

Experience, prevalence, need for treatment and cost of care for caries: A multicenter study in a developing country

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Objective: To assess the experience, prevalence, need for treatment and economic impact of caries among students 6-12 years old in four cities in Mexico. **Basic research design:** Cross-sectional clinical study. **Setting:** Elementary public schools. **Participants:** 500 schoolchildren aged 6 to 12 years. **Method:** Oral clinical examinations using WHO criteria for caries in the primary (dmft) and permanent (DMFT) dentitions. **Main outcome measures:** Indicators of caries in the primary and permanent dentitions: experience, prevalence, severity and the Significant Caries Index. In addition, we calculated the treatment needs, dental care rate and cost of care. **Results:** dmft in the primary dentition was 2.59±2.83, and DMFT was 0.82±1.44 in the permanent dentition. Caries prevalence reached 67.7% in the primary and 34.1% in permanent dentition. The treatment needs index was 85.9% and 91.3% in the primary and permanent dentitions, respectively; the dental care index was 13.9% and 8.5%, respectively. The cost of care for caries in the primary dentition was estimated at \$22.087 millions of international dollars (PPP US\$) when amalgam was the restorative material used, and PPP US\$19.107 millions for glass ionomer. For the permanent dentition, the cost was PPP US\$7.431 millions when amalgam was used and PPP US\$7.985 millions when resin/composite was used as restorative material. **Conclusions:** The prevalence and experience of caries in the primary dentition were 50% greater than those of other studies carried out in Mexico. In the permanent dentition they were less. There is considerable need for the treatment of caries and minimal experience with restorative care. The cost of care for caries may be assumed to be high for a health system such as Mexico's.

Keywords: Oral health, Dental caries, Child, Mexico, Health Care Costs, Needs Assessment

Introduction

The number of individuals with untreated oral conditions in the world rose from 2.5 billion in 1990 to 3.5 billion in 2015 (Kassebaum *et al.*, 2017). According to the Global Burden of Disease Study in 2010, untreated caries in permanent and primary teeth were the first and tenth most prevalent conditions respectively (Kassebaum *et al.*, 2015). Evidence indicates that the burden of untreated caries is shifting, with prevalence currently peaking at three ages: 6, 25 and 70. Furthermore, the prevalence and incidence of untreated caries vary not only among regions and countries, but even within countries, where they are concentrated in socially disadvantaged populations (Kassebaum *et al.*, 2017; Schwendicke *et al.*, 2015). In fact, oral health has shown little improvement in the last three decades, with dental conditions persisting as a critical challenge for public health around the world (Kassebaum *et al.*, 2017).

Caries in the primary and permanent dentitions constitutes a public health problem in Mexico. Before 2000, caries prevalence in the permanent dentition ranged between 70% and 85% among 12-year-old school children (Medina-Solis *et al.*, 2006). However, subsequent

estimates have indicated a prevalence fluctuating between 30.7% and 79.2% and a DMFT between 0.52 and 3.67. Similarly, estimates for six-year-olds have indicated a prevalence ranging from 26.3% to 77.5%, and a dmft from 0.73 to 5.35 (Medina-Solis *et al.*, 2020). This situation is compounded by high treatment need in both the primary (81.7-99.5%) and permanent (55.4-93.4%) dentitions in many population groups. These conditions impose a significant burden of disease on families and the health system (Medina-Solis *et al.*, 2020; Secretaría de Salud, 2001). The Mexican public health system does not cover most specialized dental care, providing services only for preventive care, fillings and extractions. The costs of specialized dental care are shifted to the private sector, where treatments represent a burdensome expenditure for households, who are required to incur considerable out-of-pocket expenses. Economic data about the burden of oral disease are sparse (Medina-Solis *et al.*, 2019).

The objective of the present research was to assess the experience, prevalence, need for treatment and economic impact of caries among students 6-12 years old across four cities in Mexico.

Material and Methods

We conducted a cross-sectional study of 6-to-12-year-old students in 2019. The study population comprised students in public elementary schools across four cities: Pachuca, San Luis Potosi, Tepatitlan and Toluca. The intended population included 162,172 schoolchildren. Inclusion criteria encompassed 6-to-12-year-olds enrolled in public schools whose parents were willing to sign an informed consent form. Exclusion criteria involved students who suffered from any disease that impeded a clinical examination or who refused to be clinically examined.

We performed stratified and cluster sampling. The parameter of interest for calculating sample size was the prevalence of caries. Schools were selected according to a probability proportional to the number of students. The number of schools per stratum was proportional to the total students in the stratum, having at least two schools per locality. We used the following formula to determine sample size:

$$\text{Estimate of proportions: } n = Z^2 \frac{p(1-p)}{d^2 k} (1 + \rho(k-1))$$

where p was the proportion of children with at least one decayed tooth, d the half-width of the confidence interval, ρ the intra-conglomerate correlation coefficient, k the number of students per school and $Z=1.96$ the quantile 97.5% of a standard normal distribution. The value of p was 60%, we assumed $\rho = 0.24$ and semi-amplitude (d) = 7, with a final sample of 500 students.

Oral clinical examinations were undertaken using the World Health Organization (WHO) criteria for caries in the primary (dmft) and permanent (DMFT) dentitions. Exams were performed under natural light, using a mirror, a WHO-type probe, gloves and a face mask, in a suitable location inside each school. Examinations were performed by trained and standardized dentists with experience in caries indices (Kappa >0.85). Parents were informed about the study objectives; those who agreed to participation of their children were asked to sign an informed consent form.

Our variables included (a) caries experience (dmft + DMFT); (b) caries prevalence in either dentition; (c) the proportions with low caries severity in the permanent dentition (using a threshold of DMFT ≤ 3) and (d) high caries severity in the permanent dentition, (using a threshold of DMFT >6). We used the DMFT data to calculate the Significant Caries Index (SiC), denoting the third of the population most affected by caries. We also estimated the Care Index, which represented restorative services provided to the population based on the following formula:

$$CI = \frac{\text{Filled teeth}}{\text{dmft or DMFT}} \quad (100)$$

Finally, we assessed the treatment needs index using the following formula:

$$TNI = \frac{\text{decayed teeth}}{\text{decayed teeth} + \text{filled teeth}} \quad (100)$$

Explanatory variables such as age and sex were also included in the analysis.

We estimated the cost of dental care for caries based on previously published methods (Medina-Solis *et al.*, 2020). Using the decayed components of the dmft and DMFT rates and population size, we determined the average number of decayed teeth requiring treatment for each age and city and extrapolated the estimated costs to the total of 162,172 students aged 6-12 years in the four cities. From a previous study (Medina-Solis *et al.*, 2020), we obtained two market prices for the treatment of caries: the average prices charged by publicly funded institutions (e.g., public universities) and by the private dental office sector.

We considered two treatment scenarios: one for the primary dentition, where amalgam (private sector: Average unit cost PPP US \$63.4 international dollars; public sector: Average unit cost PPP US \$9.4) and ionomer (private sector: Average unit cost PPP US \$54.8; public sector: Average unit cost PPP US \$12.1) were selected as the restorative materials. The second scenario for the permanent dentition included amalgam (private sector: Average unit cost PPP US \$63.4; public sector: Average unit cost PPP US \$10.6) and resin/composite (private sector: Average unit cost PPP US \$68.1; public sector: Average unit cost PPP US \$17.2) were selected. We then estimated the cost of care of public and private services by city. Costs were updated to 2019 Mexican pesos using the cumulative inflation rate (INEGI, 2020) and then to 2019 international dollars using the purchasing power parity (PPP US\$) exchange rate of 1 international dollar to 9.278 Mexican pesos (Organization for Economic Co-operation and Development, OECD, 2020). The international dollar (PPP US \$) is a hypothetical World Bank unit that allows adjustment for PPP; it represents the amount of local currency units needed within a to purchase the same amount of goods with one US dollar. Lastly, we calculated the proportion of cost of care for dental caries in relation to the 2019 government health expenditure at the state level using international dollars (Secretaría de Salud, 2020).

Our statistical model was based on the following assumptions: (1) participants required no other treatment in their primary (e.g., pulpotomy and/or chromium steel crown) or permanent (e.g., root canal, endodontic post or crown) dentition; and (2) children aged 6 years needed at least one permanent tooth to be considered in DMFT calculations, while those 12 years old needed at least one primary tooth to be considered in dmft calculations.

The study variables were described using appropriate univariate statistics. Bivariate analysis used the Mann-Whitney U, Kruskal-Wallis, non-parametric-trend and Chi-square tests, depending on the types of variables contrasted. All analyses used the Stata 11 statistical program.

The research complied with the Declaration of Helsinki and relevant ethical regulations. The protocol was approved by the Research Ethics Committee of the Autonomous University of the State of Hidalgo (CEEI 000019-2019). Written consent was obtained from the parents/guardians of participating children.

Results

Of the 500 participating children, 378 had primary and 477 permanent teeth. Their average age was 8.93 \pm 2.00, and 50.4% were female. Table 1 illustrates the distribution

of caries in the primary dentition by age and sex. Mean dmft was 2.59±2.84 and caries prevalence (dmft>0) was 67.7%. The SiC index reached 5.83 overall. There were differences in dmft by age (p=0.005) and sex (p=0.023). Female participants showed higher caries experience than male (p<0.001).

Table 2 presents the distribution of caries in the permanent dentition. Mean DMFT was 0.82±1.45, with a caries prevalence (DMFT>0) of 34.2% and SiC index of 2.45. There were differences in the DMFT by age (p=0.041) but not sex (p>0.05). Table 3 summarises the treatment needs and care indices in the primary and permanent dentitions.

Table 4 shows cost estimates for the clinical care of caries among 162,172 school children (intended population). For private services, costs varied depending on the materials used. In the primary dentition, the total cost was PPP US \$22.087 million if amalgam was used, and PPP US \$19.107 million for ionomer. In the permanent dentition, the total cost was PPP US \$7.431 million if amalgam was used and PPP US \$7.985 million for resin/composite. These figures represented between 0.05% and 0.14% of total government health expenditure in the four states where the sampled cities were located.

The cost estimates for clinical care of caries among 162,172 school children using public services are shown in Table 5. For the primary dentition, the total cost was PPP US \$3.264 million if amalgam was used and PPP US

\$4.213 million for ionomer. For the permanent dentition, the total cost was PPP US \$1.242 million if amalgam was used and PPP US \$2.019 million for resin/composite. These figures are equivalent to between 0.01% and 0.03% of total government health expenditure in the four states where the sampled cities were located.

Discussion

Our study aimed to ascertain various caries indicators and to estimate the costs of care. The prevalence and caries indices were higher in the primary than the permanent dentitions. A high prevalence of caries persists as a public health problem in the cities studied, affecting the permanent dentition in one out of every three students, and the primary dentition in two out of three. Furthermore, a high proportion of children needed caries treatment in both dentitions. Given this burden, treatment demands substantial allocation of resources, which could be a financial burden on the health systems of a developing country such as Mexico.

Studies of caries in the primary dentition in Mexico have estimated mean dmft ranging from 1.88 (Martínez-Pérez *et al.*, 2010), and 2.85 (Casanova-Rosado *et al.*, 2005) to 3.6 (Serrano-Piña *et al.*, 2020). Proportions with caries (dmft>0) ranged between 56.8% (Martínez-Pérez *et al.*, 2010) and 73.6% (Casanova-Rosado *et al.*, 2005). In

Table 1. Dental health of the primary dentition among school children in four cities in Mexico.

	dmft (n)*†	% dmft>0	% dmft>3	% dmft>6	SiC
Age (years)					
6	2.6±3.3 (75)	62.7	28.0	12.0	6.2
7	3.0±3.0 (72)	70.8	37.5	15.3	8.7
8	3.5±3.2 (77)	77.9	46.7	18.2	6.8
9	2.3±2.0 (66)	77.3	25.8	1.5	4.7
10	1.7±2.1 (58)	51.7	19.0	1.7	4.2
11	2.0±2.7 (19)	52.6	15.8	5.3	4.8
12	1.6±1.9 (11)	63.6	9.1	0.0	3.8
Sex					
Male	2.4±3.0 (190)¶	58.9‡	28.9	11.6	5.8
Female	2.8±2.7 (188)	76.6	32.4	8.0	5.9
Total	2.6±2.8 (378)	67.7	30.7	9.8	5.8

* p=0.005, † z = -1.96, p=0.051, ¶ p=0.023, ‡ p=0.000

Table 2. Dental health in the permanent dentition among school children in four cities in Mexico.

	DMFT (n)*†	% DMFT>0	% DMFT>3	% DMFT>6	SiC
Age (years)					
6	0.5±0.9 (55)	27.3	1.8	0.0	1.5
7	0.5±1.1 (70)	25.7	2.9	0.0	1.7
8	0.8±1.5 (77)	29.9	7.8	1.3	2.2
9	0.8±1.3 (69)	39.1	5.8	0.0	2.4
10	0.7±1.3 (71)	32.4	7.0	0.0	2.2
11	1.0±1.5 (67)	35.8	11.9	0.0	2.8
12	1.4±2.1 (68)	48.5	14.7	4.4	3.7
Sex					
Male	0.8±1.4 (233) ¶	33.5‡	6.9	0.9	2.4
Female	0.9±1.4 (244)	34.8	8.2	0.8	2.5
Total	0.8±1.5 (477)	34.2	7.5	0.8	2.5

* p=0.041, † z = 3.19, p=0.001, ¶ p=0.654, ‡ p=0.754

Table 3. Caries index, treatment needs and care index for caries in the primary and permanent dentitions.

<i>Primary</i>	<i>decayed</i>	<i>filled</i>	<i>dmft</i>	<i>TNI</i>	<i>CI</i>
n = 378	2.2	0.4	2.6	86.0	13.9
<i>Permanent</i>	<i>Decayed</i>	<i>Filled</i>	<i>DMFT</i>	<i>TNI</i>	<i>CI</i>
n = 477	0.8	0.1	0.8	91.5	8.5

TNI = treatment needs index

CI = Care index

Table 4. Cost of dental care for caries in the primary and permanent dentition in the private sector, 2019 international dollars (thousands).

<i>Primary dentition</i>						
<i>City</i>	<i>N</i>	<i>Amalgam</i>	<i>Ionomer</i>	<i>Government expenditure*</i>	<i>% of expenditure where amalgam is used</i>	<i>% of expenditure where ionomer is used</i>
Pachuca	28,880	\$ 4,687	\$ 4,055	\$ 1,344,463	0.35	0.30
San Luis Potosi	72,324	\$ 9,950	\$ 8,607	\$ 1,256,920	0.79	0.68
Tepatitlan	9,785	\$ 1,545	\$ 1,336	\$ 4,298,375	0.04	0.03
Toluca	51,183	\$ 5,096	\$ 5,109	\$ 8,501,383	0.07	0.06
Total	162,172	\$ 22,087	\$ 19,107	\$15,401,141	0.14	0.12
<i>Permanent dentition</i>						
Pachuca	28,880	\$ 1,501	\$ 1,613	\$ 1,344,463	0.05	0.07
San Luis Potosi	72,324	\$ 3,026	\$ 3,252	\$ 1,256,920	0.12	0.15
Tepatitlan	9,785	\$ 794	\$ 853	\$ 4,298,375	0.01	0.01
Toluca	51,183	\$ 2,109	\$2,267	\$ 8,501,383	0.03	0.03
Total	162,172	\$ 7,431	\$ 7,985	\$15,401,141	0.02	0.03

* = Total government expenditure in the state where the city is located, 2019 (thousands of international dollars)

Table 5. Cost of dental care for caries in primary and permanent dentition in the public sector, 2019 international dollars (thousands).

<i>Primary dentition</i>						
<i>City</i>	<i>N</i>	<i>Amalgam</i>	<i>Ionomer</i>	<i>Government Expenditure*</i>	<i>% of expenditure where amalgam is used</i>	<i>% of expenditure where ionomer is used</i>
Pachuca	28,880	\$ 693	\$ 894	\$ 1,344,463	0.05	0.07
San Luis Potosi	72,324	\$1,470	\$1,898	\$ 1,256,920	0.12	0.15
Tepatitlan	9,785	\$ 228	\$ 295	\$ 4,298,375	0.01	0.01
Toluca	51,183	\$ 873	\$1,126	\$ 8,501,383	0.01	0.01
Total	162,172	\$ 3,264	\$4,213	\$15,401,141	0.02	0.03
<i>Permanent dentition</i>						
Pachuca	28,880	\$ 251	\$ 408	\$ 1,344,463	0.02	0.03
SLP	72,324	\$ 506	\$ 822	\$ 1,256,920	0.04	0.07
Tepatitlan	9,785	\$ 133	\$ 216	\$ 4,298,375	0.00	0.01
Toluca	51,183	\$ 353	\$ 573	\$ 8,501,383	0.00	0.01
Total	162,172	\$1,242	\$2,019	\$15,401,141	0.01	0.01

* = Total government expenditure in the state where the city is located, 2019 (thousands of international dollars)

the National Caries Survey, dmft ranged between 1.00 and 2.20, and suggested a 60% caries prevalence (Medina-Solis *et al.*, 2020; Secretaría de Salud, 2006). Those figures are below those observed in the present study.

The prevalence and experience of caries for the permanent dentition were similar to those previously observed in Mexico by Serrano-Piña *et al.*, (2020) (DMFT=0.64, prevalence=32.8%). However, Casanova *et al.*, (2005)

(DMFT=1.44, prevalence=49.4%) and Martínez-Pérez *et al.*, (2010) (DMFT=1.11, prevalence=36.8%) reported higher values. According to the National Caries Survey, the DMFT index fluctuated between 0.74 and 1.38 leading to a caries prevalence between 36.2% and 52.7%; these figures are higher than findings from our study (Medina-Solis *et al.*, 2020; Secretaría de Salud, 2006).

The proportion of children needing caries treatment reached 85.9% for the primary and 91.3% for permanent dentitions. Other studies of 6 to 12 year old children in Mexico obtained similar figures (Martínez-Pérez *et al.*, 201; Irigoyen *et al.*, 2012). In general, high levels of treatment need are observed consistently.

In Mexico, specialized dental care is provided primarily by the private sector (Cerón-Zamora *et al.*, 2020). Failure of the public sector to offer the necessary coverage for the population at large represents a barrier to accessing these services, leading families to incur substantial out-of-pocket expenses (Medina-Solís *et al.*, 2019). Despite the importance of framing the costs of addressing oral health needs for both the health system and individual households against actual needs, studies of this kind have been rare in Mexico. The total cost of care for caries among children (N=162,172) varied depending on the dentition and the restorative materials used. For the permanent dentition, the cost ranged from PPP US \$7.98 to 1.24 million; for primary dentition, these figures ranged from PPP US \$22.09 to 3.26 million. Altogether, costs between PPP US \$27.8 and 185.4 for caries treatment in both dentitions per child, imposing a significant financial burden on state health systems. A previous Mexican study estimated expenditure on dental care to be PPP US 53.5 (average of PPP US \$70.2) (Medina-Solís *et al.*, 2019). Relying on out-of-pocket expenditures may lead to people in need foregoing dental services. For households with multiple children, this situation can represent a heavy financial burden (Alkenbrack *et al.*, 2015). Cost-effective preventive programs should be carried out in schools in order to reduce the number of caries lesions to avoid spending on the care of this disease (Allen and Witton, 2021).

Our study had limitations that must be considered. The use of surveys is widespread, but may introduce recall bias if respondents do not fully remember their health experiences. Furthermore, cost estimates do not consider that different treatments are employed according to the severity of the problem. Finally, we considered only direct costs; indirect costs (such as school days lost, pain and suffering, quality of life, etc.) were not accounted for.

In conclusion, the prevalence and experience of caries in the primary dentition were 50% greater than in other studies carried out in Mexico. By contrast, they were lower in permanent dentition. These results indicate urgent caries treatment needs. The cost of care for caries in both dentitions is high. Given the magnitude of the expenditures required to treat this disease, a call for action is unavoidable, highlighting the importance of documenting, designing, implementing and testing a cost-effective prevention program within the Mexican Health System. It is essential to undertake preventive actions that can help protect oral health among school-age children and help ameliorate the high costs of treating established disease.

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