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ORIGINAL ARTICLE

Dental fluorosis in cohorts born before, during, and after the national salt fluoridation program in a community in Mexico

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Abstract

Objective. To determine the prevalence and severity of dental fluorosis, as well as factors associated with its occurrence, in seven cohorts of children before and after the implementation of a fluoridated salt program in 1991. ***Material and methods***. A cross-sectional study was carried out in 1,373 children aged from 6 to 12 years in Campeche, Mexico. Data were collected by means of a questionnaire administered to mothers and a dental examination of the children. Modified Dean's criteria were used to diagnose dental fluorosis. A multivariate logistic regression model was used to evaluate the relationship between dental fluorosis and independent variables. ***Results***. The prevalence of dental fluorosis was 51.9%. The most common degree of dental fluorosis was *very mild*, with 84.7%, followed by *mild*, *moderate*, and *severe* with 13.1%, 1.7%, and 0.6%, respectively. The multivariate model adjusted by number of additional sources of fluoride, age at the beginning of use of toothpaste, and level of schooling of the mother, showed that children born in 1990 (OR = 1.74; CI 95% = 1.36–2.22), 1991 (OR = 4.03; CI 95% = 2.58–6.28), and 1992 (OR = 10.41; CI 95% = 5.77–18.78) were more likely to have dental fluorosis than those born in the period 1986–1989. The frequency of toothbrushing (OR = 1.63; CI 95% = 1.37–1.95) was also associated with dental fluorosis. ***Conclusions***. A close relationship was found between exposure to toothpaste and dental fluorosis. Implementation of the fluoridated salt program greatly increased the risk of fluorosis.

Key Words: *Fluorosis, fluoridated salt, oral health, toothpaste*

Introduction

The decline in caries prevalence observed in the past few decades has been attributed to a variety of factors, one of them the utilization of fluorides as a caries preventive measure. However, this has been accompanied by an undesirable increase in the prevalence of dental fluorosis [1,2].

Dental fluorosis is enamel hypomineralization induced by over-exposure of the developing teeth to fluorides. The clinical appearance of milder forms of enamel fluorosis is characterized by narrow white lines following the perikymata, cuspal snowcapping, and a snowflaking appearance that lacks a clear border with unaffected enamel. With increasing severity, the subsurface enamel all along the tooth becomes increasingly porous, the lesion extends toward the inner enamel, and the fluoride content increases. After eruption, the opaque areas may become stained yellow to dark brown, and the more severe forms are subject to extensive structural breakdown of the surface. Fluorosis severity is associated with length of exposure, timing with the dental enamel maturity stage and mineralization stage, and the fluoride dose [3,4]. Fluoride consumption at approximately 3 to 4 years of age, occurring during the stages of mineralization, is critical for the development of fluorosis. While this is particularly marked in esthetically important permanent teeth such as the incisors, 1st molars can also be affected [3,5]. For canines and premolars, this time limit can be extended 2 or 3 more years.

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Fluorosis prevalence varies across communities because of characteristics such as natural and artificial levels of available fluoride, climatic temperature, and geographic altitude above sea level, among others, although the index used to determine the presence of fluorosis also has a part to play [6]. Communities both with and without the public health technology to artificially adjust fluoride levels have fluorosis: figures for fluoridated communities range from 35% to 60%, and for non-fluoridated communities from 20% to 45%, with a relationship between fluoride in water and prevalence of fluorosis [7].

In Mexico, fluorosis studies have mostly taken place in the northern and central regions [6,8]. In 1991, a fluoridated salt program was introduced for the general population with the aim of decreasing the incidence of caries; however, at the same time, the program posed the threat of increasing the prevalence of fluorosis. The objective of the present study was therefore to determine the prevalence, severity, and factors associated with dental fluorosis in seven cohorts of children before, during, and after the beginning of the salt fluoridation program.

Material and methods

Study population, sample, and design

The study design and undertaking followed the ethics guidelines prescribed for conducting studies at the Autonomous University of Campeche. A cross-sectional study was conducted in 6 to 12-year-old children attending elementary schools in the Mexican city of Campeche. Four public schools with a population of 1,603 individuals were selected. After reaching agreement with teachers and principals, letters of informed consent were distributed to all of the parents whose children were attending the school. The response rate was 87.5% ($n = 1{,}403$). After applying the inclusion criteria (i.e. children born and residing all of their lives in Campeche, older than 6 and younger than 13 years of age, having index teeth for measuring dental fluorosis, attending any of the selected schools, and whose mother had signed the letter of informed consent) and the exclusion criteria (i.e. refusal to participate in the study and out of the age range), 1,373 children were included in the study.

Study variables and data collection

The dependent variable was dental fluorosis, and to diagnose it the modified Dean's index [9] was used, where 0 = no fluorosis or questionable, 1 = very mild, 2 = mild, 3 = moderate, and 4 = severe. The index was administrated to all permanent teeth and the two teeth with the worst score were used for the person-level score. Where two teeth were not affected to the same degree, the convention used in recent years seems to have been to assign a classification based on the less involved tooth of the two exhibiting the worst scores – in other words, to assign a person-level score based on the lowest of the two worst scores [9]. Independent variables were: year of birth of cohorts, sex, toothbrushing frequency, age that the child started using toothpaste, use of any other fluoride technology, number of fluoride sources, and mother's highest level of schooling.

To establish socio-demographic and socio-economic behavioral variables and exposure to fluorides during the first 6 years of life, a structured questionnaire addressed to the mothers was developed. As far as additional fluoride technologies were concerned, we considered whether the individual had been exposed at least once to such a program before 6 years of age, when fluoride drops, mouth rinses, professional administrations, self-administered fluoride in gel, and any other fluoride supplements were used. However, any given vehicle was considered as the main exposure fluoride source if it was applied consistently, at least twice a year, after 2 and before 6 years of age.

All child participants were clinically examined by one of three trained and standardized examiners in the modified Dean's Index ($\kappa = 0.85$) [9] using a flat mirror under daylight at the nurse station of each school. Children and mothers were informed of any findings that could have necessitated follow-up by a dental professional.

Statistical analyses

Descriptive and bivariate analyses: To evaluate data integrity and to describe the study population in general, an exploratory analysis for each variable was performed. Estimates of any central tendency and dispersion measures were conducted. In the case of categorical variables, frequencies and percentages were calculated for each category. The chi-squared, Mann-Whitney, and non-parametric test for trend were performed for the bivariate analyses, depending on the measurement scales of each variable. Furthermore, all variables were analyzed through bivariate logistic regression analysis to determine which of them were associated with dental fluorosis.

Multivariate analysis: A logistic binary regression multivariate model was conducted to find the variables more closely associated with dental fluorosis and to control for potential confounding variables. Only variables with bivariate analysis $p < 0.25$ were included in the final model [10]. The inflation variance factor test was conducted to analyze and prevent multicollinearity on independent variables. All interactions of theoretical interest were tested and none was < 0.15. In addition, a specification error test was performed to determine whether the outcome *logit* was a linear combination of independent variables. For continuous variables, year of birth and number of fluoride sources that remained in the final model, the Box-Tidwell test was calculated to confirm that the change in the *logit* was of the same magnitude [11]; as year of birth failed the assumption, we integrated categories for each of the study cohorts. The goodness-of-fit test was verified in the final model with the Hosmer-Lemeshow goodness-of-fit test using a cut-off point test statistic of $p > 0.10$.

The confidence intervals in both bivariate and multivariate analysis were estimated with robust standard error, i.e. cluster analysis, the reason being that the observed data were children at school; observations within a cluster could therefore be correlated, whereas observations across clusters were not necessarily correlated [12]. Statistical analyses were calculated using the STATA 8.2® software.

Results

Of the 1,373 children included in the study, 51.3% were female; average age 8.8 $\pm$ 1.8 years, mothers' schooling average 8.9 $\pm$ 4.1 years. All mothers claimed to use toothpaste for their children's toothbrushing. The characteristics of children and their mothers are given in Table I. Fluorosis prevalence was 51.9% ($n = 712$). Among children with fluorosis, the most common level of severity was *very mild*, with 84.7%, followed by *mild, moderate*, and *severe* with frequencies of 13.1%, 1.7%, and 0.6%, respectively.

The data show that the possibility of having fluorosis in the cohorts of children born in 1987, 1988, and 1999 was no different ($p > 0.05$) from the cohort of children born in 1986, but it was different ($p < 0.05$) from those born in 1990, 1991, and 1992 (Fig. 1). In the non-parametric test for trend, it was observed that the prevalence increased with successive cohorts.

Table I. Characteristics of population included in the study

Variable	Mean $\pm$ SD	Range
Age	8.83 $\pm$ 1.80	6–12
Mother's schooling	8.91 $\pm$ 4.12	0–20
No. of additional fluoride sources	2.17 $\pm$ 1.10	1–5
	n	Percentage
Sex		
Boys	669	48.7
Girls	704	51.3
Toothbrushing frequency		
Less than 7 times a week	133	9.7
At least once a day	1240	90.3
Start of toothpaste use		
After 4 years	968	70.5
Befote 4 years	405	29.5
Main fluoride source		
Self-applied	878	63.9
Drops/mouthwash/dentist	495	36.1
School		
School 1	473	34.4
School 2	259	18.9
School 3	310	22.6
School 4	331	24.1

Bivariate analysis results

Bivariate logistic regression analysis results are given in Table II. Presence of fluorosis (any severity) was associated with the number of additional sources of fluoride because for each additional source of fluoride the likelihood of having fluorosis increased by 36.0%. Children who started using toothpaste, or received fluoride, before the age of 4 years had 1.23 times the odds of presenting fluorosis than children who started using toothpaste after the age of 4 years. Frequency of toothbrushing appears to have a positive effect on dental fluorosis with OR = 1.54.

In this analysis, children from the 1990, 1991, and 1992 cohorts had a higher probability of having fluorosis with OR 1.72, 3.90, and 10.22, respectively, than those from the 1986 to 1989 cohorts. Sex, the main source of fluoride, and mother's level of schooling were not related to fluorosis ($p > 0.05$).

Multivariate analyses results

Table III gives the adjusted odds ratio and its 95% confidence intervals: once a day toothbrushing frequency with fluoride toothpaste increased the odds (OR = 1.63; CI 95% = 1.37–1.95) of having dental fluorosis compared to children who brushed their teeth fewer than seven times week. A strong relationship was observed between fluorosis and year of birth: children born in 1990 had almost twice the odds of having dental fluorosis (OR = 1.74; CI 95% = 1.36–2.22) than children in the 1986 to 1989 cohorts. The probability of having fluorosis doubled (OR = 4.03; CI 95% = 2.58–6.28) in children born in 1991 (compared to children from the 1986 to 1989 cohorts), and doubled again in children born in 1992 (OR = 10.41; CI 95% = 5.77–18.78). The multivariate analysis did not reveal evidence of interaction between variables that remained in the final model.

Discussion

Since water fluoridation started in the United States as a public health program for caries prevention, the use of fluoride technologies such as toothpastes, mouthwashes, and self-administered vehicles has increased greatly. It is also known that, with this increased use, dental fluorosis might manifest as a side effect due to excessive fluoride exposure during key times in tooth development, i.e. between ages 2.5 and 5.5 years [3,5]. One of the largest public

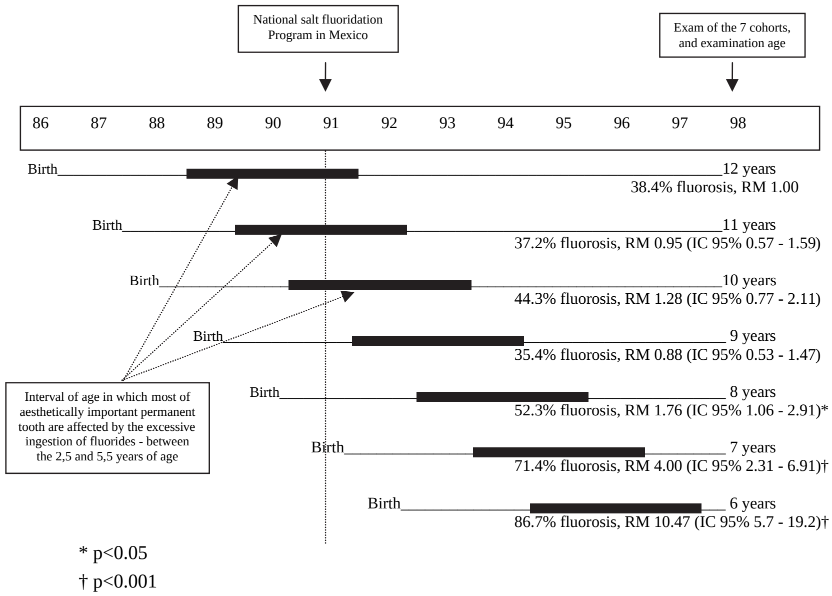

Figure 1. Dental fluorosis prevalence through study cohorts (born between 1986 and 1992) in the context of fluoride availability in edible salt. In this figure Odds ratios by cohort are observed.

health challenges – both yesterday and today – is how to reduce the negative impact of dental fluorosis while optimizing the preventive effect [3,13,14]. In the present study, we observed that the total prevalence of fluorosis was approximately 50%, with an increase in the percentage of children with any level of fluorosis after the salt fluoridation program started.

The timing of enamel mineralization varies between different teeth. Fluorosis prevalence and severity will depend, among other factors, on when the fluoride exposure starts [3,7,15]. Bardsen [3] found that children who were exposed to fluoride for more than 2 years in their first 4 years of life were at 6 times more risk of developing fluorosis than children exposed for shorter periods. Our findings are consistent with this statement, as we found that children born between 1990 and 1992 were at 2 to 10 times higher risk of developing fluorosis than children in the cohorts preceding 1990. The most important factor separating the two eras is the implementation of the fluoridated salt program in 1991 (Figure 1). While our speculation was that timing of the program implementation should have, at least partially, coincided with the increased susceptibility of the cohorts born in 1988 and

Table II. Binary logistic bivariate regression analysis between fluorosis (level 0 versus >0) and independent variables

Variable	OR	CI 95%	p-value
Mother's schooling	1.02	0.99–1.04	0.193
No. of additional fluoride sources	1.36	1.12–1.65	0.002
Cohorts			
1986/1989	1*		
1990	1.72	1.32–2.23	<0.001
1991	3.90	2.75–5.51	<0.001
1992	10.22	6.93–17.63	<0.001
Sex			
Boys	1*		
Girls	0.93	0.73–1.20	0.583
Toothbrushing frequency			
Less than 7 times a week	1*		
At least once a day	1.54	1.19–2.01	0.001
Start of toothpaste use			
Alter 4 years	1*		
Before 4 years	1.23	1.04–1.46	0.015
Main fluoride source			
Self-applied	1*		
Drops/mouthwash/dentist	1.31	0.84–2.03	0.228

*Reference category.
95% confidence intervals with robust standard errors.

Table III. Multivariate analysis results for dental fluorosis in a community of Mexico

Variable	OR*	CI 95%	p-value
Cohorts			
1986/1989	1†		
1990	1.74	1.36–2.22	<0.001
1991	4.03	2.58–6.28	<0.001
1992	10.41	5.77–18.78	<0.001
Toothbrush frequency			
Less than 7 times a week	1†		
At least once a day	1.63	1.37–1.95	<0.001

*Adjusted odds ratio by variables in table, plus additional fluoride sources, beginning of toothpaste use, mother's schooling and main fluoride exposure source. 95% confidence intervals, estimated with robust standard errors.
†Reference category.
Hosmer-Lemeshow goodness-of-fit test: chi-square (8) = 0.51; $p = 0.9999$.
Specification error test (linktest), predictor <0.001; predictor^2 = 0.900.

1989, this reasoning was not fully supported by our data. Our interpretation of this paradox hinges upon the documented discontinuity in fluoride dosage between 1991 and 1993, whereby the availability of fluoride through the salt program was patchy during the first years of implementation. We propose that improvements in industrial processes and invigilation procedures through longitudinal quality control has led to better fluoride dosages, in turn leading to increased fluorosis after 1993 (Figure 1).

An additional explanation of why fluorosis prevalence was not different in 1988 and 1989 from that in 1986 is that even though fluorosis is related to time, duration, and exposure dose to fluorides, such a relationship is not direct. Physiologic conditions, including calcium deficiency, acidic-alkaline balance disorders, urinary flow disturbances, and renal management of fluorides and diet [8,16] over the longer term, may affect the onset and development of dental fluorosis.

Other sources of fluoride are involved in dental fluorosis. Mexican children are exposed to different fluoride sources [6,8]. Some authors mention that toothpaste ingestion during toothbrushing is common among children. A recent study [17] concluded that the main source of fluoride intake was the use of toothpaste. Although toothpaste intake was not quantified in the present study, frequency of toothbrushing was associated with the presence of fluorosis, even after controlling for variables such as number of additional sources of fluorides and age at beginning of toothpaste use. Even when toothbrushing is helpful in preventing dental caries [18], our finding confirmed previous reports with regard to toothbrushing frequency, as well as type and quantity of toothpaste, being risk factors for dental fluorosis [15,17,19].

The limitations of the present work have to be taken into account when interpreting the results. As with any cross-sectional analysis, the problem of temporal ambiguity precludes a clear interpretation of cause and effect, since these are measured simultaneously. Another limitation is the method for measuring exposure to different fluoride technologies; mothers may have their recollection affected by recall bias. Despite these design limitations, we found a very strong relationship between children born in different cohorts, and thus exposed to different levels of fluoride, and the prevalence of fluorosis. The change in fluorosis experience in terms of birth cohort suggests that exposure to fluoridated salt was an important risk factor for dental fluorosis. This study also provides evidence that toothbrushing frequency, in association with fluoridated toothpaste, can be a risk factor for fluorosis. It is suggested that fluoride sources and their effect on susceptible populations be constantly and objectively monitored, as recommended by international agencies.

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