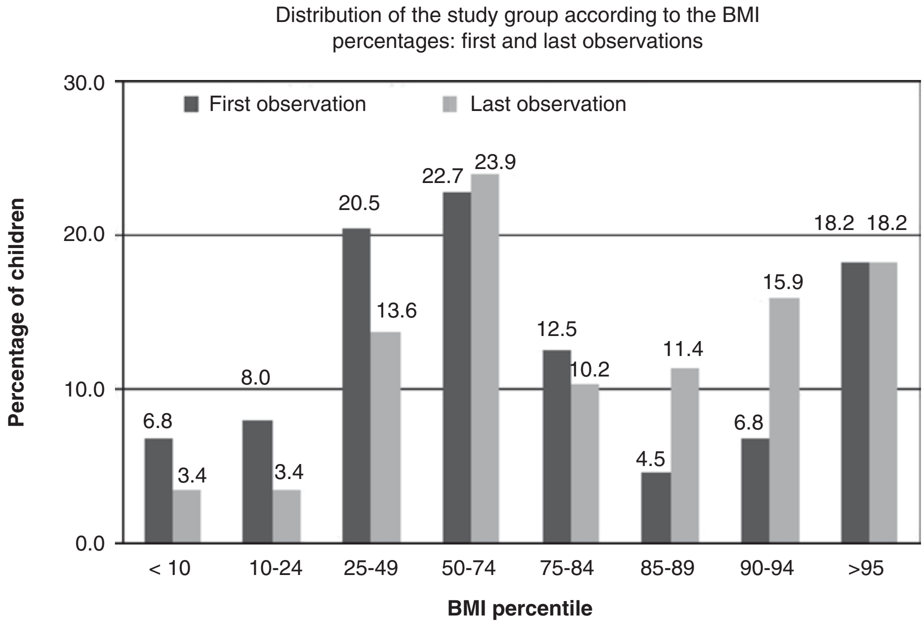

Figure 1. The same children were measured annually to obtain their BMI. The percentages of children in the different BMI percentiles are shown at baseline (7 years old) and at the end of the follow-up period (11 years old). The changes in these distributions indicate increments in the higher percentiles of the BMI as the children grow.

percentile of 68.88th (SD 24.76th), and for those in the middle–low class, it was 65.21th (SD 28.18th).

Tooth eruption timing

The mean number of permanent teeth present in each year from the beginning to the end of the study was 7.07 (SD 3.1), 9.59 (SD 2.8), 11.81 (SD 2.7), 14.88 (SD 4.3) and 18.19 (SD 5.1), respectively. A significant association was detected between the number of teeth erupted and the BMI ($p < 0.001$), controlling by sex ($p = 0.007$) and age at baseline ($p < 0.001$). The cross-sectional and longitudinal effects estimated by the mixed model are presented in Table II. The positive longitudinal effect of the risk of being overweight and overweight categories indicates a higher eruption rate as the children's BMI increased over time. Figure 2 presents the mixed model of the estimated number of teeth erupted by age during the follow-up period. At 11 years of age, the children in the overweight group had about five more permanent teeth than children in the thin group; children in the thin group had 15.9 permanent teeth, while children who were overweight had 21.6 permanent teeth erupted.

Dental caries

The dental caries indices for the primary and permanent dentition in each year of the study are presented in Table III. The highest dmfs index was found in the 8-year-old children (dmfs = 5.44, SD 7.57). The mean DMFS was 0.82 (SD 1.80) in the 11-year-old group. No permanent teeth were extracted as a result of caries lesions during the study. The percentages of children with caries-free primary teeth (dmft = 0) at ages 7–11 years were 40.9%, 44.3%, 40.9%, 50.0% and 59.1%, respectively, and the percentages of children with caries-free permanent teeth (DMFT = 0) for the same age range were 97.7%, 85.2%, 80.7%, 77.3%

Table II. Estimates of effects of BMI categories of mixed-effect models on tooth eruption and dental caries in the primary teeth (dmfs).

	Tooth eruption coefficient[b]			Dental caries (dmfs) coefficient[c]		
BMI category[a]	Cross-sectional effect at baseline	Longitudinal effect	p	Cross-sectional effect at baseline	Longitudinal effect	p
Normal	1.33	1.85	0.057	–0.99	0.38	0.650
Risk of being overweight	3.48	5.04	< 0.001	–0.12	–2.30	0.032
Overweight	4.29	5.05	< 0.001	–2.01	–2.69	0.035

[a]Reference group: thin children (BMI between the 5th and less than the 50th percentiles).
[b]Model adjusted for sex and age at baseline.
[c]Model adjusted for sex, age at baseline, socioeconomic stratum and primary teeth present.

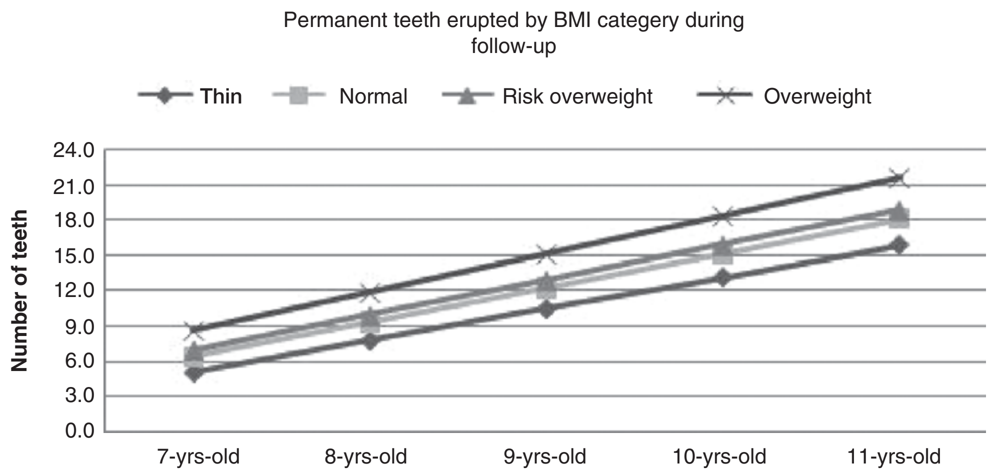

Figure 2. Number of permanent teeth erupted for each year of follow-up estimated by a mixed model by category of BMI. Thin children had a BMI between the 5th and less than the 50th percentile; the normal category was from the 50th to less than the 85th percentile; the risk-of-overweight category was between the 85th to less than the 95th percentile and overweight children were those in the 95th or higher percentile of the BMI. Children in the overweight group had more teeth erupted during follow-up. Regression lines estimated using results from the mixed-effects model.

and 72.7%, respectively. At 7 years of age, the mean dmfs for the middle–low SE group was 6.73 (SD 7.99), and in the middle SE group it was 3.33 (SD 5.77) ($p = 0.028$); by age 9 years the indices were 6.39 (SD 7.60) and 3.44 (SD 4.56), respectively ($p = 0.036$). Considering the SE status and the dental caries index in the permanent dentition, for the middle–low income group the mean DMFS index was 1.12 (SD 0.25), and in the middle SE group it was 0.43 (SD 0.28) ($p = 0.075$).

The results of the mixed model fitted for caries in the primary teeth (dmfs) showed that children with a high BMI had lower levels of dental caries ($p < 0.01$). The model was constructed by controlling for age at baseline ($p = 0.59$), sex ($p = 0.61$), number of primary teeth ($p = 0.39$) and SE stratum ($p < 0.01$). The cross-sectional and longitudinal effects are presented in Table II. The effects of the risk of being overweight and actually being overweight were negative when compared with the thin children, who formed the reference group. At 7 years of age, children in the overweight group had a dmfs of 3.2, while in the thin children, the dmfs was 6.2; at 9 years of age, the indices were 2.1 and 5.8, respectively. The longitudinal effect suggested that the children in the higher categories of BMI experienced a lower risk of caries. The SE level was significant in the model, as children with lower economic resources had higher dmfs scores ($\beta = 3.22$; $p = 0.01$).

No association was detected between BMI and DMFS scores ($p > 0.05$). The mixed model fitted for DMFS, controlled by age, sex, SE status and permanent teeth present in the middle of the study period was not statistically significant (data not shown).

Table III. Dental caries indices in the primary and permanent dentition during the follow-up period.

Age (years)	dmft	SD	DMFT	SD	dmft+DMFT	SD
7	2.70	3.19	0.01	0.11	2.71	3.21
8	2.65	3.11	0.13	0.33	2.78	3.19
9	2.55	3.03	0.24	0.58	2.79	3.29
10	2.22	2.75	0.40	0.86	2.62	6.14
11	1.46	2.01	0.54	1.01	2.00	2.68
Age (years)	dmfs	SD	DMFS	SD	dmfs+DMFS	SD
7	5.23	7.26	0.02	0.15	5.25	7.25
8	5.44	7.57	0.15	0.36	5.59	7.68
9	5.08	6.57	0.31	0.96	5.39	6.92
10	3.89	5.99	0.59	1.54	4.48	6.55
11	2.52	4.86	0.82	1.80	3.34	5.86

Discussion

The children studied showed a high prevalence of risk of being overweight and being overweight, based on the 2000 CDC criteria (45.5% for children aged 11 years). The prevalence was higher than that found in a national sample of Mexican children, in which approximately 28% of the 11-year-olds were overweight or obese [26], and it was close to that detected in 6- to 11-year-old Mexican–American children (39.3%) in the NHANES 1999–00. The incidence of this condition appears to be increasing in the young U.S. population, particularly affecting Mexican–American children who have a severe obesity problem [27]. A trend toward a higher prevalence of obesity has also been detected in Mexican groups [28]. Accordingly, in the present study, the results of the follow-up confirmed a trend toward increasing risk of being overweight with increasing age. At 7 years of age, less than a third of the children were in the risk of being overweight or overweight categories but, by the age of 11 years, this percentage had risen to 45.5%. The high proportion of children in the high BMI percentiles and its increasing trend is a serious problem given the high risk of systemic diseases associated with high body fat content, and no less important are the negative psychological consequences [29,30].

Children with a high BMI had higher eruption rates. This finding is consistent with the results of a study in the USA, in which overweight children had a larger number of erupted teeth [7]. A study of Brazilian children also detected this association; moreover, it was concluded that both age and height influenced tooth eruption [8]. In the present study, children with the highest BMI adjusted for age and sex also had the highest stature. Elevated BMI has been related to accelerated linear growth and early sexual maturation. Obesity is considered to be the most common cause of accelerated growth [2].

There is evidence suggesting that over-nutrition during childhood causes hyperinsulinemia and may also increase insulin-like growth factor-1 (IGF-1) secretion and growth hormone receptors [31]. In addition, after controlling for sex and pubertal stage, a significant correlation was found between BMI and IGF1-Standard Deviation Scores in obese children, suggesting that this hormone may play a key role in the acceleration of bone maturation [32]. Hormonal changes in the obese patient may affect mineral metabolism [33]. Lower levels of serum calcium and phosphate were observed in obese children during a glucose tolerance test, and serum parathyroid hormone and calcitonin levels showed smaller increases in obese children compared with their non-obese counterparts [34]. It is likely that the metabolic changes caused by obesity that have an impact on bone growth also affect tooth eruption. However, more studies are required to identify the specific mechanism involved in tooth eruption timing that is affected by high body fat content in children and adolescents.

The dental caries indices found in this study were lower than those reported for Mexico City in the National Caries Survey 2001, which suggests a reduction in the dental caries index; this reduction may be the result of the use of fluoridated dentifrices and the implementation of the national salt fluoridation program, which was established in 1995; other groups of Mexican children have also shown reductions in dental caries [21].

Children in the middle–low SE group had a higher caries index than children in the middle SE group. Numerous studies have shown that decreasing SE status is associated with increasing caries indices [9,20,35].

An association was detected between the BMI and caries index in the primary dentition. Since we found an effect of BMI on tooth eruption, it was appropriate to control for the number of teeth present when conducting the analysis. The results indicated that overweight children had low caries indices (dmfs).

Analysis of the information regarding 6- to 17-year-old children and adolescents studied in the NHANES 1999–02 also showed that the overweight group had a lower DMFT index [19]. A possible explanation for this finding is that overweight children are identified by their parents, who then impose restrictions on the consumption of candy and other sugary food; however, the children still ingest more calories than they expend and remain overweight. It has been shown that the Mexican diet has changed in recent years, and that the proportion of calories obtained from fats is greater than previously observed. Information on the diet of Mexico City residents in 1988 showed that 24.8% of the total caloric intake was derived from fats; this increased to 32.4% in 1998, while the proportion of calories obtained from carbohydrates decreased [12]. These changes have been accompanied by increases in overweight individuals and obesity [12]. In addition, another possible explanation for the low caries indices detected in the overweight children is that this group, as they eat more and probably more frequently, was exposed more often than thin children to fluoride salt, which is the only type of table salt available in Mexico City.

In this study, no significant difference in BMI was detected between the two SE groups (middle and middle–low). It is possible that a more heterogeneous group would be needed to detect this difference. However, the results indicated that children with a higher dmfs index belong to the lower SE group. It is possible that overweight children came from families that provided fluoridated dentifrices more often than families of thin children; consequently, overweight children maintained a healthier oral environment. Additionally, in the group studied, overweight children probably came from families with better access to dental services. In Mexico, approximately half of the population has access to health services as a benefit of their employment, and the other half can access "popular insurance"; both systems have limited dental services, and the latter does not include restorative services. In spite of the efforts of public institutions to offer a number of dental services, private practitioners are essential providers of dental care in Mexico, but their services are only available, basically, to those who can afford them [36].

Studies on other groups of children and adolescents found that heavier children had more dental caries lesions than those in normal-weight groups [35,37,38]. In the Mexican children studied here, no significant association was detected between dental caries in permanent dentition and BMI. Most likely, higher caries incidence rates in the permanent teeth would enable the detection of a statistically significant association between these variables. In the present study, a large proportion of the children remained caries-free (DMFT = 0) during the study period. Moreover, it is possible that a longer time of exposure of the permanent dentition is necessary to detect significant differences [37].

Given that dental caries is a multifactorial disease in which social and behavioral aspects play an important role, the different trends observed in the association between obesity and dental caries reflect the complex etiology of both conditions.

Some of the limitations of the present study derive from its small sample size; however, some significant associations became apparent, probably due to the repeated-measurements design, which improved the statistical power of the study. In addition, several variables related to dental caries, such as oral hygiene and diet, were not controlled for, which decreased the explanatory capacity of the models. In addition, the study had the advantage of its longitudinal design, which allowed the time sequence of the events to be identified.

The children lost during the follow-up period had a similar BMI, number of teeth erupted and caries index at the beginning of the study to the children who completed the study. The loss of participants decreased the precision of the estimates; however, we believe that this loss did not bias the results.

Health professionals should be aware of the high prevalence and incidence of overweight and obese children and collaborate in solving this health problem. Dentists could contribute to raising awareness regarding the risk of obesity in children and counsel parents about the need to help their children to adopt healthy lifestyles as they grow. The tendency for accelerated tooth eruption in the high-BMI children should be taken into account in dental care, particularly in those children who require interceptive, early orthodontic treatment or orthopedic appliances, among other treatments impacted by tooth eruption. Dental professionals should consider the complex relationship between the eating habits of children, their body composition and their oral health, in order to provide the best service for pediatric patients and their families.

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