Ecological study on needs and cost of treatment for dental caries in schoolchildren aged 6, 12, and 15 years

Data from a national survey in Mexico

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Abstract

To determine the treatment needs and the care index for dental caries in the primary dentition and permanent dentition of schoolchildren and to quantify the cost of care that would represent the treatment of dental caries in Mexico.

A secondary analysis of data from the First National Caries Survey was conducted, which was a cross-sectional study conducted in the 32 states of Mexico. Based on dmft (average number of decayed, extracted, and filled teeth in the primary dentition) and DMFT (average number of decayed, extracted, and filled teeth in permanent dentition) information, a treatment needs index (TNI) and a caries care index (CI) were calculated.

At age 6, the TNI for the primary dentition ranged from 81.7% to 99.5% and the CI ranged from 0.5% to 17.6%. In the permanent dentition, the TNI ranged from 58.8% to 100%, and the CI ranged from 0.0% to 41.2%. *At age 12*, the TNI ranged from 55.4% to 93.4%, and the CI ranged from 6.5% to 43.4%. *At age 15*, the TNI ranged from 50.4% to 98.4%, and the CI ranged from 1.4% to 48.3%. The total cost of treatment at 6 years of age was estimated to range from a purchasing power parity (PPP) of USD $49.1 to 287.7 million in the primary dentition, and from a PPP of USD $3.7 to 24 million in the permanent dentition. For the treatment of the permanent dentition of 12-year-olds, the PPP ranged from USD $13.3 to 85.4 million. The estimated cost of treatment of the

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permanent dentition of the 15-year-olds ranged from a PPP of USD $10.9 to 70.3 million. The total estimated cost of caries treatment ranged from a PPP of USD $77.1 to 499.6 million, depending on the type of treatment and provider (public or private).

High percentages of TNI for dental caries and low CI values were observed. The estimated costs associated with the treatment for caries have an impact because they represent a considerable percentage of the total health expenditure in Mexico.

Abbreviations: 95% CI = 95% confidence intervals, CI = caries care index, DMFT = average number of decayed, extracted and filled teeth in permanent dentition, dmft = average number of decayed, extracted and filled teeth in the primary dentition, FNCS-M = First National Caries Survey of Mexico, mm = millimeters, NA = not available, PPP = purchasing power parity, SD = standard deviation, TNI = treatment needs index.

Keywords: dental caries, oral health, permanent dentition, primary dentition, schoolchildren, treatment cost

1. Introduction

Dental caries is one of the most common childhood diseases worldwide and continues to be significant throughout life. It is considered the main public health problem in the dental field.[1,2] This multifactorial disease caused by a physiological imbalance between the minerals of the tooth and the dental plaque results in a net loss of dental minerals[3] that is reversible in the initial stages through remineralizing treatments with fluoride compounds,[4,5] or simply by deposition of minerals obtained from saliva and diet. However, once the imbalance is more advanced, the localized lesion grows slowly, undermining hard tissues of the tooth. If a timely intervention does not take place, the lesion can affect the tooth, with caries being the main cause of tooth extraction in children.[6,7]

Caries are largely preventable with simple procedures that have proven to be cost-effective, such as tooth brushing with fluoride toothpaste[4,8] or professional applications of topical fluoride treatments.[5,9–11] In various developed and developing countries, dental caries is an unmet dental need among children and adolescents; it is prevalent in socially disadvantaged population groups.[6,12,13] In Mexico, the prevalence of caries in the permanent dentition ranges from 70% to 85% among 12-year-old children.[14] Due to its high prevalence, treating it represents a significant proportion of the costs associated with health systems: given the limited supply of dental services in the public health sector, households must often pay out-of-pocket expenses for private services.[15] According to the World Health Organization, conventional curative dental care consumes between 5% and 10% of public health expenditures in high-income countries.[16] Detailed information for public health expenditures for caries is not available for many countries with emerging economies, including Mexico.

An important aspect in planning health services, particularly to set goals and priorities of care, is quantification of health needs.[17–19] "Health needs" are defined as the identification of deficiencies requiring health care. This depends on the contrast between basic needs of the individual and the intermediate needs, which in turn are influenced and defined by the sociopolitical and cultural circumstances of each population.[17] From the perspective of decision-makers in a health system, the definition of health needs is based on two criteria: the normative parameters and the services that can be provided. However, patients may have a completely different view that may not coincide with the professional definition; their perspectives may change over time and may not always be amenable to clinical intervention.[17,18] Consequently, provision of clinical services should consider technical knowledge and opinions, demographic, and epidemiological characteristics of the population, as well as their perceived needs.[20]

Regarding oral health needs, studies conducted in countries such as India[21,22] indicated that more than 80% of caries lesions in primary and permanent teeth require restorative treatment. In Qatar, treatment needs reached 75% in the primary dentition of patients aged 6 years.[23] In Nicaragua, treatment needs reached ~50%.[24] The identification and quantification of resources needed to treat dental caries care by health providers, households, and society are necessary not only to determine the economic burden but also to appraise the potential savings if that disease was eradicated.[15,25] Studies conducted around the world[26–33] and in Mexico[34–36] have estimated the costs of diagnosis, treatment, comorbidities, or prevention in health systems. An estimate of the economic burden imposed by dental diseases would provide information for health policy decision-makers to evaluate the importance of improving preventive services. However, information about the cost of care has been very limited.[15,25]

In Mexico, national estimates of treatment needs, treatments that have already been performed, or the cost of caries treatment at the national level are not available. The objectives of this study were to determine the treatment needs and the care index for dental caries in the primary dentition and permanent dentition of schoolchildren, and to estimate the cost of care for dental caries in Mexico. In addition, we compared treatment needs with official Federal (social) poverty indices. We focused these assessments on populations aged 6, 12, and 15 years.

2. Materials and methods

2.1. Design and sample

An ecological study was undertaken using data obtained from the First National Caries Survey of Mexico (FNCS-M).[37] FNCS-M is a cross-sectional study that included the 32 states of Mexico. The survey addressed oral health related to the presence of caries, restorations and tooth loss in the primary and permanent dentition of children aged 6 to 12 years and in the permanent dentition of adolescents aged 15 years. This information allows researchers to calculate the dental care needs for this disease.

The National Survey was conducted based on a complex sample design stratified by two-stage clusters applied in each state to achieve state-level representation and national level homogeneity. The primary sampling units (clusters) comprised the schools; children and adolescents constituted a secondary sampling unit. Its design accounted for stratification of the study population in terms of number of inhabitants in each municipality. Six-year old children were identified in elementary schools: the sampling framework included the overall number of those children in public and private schools. For 12 and 15 year olds,

the sampling framework was focused on middle schools—both public and private. Sample size for each stratum incorporated an effect value of 1.2, a response rate of 90%, a confidence interval of 95%, and a relative error of 0.10. Using a systematic sampling approach, schools were selected and then the number of children to be recruited into the study for each target age group.

The sample size was calculated for each of the states and for each of the age groups. In particular, the National Survey included 22,328 six-year-old schoolchildren who represented 2,298,932 children; 11,660 adolescents aged 12 years who represented 694,105 individuals; and 15,004 schoolchildren aged 15 years who represented 443,520 adolescents (all results are subsequently presented as weighted populations). The present analysis included only schoolchildren and adolescents at the key index ages designated by the World Health Organization (WHO) (6, 12, and 15 years).

2.2. Variables and data collection

Ministry of Health dental personnel used caries indices according to international criteria defined by the WHO, after being trained and calibrated using standardized methods. Using the data for the dmft indices (average number of decayed, extracted and filled teeth in the primary dentition) and DMFT (average number of decayed, extracted and filled teeth in permanent dentition), the care index (CI) and the treatment needs index (TNI) were defined using the following formulae[38,39]:

$$CI = \frac{filled\ teeth}{decayed + missing + filled} \times 100$$

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

The CI summarizes the restorative care already delivered, while the TNI indicates the existing (unmet) treatment needs in the population; both are reported as percentages.

When mixed dentition was present, dmft and DMFT indices were separately presented, as customarily done.

2.3. Costs of care

The estimation of cost of caries treatment was a stepwise process. First, based on the information provided by the dmft and DMFT indices and the population size of each age group, the number of decayed teeth in need of treatment was estimated for each state. Subsequently, two unit prices were obtained for treating dental caries available in 10 large cities in Mexico; one was the average cost of care for caries treatment at public institutions (e.g., through public universities, which offer low-cost treatment), and the second was the average cost charged by private dental offices (Table 1). Two treatment scenarios were considered based on the type of

dentition: amalgam and glass ionomer for primary dentition, and amalgam and resin for permanent dentition. Using this information, the cost of caries care for each state was estimated after considering whether a public or private service provided the clinical care and the type of treatment (amalgam, resin, or ionomer). Estimates were obtained at the national level. The amounts were initially calculated in 2017 Mexican pesos and then were converted into 2017 international dollars (PPP USD $) using the purchasing power parity (PPP) rate of 1 international dollar for 9.04 pesos, as estimated by the Organization for Economic Cooperation and Development (OCDE).[40] The international dollar (PPP US $) is a hypothetical unit calculated by the World Bank that allows adjustment for PPP[41]; it represents the amount of local currency units needed within the country in question to purchase the same amount of goods with one US dollar.

The assumptions of the model were

1. that no other treatment was required, such as pulpotomies and steel crowns in the primary dentition, nor endodontics, pins and cores, or crowns in the permanent dentition, and
2. that 6-year-old children had at least one permanent tooth to enter in the calculation of the DMFT index.

2.4. Analytical strategy

Tooth status scores were obtained for primary teeth (using dmft) and permanent teeth (using DMFT) in participants in the National Survey.[37] Based on this information, TNI and CI were calculated. In addition, a Spearman correlation analysis was performed with the various components of caries indices (dmft and DMFT) and the State Poverty Index developed by the National Population Council.[42] The poverty index is a generally accepted, Federal scale used in Mexico to estimate financial resources and similar resources in the household: higher index indicates fewer resources. The calculation and analysis were performed with Stata 11.0 software (StataCorp LLC, College Station, TX).

2.5. Ethical issues

This study was based on secondary data obtained from several publicly available datasets; therefore, direct informed consent was not required, as established by the relevant institutional review board (IRB) at the academic organization in which the lead author is employed.

3. Results

3.1. At 6 years of age

Supplemental Tables S1, http://links.lww.com/MD/D738 and S2, http://links.lww.com/MD/D739 show the results for the TNI and

Table 1

Average costs used to calculate dental care costs for each type of dentition.

	Primary dentition				Permanent dentition			
	Amalgam		Ionomer		Amalgam		Resin	
	Uni	Private	Uni	Private	Uni	Private	Uni	Private
Pesos	82.50	558.33	106.50	483.33	93.33	558.33	151.67	600.00
I-USD*	8.94	60.49	11.54	52.37	10.11	60.49	16.43	65.01

I-USD = International Dollars 2017, Private = care provided by the private sector, Uni = care provided by public universities, USD = American Dollars.
* For international comparisons. 1 International dollar in 2017 = 9.23 pesos.

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CI in the primary and permanent dentition, respectively, of 6-year-old schoolchildren. In the primary dentition, the TNI ranged from 81.7% (State of Mexico) to 99.5% (Baja California); the CI ranged from 0.5% (Baja California) to 17.6% (State of Mexico). The component extracted teeth negatively correlated with the poverty index ($r = -0.4433$, $P = .0111$), that is, a larger number of extracted teeth indicated higher poverty (Supplemental Table S1, http://links.lww.com/MD/D738). In contrast, in the permanent dentition, the TNI ranged from 58.8% (Aguascalientes) to 100% (Guerrero and Oaxaca), and the CI ranged from 0.0% (Guerrero and Oaxaca) to 41.2% (Aguascalientes). Negative correlations were observed between the number of missing teeth ($r = -0.4117$, $P = .0192$) and the CI ($r = -0.3693$, $P = .0375$) with the poverty index, indicating that higher poverty was associated with fewer filled teeth and less restorative care. A positive correlation was observed between the TNI ($r = 0.3686$, $P = .0379$) and the poverty index, indicating that higher poverty was associated with greater TNI.

3.2. At 12 years of age

The results for TNI and CI in the permanent dentition of 12-year-old adolescents are presented in Supplemental Table S3, http://links.lww.com/MD/D740. The TNI ranged from 55.4% (Colima) to 93.4% (Durango), while the CI ranged from 6.5% (Durango) to 43.4% (Colima). No statistically significant correlations were observed between the poverty index and oral health indicators.

3.3. At 15 years of age

The results for TNI and CI in the permanent dentition of adolescents aged 15 years revealed a TNI ranging from 50.4% (Coahuila) to 98.1% (Mexico City) and a CI ranging from 1.5% (Mexico City (DF)) to 48.3% (Coahuila). For this age group, statistically significant correlations were not observed between the poverty index and the oral health indicators presented in Supplemental Table S4, http://links.lww.com/MD/D741.

3.4. Dental care costs in the 32 states of Mexico

Caries care costs estimated the amount of funds that would be needed to provide clinical care for untreated tooth decay, as identified in the National Survey. The treatment of caries in the primary dentition of 6-year-old schoolchildren would represent a cost of PPP USD $ 49.1 million at the national level if caries were treated with an amalgam restoration in the public sector and would amount to PPP USD 332.3 million if care was provided in the private sector. If ionomer treatment was provided, this cost

was PPP USD 63.4 and 287.7 million in the public and private sectors, respectively. The state with the highest costs was the State of Mexico, while Colima was the state with the lowest costs (Supplemental Table S5, http://links.lww.com/MD/D742).

In this same group of 6-year-old schoolchildren, at the national level the cost of treatment of caries in the permanent dentition with amalgam was PPP USD 3.7 million in the public sector and 22.3 million in the private sector. For resin restorations, treatment costs were PPP USD $ 6.1 million in the public sector and $24 million in the private sector. The highest costs were recorded in Mexico City, while the lowest costs were again observed in Colima (Supplemental Table S6, http://links.lww.com/MD/D743).

As shown in Supplemental Table S7, http://links.lww.com/MD/D744, the national costs of caries care in the permanent dentition of 12-year-old schoolchildren treated with amalgam in the public sector was PPP USD $13.3 million and $79.5 million in the private sector. For restorations with resin, these costs were PPP USD $21.6 and 85.4 million for treatments in the public and private sectors, respectively. Treatment costs for Mexico City and the State of Mexico were not calculated due to the lack of information on caries indices for this age group in the National Survey itself. The highest treatment costs were observed in Puebla and the lowest costs were reported in Colima.

Among 15-year-old schoolchildren, the total cost for caries care in the permanent dentition was PPP USD $10.9 million for amalgam restorations or PPP USD $17.8 million for resin restorations when treatment took place in the public sector. In the private sector, the cost increased to PPP USD $65.4 and $70.3 million per treatment with amalgam or resin, respectively (Supplemental Table S8, http://links.lww.com/MD/D745).

The most recent estimate of overall health expenditures in 2017 indicates that expenditures by the public sector was PPP USD $68 billion 909 million, while expenditures by the private sector was PPP USD $64 billion 863 million. According to the results, the cost of caries care in the public sector for the three age groups increased to PPP USD $ 77.1 million for amalgam restorations, and PPP USD $ 108.8 million for ionomer restorations in the primary dentition and resin restorations in the permanent dentition. These costs were equivalent to 0.11% and 0.16%, respectively, of overall health expenditures in the public sector. The total cost of caries care in the private sector was PPP USD $499.6 million for amalgam restorations, and $467.4 million for ionomer or resin restorations; these costs were equivalent to 0.8% and 0.7%, respectively, of overall health expenditures by the private sector (Table 2).

4. Discussion

The objective of this study was to determine the treatment needs and the care index in the school-aged population in Mexico and

Table 2

Total costs for each type of caries treatment in the three groups of schoolchildren stratified by sector (public or private) in Mexico, USD thousands of US dollars (PPP 2017).

Group of schoolchildren	Amalgam		Ionomer or resin	
	Public care	Private care	Public care	Private care
6 years old (primary dentition)	$49.1	$332.3	$63.4	$287.7
6 years old (permanent dentition)	$3.7	$22.3	$6.1	$24.0
12 years old (permanent dentition)	$13.3	$79.5	$21.6	$85.4
15 years old (permanent dentition)	$10.9	$65.4	$17.8	$70.3
National total	$77.1	$499.6	$108.8	$467.4

Note: Exchange rate: 1 PPP USD Dollar in 2017 = 9.04 pesos.

to estimate costs associated with treatment in three priority age groups established by the WHO. High needs for dental caries care in the three age groups and in both types of dentition were observed. Greater treatments needs were observed in the primary dentition than in the permanent dentition. In contrast, access to curative services was low. Similar results have been reported in several studies conducted in Latin America and other developing countries, where treatment needs reach 80%.[21–24] This high percentage has economic implications for health system and households because dental care costs are burdensome for a developing country such as Mexico.

The estimation of treatment needs is an important requirement in the planning of oral health care. Therefore, one of the first steps in the organization of dental services is the collection of epidemiological information and health needs of the population. Using this information, future treatment needs and service demands are evaluated. The standard treatment for dental caries involves the placement of fillings, according to the degree of involvement.[43] According to our results, the high health needs observed imply four likely situations:

1. lack of access and limited supply of oral health services;
2. economic, geographic, and social barriers;
3. poor dental knowledge in the population; or
4. a lack of investment by the health system in cost-effective actions to prevent caries.

The high percentage of treatment needs for dental caries observed is consistent with findings reported in other developing countries.[21–24] Oral diseases in children have several repercussions, such as significant pain and interference with diet, and impacts on daily activities, such as playing, sleeping or school. Untreated dental caries have been shown to have a negative effect on quality of life. Although caries are largely preventable, they continue to be a major public health problem worldwide and are most prevalent in socially disadvantaged populations.[21,44]

In a recent study, the direct costs of treatment due to dental diseases worldwide were estimated at PPP US $298 billion annually, which is about 4.6% of global health expenditures. Indirect costs due to dental disease worldwide amounted to PPP US $144 billion annually, which is comparable to economic losses attributed to the 10 most common causes of death worldwide.[25] The economic impact of curative treatment for oral diseases is considerable. According to the WHO, between 5% and 10% of health expenditures in some high-income countries is spent on oral health. In low- and middle-income countries, the availability of public oral health programs is limited, and the nature of these services tends to be mainly surgical, as in tooth extractions. Caries care in a group of schoolchildren reached up to 0.17% of total public health expenditure when care was provided by public providers; however, care provided by private providers represented approximately 1% of the total private health expenditures. A portion of these resources could be saved by implementing effective prevention and health promotion measures.[45] Our study adds valuable information about the economic burden of oral diseases when evaluating the appropriateness and social relevance of preventing and treating oral diseases.[25] Since we are presenting disaggregated results for each state in Mexico, it is feasible to identify which states have larger caries experience and greater potential to incur in clinical care expenses—or greater savings if health promotion programs in fact ameliorate caries experience.

Some countries, such as Norway, Denmark, and Sweden, have recommended prohibiting the use of mercury in dental amalgams,[46] and the use of amalgams contamination has been discontinued throughout Europe within the last year due to perceived risks associated with mercury.[47] In the present study, we have included cost estimates using amalgam because this material is commonly used in restoration procedures in Mexico, similar to other countries.

It is worthwhile pointing out that future national surveys would render a more accurate landscape of oral health and dental care (and associated expenditures) if socioeconomic and socio-demographic variables are included; a similar case can be made for behavioral variables associated with oral health.

4.1. Limitations

Several limitations of this study must be considered. First, the estimation of treatment needs, the dental care index and the estimation of the cost of dental caries care are directly related to the prevalence data available; this study used prevalence information provided by the National Caries Survey conducted in 2006.[37] To date, no other source has provided information about dental caries on a per-carious lesion basis. The National Caries and Fluorosis Dental Survey conducted in 2011 to 2014[48] contains valuable information on these parameters; the indices considered cavitated carious lesions and incipient carious lesions (non-cavitated). However, for a third of states, the survey does not provide information on caries indices for the permanent dentition, which includes carious lesions that are only cavitated. Second, the treatment costs were estimated only for school-children in the index age groups indicated by the WHO (6, 12, and 15 years); treatment costs for the adult population were not calculated. Consequently, treatment costs for caries in the Mexican population at large are not included in our estimates. No previous studies have estimated the economic burden of dental caries in Mexico; thus, we were unable to determine the magnitude of this underestimation. Third, the estimates do not consider the different stages of dental caries, where different treatments would be applied according to caries severity. Another limitation is how current are these data, which are derived from a national survey published in 2006.[25] One of the assumptions, as mentioned in the model, is that caries indices have not changed over the years.

We propose that methodological improvements should be contemplated for future studies. Estimates of prevalence of oral diseases, particularly epidemiologically important diseases such as caries, are required to better ascertain economic burden. Additionally, these estimates should include three categories of expenses: direct costs (diagnosis, treatment, routine care, and comorbidities/associated complications), indirect costs (missed days of school, loss of income and productivity due to caregiver involvement), and intangible costs (pain and suffering). Intangible costs are difficult to evaluate but can be estimated using quality-adjusted life years. This approach will help researchers to place more accurately oral health in context as a public health problem due to the costs incurred by families and health systems.

5. Conclusions

Our findings begin to establish a valuable platform to efficiently plan preventive and curative oral health programs in Mexico. The magnitude of costs to treat dental caries highlights the need

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for a cost-effective prevention program. Using pit and fissure sealants in schoolchildren, and promoting tooth brushing with fluoridated toothpaste should be included in prevention programs. We observed high percentages of TNI for dental caries and low values for the CI at the state and national levels. These findings emphasize the need for oral health programs to reduce the need for caries treatment. Health policies should be aimed at preventing dental caries because rehabilitation costs represent a significant burden for both families and health systems.

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