

A review of the prevalence of dental fluorosis in Mexico

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ABSTRACT **Objective.** *There has been a worrisome increase in the prevalence of dental fluorosis worldwide. The objective of this study was to review research on dental fluorosis prevalence in Mexico in order to assess if that prevalence is rising and if dental fluorosis constitutes a public health problem for the country.*

Methods. *Clinical, experimental, and review reports were searched for in a number of bibliographic databases for scientific literature, using the search phrase "fluorosis and Mexico." All the materials that were initially identified had to satisfy eight specific criteria in order to be included in our study.*

Results. *Of the 24 publications that the literature search yielded, 14 satisfied all the inclusion criteria. The prevalence of dental fluorosis reported in Mexico ranged from 30% to 100% in areas where water is naturally fluoridated and from 52% to 82% in areas where fluoridated salt is used. Most of the 14 studies were conducted in areas where water fluoride levels were above optimal, and the fluorosis cases reported in these publications ranged from "mild" to "severe." There have been only a small number of reports on dental fluorosis since the introduction of fluoridated salt in the country in 1991. However, some of those studies have shown that the prevalence of fluorosis was higher than what would be expected given the historical data from communities with optimal fluoridation in other countries.*

Conclusion. *Due to the limited amount of information, it is not possible to determine if the prevalence of dental fluorosis in Mexico is rising or if it constitutes a public health problem. To objectively answer these questions more controlled studies are needed in areas where fluoridated salt is distributed, where water fluoride is above optimal, and where residents live at a high altitude.*

Key words Fluorosis, dental; fluoridation; oral health; Mexico.

In 1888 Kuhns reported that a clinical condition, similar to what is now called

dental fluorosis, had been observed in Mexico (1). He described the teeth of a family who lived in the city of Durango, Mexico, as opaque, discolored, and disfigured. Years later a comparable condition was reported in the United States of America by Black and McKay (2), who observed brownish-red stains in many of their patients; these stains would later become known as "mottled enamel."

As described by Cutress and Suckling (3), the first clinical signs of dental

fluorosis are thin white striae across the teeth surfaces. These fine opaque lines seem to follow the perikymata pattern. The cusp tips, incisal edges, and marginal ridges may appear completely opaque, a condition that has been defined as "snow-capping." In moderately affected teeth, the white lines appear more pronounced. The lines may merge and produce areas that will appear cloudy and will be scattered over the tooth surface. With increasing severity, the entire surface

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exhibits opaque, cloudy areas that may be mixed with areas of brownish discoloration. In the most severe cases, pitting of the enamel surface occurs.

From 1920 to 1940 several epidemiological and laboratory studies suggested an association between fluoride intake and these enamel defects (4–8). This condition was then named dental fluorosis. The conclusive piece of epidemiological evidence that linked dental fluorosis to excessive fluoride in the drinking water was provided by the multiple studies done by Dean and co-workers. In the late 1930s and early 1940s those researchers conducted epidemiological studies of approximately 7 000 children in 21 cities in states of the United States that included Colorado, Illinois, Indiana, and Ohio. Dean and his colleagues were able to determine fluoride's relationship to the prevalence of caries and to dental fluorosis. These investigators concluded that when fluoride was present in the water at a certain level, it would prevent dental caries, but if it exceeded that certain level, it would lead to fluorosed teeth. The optimal level of water fluoride, which would optimize its beneficial effects while minimizing its detrimental effects, was determined to be 1 part per million (ppm) (9).

Based on the understanding of fluoride's caries-preventive effects, water fluoridation programs have been implemented worldwide. Alternative vehicles such as salt and milk have been employed to distribute fluoride where water fluoridation is not possible. A salt fluoridation program to prevent dental decay was introduced in selected states of Mexico in 1981 (10) and implemented nationally in 1995 (11). The salt fluoridation program clearly stated that this type of salt should not be distributed in cities in which the water for human consumption had fluoride content above 0.7 ppm.

In 1973 it was reported that at least 19 communities in Mexico—in the states of Aguascalientes, Baja California Norte, Chihuahua, Durango, Jalisco, Sonora, and Tamaulipas—had natural concentrations of fluoride in the drinking water that were above the optimal level of 0.7 to 1.5 ppm (12).

Later, the following states were also reported as having communities where fluoride was above optimal: Guanajuato, San Luis Potosí, and Zacatecas (13). In all 10 of these states there were several communities where a high prevalence of dental fluorosis was of concern. Although water fluoride concentrations are still above optimal in all of these communities, to date there has been no comprehensive data collection to study either dental fluorosis or the impact that these fluoride concentration levels have on the patterns and prevalence of tooth decay in most of these communities.

The determination of all the areas where excess fluoride in the water may constitute a problem for the population is complicated in Mexico because of the multiple water sources that may serve a single community (14, 15). Access to safe tap water in Mexico may vary much from state to state, from city to city, and from area to area within a city. Tap water may be obtained from various overground sources (rivers, lakes, and reservoirs), underground wells, or both. Quality may vary as well. Areas within a single city may have different water quality, with the water even being unsafe to drink in some of the areas. This detailed information is not readily available to the public. Therefore, the boiling of tap water is a common practice even in areas where its quality is good. Further, because of this general situation, the use of bottled water is widespread and increasing. The precise percentage of people who use bottled water is unknown and varies from state to state. Most people obtain it in large bottles either delivered to their homes or purchased and brought home from a store. Many households use both bottled water and tap water (both boiled and not boiled). In 1990, access to potable water was some 80% for the country overall, with most cities having coverage above 90%.

Around the world, dental fluorosis has always been regarded as a public health problem in those areas where natural fluoride in the water exceeds optimal levels; residents of optimally fluoridated areas have not been con-

sidered to be at risk for dental fluorosis. However, due to the widespread use of fluoridated products, concern has been expressed in recent years over a possible increase in the prevalence of dental fluorosis worldwide in optimally fluoridated and even suboptimally fluoridated areas. When recent data are compared to historical data, the results seem to indicate a trend toward a higher prevalence of fluorosis (16). Living at a high altitude has been reported as contributing to the development of dental fluorosis (1). In Mexico these various trends have led to an interest in reviewing reports on dental fluorosis in order to assess if it now constitutes a widespread public health problem in the country. This review evaluated published data regarding dental fluorosis in Mexico to assess if sufficient data have been obtained in order to determine if dental fluorosis is rising and if it constitutes a public health problem in the country.

MATERIALS AND METHODS

We searched seven bibliographic databases of scientific literature for clinical, experimental, and review reports, using the search term "fluorosis and Mexico." The seven databases were: (1) MEDLINE (compiled by the National Library of Medicine of the United States); (2) PubMed (also compiled by the National Library of Medicine of the United States); (3) Current Contents (compiled by Thomson ISI (founded as the Institute for Scientific Information) and published on the Web by the ISI Web of Knowledge); (4) Ovid (owned by the Wolters Kluwer corporation); (5) LILACS (*Literatura Latinoamericana y del Caribe en Ciencias de la Salud*) (Latin American and Caribbean Health Sciences Literature), compiled and published by the *Centro Latinoamericano y del Caribe de Información en Ciencias de la Salud* (Latin American and Caribbean Center on Health Sciences Information), São Paulo, Brazil; (6) EMBASE (*Excerpta Medica*), produced by Elsevier Science; and (7) Artemisa, (*Artículos Editados en México sobre Información en*

Salud (Articles Edited in Mexico on Health Information), published by the *Secretaría de Salud de México* (Secretariat of Health of Mexico).

With the articles located through that searching, we reviewed all the references that they cited, in order to locate additional reports. We also did manual searching of nonindexed materials, especially in journals that were once included in databases but no longer are. The search included articles published from January 1970 through December 2001. We excluded case reports, letters to the editor, news or commentary pieces, and clinical descriptions. In order to qualify for review in this article, the remaining manuscripts had to fulfill the following eight inclusion criteria:

- 1) Papers had to be published in a peer-reviewed journal. However, inclusion of the journal in the ISI Science Citation Index (SCI) or in a database or index other than the SCI was not mandatory.
- 2) The studies had to include dental examinations performed with the aid of an index of dental fluorosis, properly described in the article.
- 3) The clinicians who assessed the dental fluorosis had to be trained and/or calibrated.
- 4) The residence of the study participants had to be documented.
- 5) The content of fluoride in water had to be stated.
- 6) The main source of fluoride in the population studied had to be mentioned.
- 7) The results and/or tables had to be properly presented and described, in order to be analyzed and used to extract data for this review.
- 8) Adequate conclusions had to be stated, and the conclusions had to correspond to the aims of the study.

Using these eight standards, we assessed the publications that we had located. With publications that met those criteria, we recorded the information from them on a data extraction sheet. Differences among studies, such as which index of dental fluorosis was used, population selection criteria, and

retrospective information, were also assessed.

RESULTS

The literature search yielded 24 papers. Of those 24, 14 of them met our inclusion criteria. We divided those 14 papers into three groups. The first group dealt with studies conducted in naturally fluoridated areas where water fluoride was above optimal (those studies will be shown in Table 1). The second group (which will be shown in Table 2) included studies conducted in areas where water had negligible, unknown, or optimal amounts of fluoride and fluoridated salt was used. The third group (which will be shown in Table 3) dealt with studies where the altitude of residence was reported to be related to a higher prevalence of dental fluorosis, where fluoridated salt may have been distributed, and where the water fluoride content was unknown, negligible, optimal, or above optimal.

Of the 14 studies, 7 of them were conducted in endemic areas or communities where water fluoride appeared to be a problem. The other 7 studies were performed in areas where water fluoride was not above optimal levels or was unknown and where fluoridated salt had been implemented as a prevention measure. Of the 14 studies included in this review, 4 studies were performed in high-altitude areas (above 2 000 m), 8 in the range of 1 000 to 2 000 m, and 2 at sea level.

The tables included in this article show only the fluoride content of regular tap water. However, the fluoride content in other types of water (boiled tap water, bottled water, and well water) are sometimes also mentioned in the text sections that follow.

Communities where the fluoride content in naturally fluoridated water was above optimal

Many of the studies on dental fluorosis prevalence in Mexico have been conducted in areas where tap water fluoride had been reported to be above

1.5 ppm. For example, as shown in Table 1, Lozano-Montemayor (17) studied four groups of children of various ages in the city of Ensenada, in the state of Baja California Norte. Children were studied at four different times, from 1979 to 1990. He reported a high prevalence of dental fluorosis, using a modification of Dean's Index for fluorosis, as described in the World Health Organization guidelines (18). Training of examiners was mentioned, but no information on the number of examiners or calibration procedures was included. The article mentioned the mean or range of fluoride content from several analyses of water done at different times, including: (1) from the late 1950s, when one bottled water sample showed 8 ppm of fluoride; (2) in 1980, when one well water sample had 4.6 ppm; (3) in 1981, when an analysis of fluoride content in bottled water showed values from 0.51 to 2.62 ppm; and (4) in the early 1990s, when fluoride content in tap water samples ranged from 0 to 2.6 ppm of fluoride. The author reported that despite efforts undertaken between 1979 and 1990 by dental and governmental authorities to diminish dental fluorosis, no decrease in its prevalence was found when results of clinical studies conducted in 1979 were compared to results obtained in 1990.

Barrandey-Orozco et al. (19) reported a high prevalence of dental fluorosis in the city of Chihuahua, which is in the state of the same name (Table 1). For example, 96.5% of the children had their front teeth affected. Trained fourth-year dental students obtained the data, but no information on calibration procedures was described. Local authorities provided the authors the information on past and current tap water fluoride content, from some areas of the city of Chihuahua and other areas in the state of Chihuahua. In addition, these investigators analyzed 61 of the 76 sources of tap water in the city of Chihuahua. Previous reports had shown that tap water fluoride content ranged from 0 to 3 ppm in the city of Chihuahua and from 0.1 to 10 ppm in other communities in the state. In this study, tap water fluoride

TABLE 1. Prevalence of dental fluorosis in Mexican communities where water fluoride content was known to be above optimal

Community and state, altitude, (reference)	Sample size	Study date	Age of subjects (yr)	Index of dental fluorosis	Fluorosis prevalence (%)	Severe fluorosis (%)	Mean or range of fluoride content in tap water (ppm) ^{a,b}
Ensenada, Baja California Norte, 10 m (17)	2 140	1979	5–15	Modified	96.5	6.3	NS ^c
	2 039	1981	5–15	Dean's	98.9	13.2	NS
	928	1985	3–6		51.1	11.0	NS
	2 163	1990	6–15		95.0	10.0	0.00–2.60
Chihuahua, Chihuahua, 1 440 m (19)	1 379	1992	10–12	Modified Dean's	76.2	23.1	0.12–2.36
San Luis Potosí, San Luis Potosí, 1 860 m (20) ^d	16	NS	11–13	Modified	69.0	18.5	< 0.70
	67		11–13	Dean's	87.0	12.0	0.70–1.20
	58		11–13		91.3	27.6	1.20–2.00
	58		11–13		98.3	62.1	> 2.00
San Luis Potosí, San Luis Potosí, 1 860 m (21) ^e	100	1992	11–13	Modified	74.0	28.0	0.90
	154		11–13	Dean's	100.0	57.0	1.69
	47		11–13		83.0	57.0	2.37
	51		11–13		96.0	84.0	3.29
San Luis Potosí, San Luis Potosí, 1 860 m (22) ^f	100	1997–1999	3–6	IFTD ^g	66.2	10.8	0–1.20
	100		3–6		81.3	11.3	1.30–3.00
	100		3–6		92.9	42.4	> 3.00
Durango, Durango, 1 880 m (23) ^h	97	1990	6–12	Modified	76.0	2.0	< 1.50
	112			Dean's	86.0	2.0	1.51–4.99
	38				95.0	0.0	5.00–8.49
	27				85.0	4.0	8.50–11.99
	59				100.0	35	12.00–16.00
Aguascalientes, Aguascalientes, 1 870 m (25)	643	NS	6–12	Modified Dean's	70.0	4.0	0.70–4.60

^a Some studies provided the mean of the fluoride content in the tap water, and other studies provided the range of the fluoride content.

^b ppm = parts per million.

^c NS = not stated (information not provided in the study).

^d Children were divided into groups according to the fluoride content in the tap water.

^e Children were divided into groups according to the mean fluoride content in the tap water.

^f Three groups of children were selected at random from "risk areas" according to the fluoride content in the water.

^g IFTD = Index of Fluorosis for Temporary Dentition, developed and adapted from Dean's Index by the investigator.

^h Children were divided into cohorts according to the fluoride content in the tap water.

content was reported at high levels in some areas of the city of Chihuahua (Table 1). In addition, fluoridated salt was being distributed in the state at that time, as confirmed by the authors (19). Knowledge of dental fluorosis issues was assessed in a group of dentists, and most of them were not aware of the amount of fluoride contained in the water supply. All of the dentists mentioned that they observed fluorosis in their patients, either frequently or regularly, and they described it as moderate or severe. Still, few reported using systemic fluoride.

In the city of San Luis Potosí, which is in the state of the same name, several studies (20–22) documented high fluoride contents in tap, well, boiled,

and bottled water. Grimaldo et al. (20, 21) conducted several studies in this state and reported that the prevalence of fluorosis was high. No calibration data were given in the articles. The first study (20) looked at 199 children who were grouped according to tap water fluoride content (Table 1). The fluoride concentration of tap and bottled water ranged from low to high: 61% of the tap water samples had more than 1.2 ppm, and the bottled water analyzed ranged from 0.33 to 6.97 ppm. In a second study (21), these authors grouped 352 children according to tap water fluoride content (Table 1). In this study, high fluorosis prevalence was associated with fluoride intake from both tap and bottled

water in roughly one third of all of the cases, according to the authors. This was shown by the high prevalence of dental fluorosis in the subgroup of children of high socioeconomic status; the fluoride content of their tap water was on average 0.9 ppm, but 80% of those children reported drinking bottled water (which was high in fluoride content). Among all the groups in San Luis Potosí the high prevalence of dental fluorosis was attributed to such sources of fluoride as beverages (including soft drinks and fruit juices), food cooked with polluted water (which is high in minerals, including fluoride), and boiled water. In addition, these researchers studied the effect that boiling of tap water had on its

fluoride content, and they reported that it increased its fluoride content dramatically. Nevertheless, they could not associate the use of just boiled tap water with the presence of fluorosis.

In another study done in the city of San Luis Potosí, Loyola-Rodríguez et al. (22) reported a high prevalence of dental fluorosis on deciduous teeth (Table 1). They studied 300 children selected at random from kindergartens located in three different "risk areas," according to the fluoride content in tap water. These investigators designed a special index for fluorosis in temporary teeth, with scores ranging from 0 to 4. They validated this index objectively by studying the fluoride concentrations in samples of exfoliated enamel, and they reported a significant correlation with the index. The investigators were calibrated (Kappa 0.90). The authors concluded that the high prevalence of dental fluorosis was the result of fluoride intake after birth. These investigators related grades of fluorosis to the concentration of fluoride in water, and they associated some of the severe fluorosis cases with the use of boiled water.

In the city of Durango, which is in the state of the same name, high concentrations of fluoride in water were found, and a high prevalence of dental fluorosis was reported (23). The researchers were trained but not calibrated to conduct the examinations. The investigators studied 333 children, who were placed into five groups according to the fluoride content in their

tap water (Table 1). In the group with the highest concentration of fluoride in water, all of the children presented dental fluorosis, and 59% of these were classified as moderate to severe cases. These authors stated that 35% of the children exposed to the highest fluoride concentration in water were at risk of losing teeth at an early age due to severe damage attributable to dental fluorosis. The mean community index of dental fluorosis (CIDF) (24) was calculated to be 1.49 for the five groups, which exceeds the limit of 0.6 recommended for public health purposes. These authors compared the 1.49 that they found with a CIDF of 1.42 obtained in 1982 for the city of Durango, and they suggested that the increase was due to a higher demand for water, resulting in the drilling of deeper wells, which contained higher fluoride concentrations.

In the city of Aguascalientes, in the state of the same name, Márquez-Algara (25) reported a high prevalence of dental fluorosis (Table 1). Severe to moderate dental fluorosis was found in 17% of this sample, and 44% of children were free of dental decay. Although this researcher did not analyze the fluoride content in tap water, he reported that in this city it ranged from 0.7 to 4.6 ppm, but the source of this information was not mentioned in the article. A fourth-year dental student who had been calibrated performed the exams, but specific information about the calibration procedure was not reported in the article.

Communities where the fluoride content in water was unknown, negligible, or optimal and where fluoridated salt was distributed

There are several studies on dental fluorosis prevalence in Mexico that have been conducted in communities where salt was distributed and where the tap water fluoride content was unknown or was within optimal levels (0.7 to 1.0 ppm). For example, Vallejos-Sánchez et al. (26) reported a moderate to high prevalence of dental fluorosis in the city of Campeche, which is in the state of the same name (Table 2). The Kappa value for interexaminer calibration was 0.85. Fluoridated salt was the main source of fluoride; the researchers did not provide any information about the fluoride content in the water supplies. Exposure to various sources of fluoride was described as the main reason for this fluorosis prevalence. In order of importance, these sources were: fluoridated dental toothpaste used before 3 years of age, fluoride self-application in the schools, and fluoride supplements.

In the city of Guadalajara, Jalisco, a moderate prevalence of dental fluorosis was reported by Espinosa-Fernández et al. (27, 28) in two schools located in different neighborhoods (Table 2). Training of examiners was conducted, but the article did not mention calibration for them. The authors found a prevalence of 33%. Although this prevalence did not justify the authors' claim, they stated that the city of

TABLE 2. Prevalence of dental fluorosis in Mexican communities where fluoridated salt was distributed and where the water fluoride content was unknown, negligible, or optimal

Community and state, altitude, (reference)	Sample size	Study date	Age of subjects (yr)	Index of dental fluorosis	Fluorosis prevalence (%)	Severe fluorosis (%)	Mean of fluoride content in tap water (ppm) ^a
Campeche, Campeche, 10 m (26) ^b	1 373	1997–1998	6–12	Dean's	51.9	0.3	NS ^c
Guadalajara, Jalisco, 1 540 m (27) ^d	530	NS	8–14	TF ^e	30.0	3.4	1.01
	410	NS	8–14		35.0	11.9	1.01

^a ppm = parts per million.

^b The authors did not give information on the fluoride content in salt or water.

^c NS = not stated (information not provided in the study).

^d The investigator studied two groups from schools located in different areas of the city.

^e TF = Thrylsup-Fejerskov Index.

Guadalajara should be declared an “endemic” area for dental fluorosis, apparently in an attempt to attract the attention of authorities. The fluoride content of tap water was reported as optimal. The authors confirmed that fluoridated salt was distributed freely in the state of Jalisco, but they did not provide evidence that it had had an impact on the prevalence of dental fluorosis that they found (27, 28).

Communities where altitude was associated with dental fluorosis, where fluoridated salt may have been distributed, and where the fluoride content in water was unknown, negligible, optimal, or above optimal

Of the 14 studies included in this review, 5 of them (1, 29–32) were conducted in areas where the altitude had been related to dental fluorosis prevalence (Table 3). Luengas-Aguirre et al. (1) studied the city of Tula de Allende, in the state of Hidalgo. The tap water

fluoride concentration was high, and the investigators reported very high fluorosis prevalence, 97.3%. Most of the fluorosis cases were considered moderate to severe. The authors suggested that this strikingly high prevalence of fluorosis could be due to factors affecting fluoride metabolism in these children, such as altitude, malnutrition, and climate. Training and calibration procedures were not mentioned in the article.

The same group of researchers later published further studies that were performed in the same city and in other communities in the state of Hidalgo (29, 30) (Table 3). In the first study (29) they still reported a very high prevalence of dental fluorosis for a city located at 2 066 m above sea level (the name of the city was not given in the article but it is assumed to be Tula de Allende), and the fluoride content in the tap water ranged from 2.40 to 3.30 ppm. In the second study (30) the tap water fluoride concentrations for the four communities that they studied ranged from low to high,

and the fluorosis prevalence was 90.0% or higher in all four. Consumption of fluoridated salt was not assessed. All examiners were trained and calibrated (Kappa 0.72). The participants’ residence from birth to 6 years of age was documented. Although the fluoride levels in the water were above optimal in three of the four communities, these authors associated the extremely high fluorosis prevalence with the fact that all these communities were located at a high altitude. The researchers reached that conclusion after comparing their results with results from other communities where tap water fluoride levels were similarly high.

Also in the state of Hidalgo, Molina-Frechero et al. (31) reported a very high prevalence of dental fluorosis in the town of Ixmiquilpan, which is at an altitude of 1 745 m. The fluoride concentration in tap water was low. The investigators attributed the high prevalence of fluorosis to the altitude, but they did not study other sources of fluoride. Calibration procedures were

TABLE 3. Prevalence of dental fluorosis in Mexican communities in which the altitude was associated with fluorosis, where fluoridated salt may have been distributed, and where the water fluoride content was unknown, negligible, optimal, or above optimal

Community and state, altitude, (reference)	Sample size	Study date	Age of subjects (yr)	Index of dental fluorosis	Fluorosis prevalence (%)	Severe fluorosis (%)	Mean or range of fluoride content in tap water (ppm) ^{a,b}
Tula de Allende, Hidalgo, 2 066 m (1)	151	NS ^c	6–14	Dean’s	97.3	21.8	2.83
NS, Hidalgo, 2 066 m (29) ^d	93	NS	10–12	Modified Dean’s	100.0	19.0	2.80
Santo Domingo Guzmán, Hidalgo, 2 567 m (30) ^e	83	NS	9–12	Modified Dean’s	90.2	0.0	0.55–0.60
Nexquipayac, Hidalgo, 2 300 m	71				97.0	2.0	1.20–1.60
Tenango, Hidalgo, 2 600 m	93				96.6	4.0	1.50–1.70
Tula de Allende, Hidalgo, 2 066 m	69				97.0	19.0	2.40–3.30
Ixmiquilpan, Hidalgo, 1 745 m (31)	94	NS	10–12	Dean’s	91.5	6.4	0.50
Mexico City, Federal District, 2 240 m (32)	44	NS	7–14	Dean’s	81.9	4.5	1.03 ± 0.23

^a Some studies provided the mean (± standard deviation when available) of the fluoride content in the tap water, and other studies provided the range of the fluoride content.

^b ppm = parts per million.

^c NS = not stated (information not provided in the study).

^d Information on the name of the city studied was not given in the article but we assumed it was the city of Tula de Allende because of the altitude specified.

^e In this study (30), four different cities in the state of Hidalgo with different altitudes and water fluoride concentrations were investigated.

performed as well as verification of residence and birthplace of children.

A study conducted in Mexico City, by Jiménez-Farfán and colleagues (32), found a high prevalence of dental fluorosis (Table 3). The fluoride content in tap water and in bottled water (mean of 1.08 ppm for bottled water) was reported as being within optimal levels. Of the children studied, 18% of them received fluoride supplements, 50% of them received topical fluoride treatments, and all of them had used fluoridated toothpaste from the age of 2 years. The researchers attributed the high level of fluorosis to altitude and toothpaste. However, the investigators did not mention how many samples of tap and bottled water were analyzed. In addition, fluoridated salt was being distributed at the time of the investigation, but its fluoride content was not analyzed. The investigators were trained and calibrated (Kappa 0.85), and they verified the residence and birthplace of the children.

DISCUSSION

There is relatively little information concerning the epidemiology of dental fluorosis in Mexico, and most of what has been published has appeared in nonrefereed local dental journals. Only 1 paper from the 24 publications found was published before 1990 (10). From the 14 reviewed publications that met the inclusion criteria, a high prevalence of dental fluorosis was reported in 12 of them (1, 17, 19–23, 25, 29–32). Two of the publications reported it as being in the low to medium range (26, 27). Most of the calculations of dental fluorosis were obtained through the use of convenience samples. Dental fluorosis was associated with the following reported risk factors: bottled water, soft drinks, and juices; excessive fluoride in water (deeper wells); boiled water; concurrent distribution of fluoridated salt in areas where tap water is above negligible in fluoride content; fluoride intake from meals prepared with fluoridated salt; living at a high altitude; living in a hot climate; and malnutrition. Also associated with

dental fluorosis was the use of fluoridated products, including the use of fluoridated toothpaste before 3 years of age, fluoride self-applications, the use of fluoride supplements, and visits to the dentist for fluoride applications. Eleven of the articles reported high water fluoride concentrations levels, that is, above 1.5 ppm.

From our assessment it was evident that a large amount of the published data may be questionable for use in determining if dental fluorosis constitutes a generalized problem in Mexico, mostly due to problems inherent in the design of many of the studies. Among these study shortcomings, two stand out: (1) the researchers failed to verify the residence of their study participants from birth to age 6 years (19, 25–27), and (2) the researchers did not record the residence of their participants at the time of examination (25–27). As a result it is not possible to determine if the fluorosis observed in these samples was a true reflection of the communities' prevalence levels. There could have been bias if some of the participants were not living in those communities when their fluorosis was developing and were thus not representative members of the communities. This makes it difficult to determine if the problem of dental fluorosis in Mexico is confined to specific areas or if it is becoming generalized. Adding to the doubts about the representativeness of the samples is the fact that many of the studies were conducted using convenience samples.

A third concern with the studies included in this review was that some kind of training of examiners was reported in all of them but that measurements of calibration were rarely reported. Fluorosis is a difficult condition to diagnose, even for the experienced examiner (24). This lack of information provided on the accuracy of the examiners who were determining fluorosis presence makes it difficult to know whether differences reported among regions or in time were a true reflection of the populations' differences in fluorosis prevalence or they were instead a reflection of differences in the examiners' assessments.

It is also difficult to compare the data due to the differences in the methodology used to collect them. Of the 14 studies reviewed, 12 of them (1, 17, 19–21, 23, 25, 26, 29–32) used the Dean's Index or its modification (18). One study (27) used the Thylstrup-Fejerskov Index (TFI) (33), and others (1, 25) supplemented the Dean's Index with the community index of dental fluorosis (24). This variety of indices makes direct data comparison difficult and at best unreliable. The apparent prevalence of fluorosis reported for a population can be influenced by factors other than true differences in fluoride exposure, such as differences in the methodology used to conduct the examinations. These differences, intrinsic in the design of the different indices used, may account at least in part for some of the difference observed among studies conducted at different times (in addition, some articles did not provide information on when the investigations were performed) or in different areas within communities or states in Mexico. Even when comparing prevalence results obtained using the same index, caution must be exercised (24). In addition, it must be kept in mind that fluorosis prevalence is directly influenced by the case definition used to calculate it. For example, the case definition for the Tooth Surface Index of Fluorosis is based on the tooth surface unit, while Dean's Index defines cases of fluorosis on the basis of individual teeth.

These various problems not only contributed to our difficulties in determining if dental fluorosis constitutes a generalized problem in Mexico, they also interfered with resolving whether or not there has been a recent increase in the fluorosis prevalence in the country. Nevertheless, a more important factor that precludes us from determining if fluorosis is indeed increasing in Mexico is the lack of available local historical prevalence data. Only 1 of the 24 articles that we obtained was published before 1990, with all the other studies being conducted after salt fluoridation was introduced nationally in Mexico in 1991. Direct comparisons of similar populations before and after salt fluoridi-

dation was introduced were not possible. Only one study concluded that fluorosis prevalence might be linked to the use of fluoridated salt; that was the Espinosa-Fernández et al. (27) article on the city of Guadalajara. However, the fluoridated salt probably did not have an impact in the Guadalajara sample because the distribution of that salt began when the children in the samples were old enough to no longer be susceptible to developing dental fluorosis. The fluorosis could have been due to other sources that were not studied.

The situation was clearer for the water fluoride determinations in the reviewed articles because that analysis had fewer methodological problems. Nevertheless, the issues of representativeness and generalizability of results still need to be considered. In all of the 14 reviewed studies, the analytical techniques that were described have been validated, and all of the studies that used these techniques described the internal quality control checks, indicating that the determinations were accurate. However, the water samples obtained in some studies (1, 17, 23, 25, 29–32) were not collected at random, again making it difficult to determine how representative their results were. The sources of water fluoride content were not always stated, or the information was not available.

The strongest evidence reported to date of a possible fluorosis problem in Mexico comes from the studies conducted in communities located at high altitudes. Epidemiological studies performed in the countries of Kenya and Tanzania have indicated that higher prevalence and severity of fluorosis may be related to high altitude, even when suboptimal concentrations of fluoride are present in the drinking water (34, 35). According to its 2000 census, Mexico had six large cities (that is, above 500 000 in population) and many smaller cities and towns that were located at 2 000 m above sea level or higher. Therefore, based on the results from the studies conducted in communities located at high altitude (1, 29–32), a difference might be expected in fluo-

rosis prevalence among populations in Mexico ingesting equivalent amounts of fluoride but living at different altitudes. One study (1) concluded that several factors, such as high altitude and malnutrition, might affect fluoride metabolism, thus increasing the risk of developing dental fluorosis.

The question of reliability has to be kept in mind when summarizing findings. However, it is possible to conclude that the results of the 14 studies we reviewed here have shown that some tap water supplies and some bottled water sold in Mexico are obviously above optimal in fluoride content. In the areas where this is true, fluorosis could be a public health problem.

Regardless of the fact that it is not possible to determine if the estimates of fluorosis prevalence in Mexico are a true reflection of the studied populations' prevalence levels, it cannot be ignored that high dental fluorosis was reported by 12 of the 14 reviewed studies. The few studies that have been conducted after the introduction of fluoridated salt in Mexico have shown that the prevalence of fluorosis was higher than what should be expected when compared to historical data from communities with optimal fluoridation in other countries. However, due to both the scarcity of the information and the methodological characteristics of the studies conducted in Mexico, it is not possible to conclude if fluorosis is a generalized public health problem in the country, nor is it possible to know if the prevalence of fluorosis is increasing.

In spite of this poorly defined epidemiological background, Mexico has a public health fluoridation program that operates nationally. As an alternative to water fluoridation, salt fluoridation is successfully used in several other countries throughout the world (36). In Mexico, salt fluoridation was developed and tested during the 1980s (10). It was implemented nationally in 1991 even though the program did not become official until 1995 (11). However, results of studies undertaken by health authorities to monitor urinary

fluoride excretion, conduct quality control audits, and determine fluorosis epidemiology trends have not been published. Results from at least one study have shown that the fluoride content in the salt available in Mexico was variable, either more or less than 250 ppm, which is the average concentration recommended by the Mexican Public Health Service (37).

When the fluorosis prevalence estimates from the studies reviewed in this article are compared with the availability of fluoridated salt, the results of the studies conducted in communities located at high altitudes are of particular concern. Several studies reported the distribution of fluoridated salt in areas where water fluoride is above optimal. Provisions are made in the regulations to avoid the distribution of fluoridated salt in the areas where water fluoride is above negligible, but the regulations do not consider the effect that altitude appears to have on fluoride metabolism and fluorosis prevalence, and no adjustments in the amount of fluoride added to salt are recommended for salt distributed in communities at high altitudes.

Systematic data collection on the prevalence of dental fluorosis has not been achieved in Mexico. Nevertheless, it could be argued that the small number of studies that have been conducted have found that most of the dental fluorosis reported in Mexico fell into the "mild" to "moderate" categories, which cannot be considered a public health problem, other than the aesthetic concerns. It could also be argued that specific problem areas have been identified and are addressed by the current regulations.

Official figures have not yet been published regarding salt fluoridation efficacy and toxicity in Mexico. As long as there is no comprehensive study of dental fluorosis that encompasses fluorosis prevalence and the general public's perceptions of this prevalence, it will be impossible to determine if dental fluorosis is a public health problem in Mexico and if it is increasing.

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Revisión de la prevalencia de fluorosis dental en México

RESUMEN

Objetivos. La prevalencia de fluorosis dental ha aumentado de forma alarmante en todo el mundo. El objetivo de este estudio fue analizar las investigaciones publicadas sobre la prevalencia de fluorosis dental en México, a fin de valorar si hay un aumento de esta prevalencia y si la fluorosis dental constituye un problema de salud pública en el país.

Métodos. Se examinaron los artículos de corte clínico, experimental y de revisión publicados en varias bases de datos bibliográficas dedicadas a la literatura científica, utilizando "fluorosis y Mexico" para hacer la búsqueda. Para incluirse en el estudio, los materiales identificados tenían que satisfacer ocho criterios específicos adicionales.

Resultados. De los 24 artículos identificados en la búsqueda bibliográfica, 14 cumplieron todos los criterios de inclusión. La prevalencia de fluorosis dental informada para México fue de 30 a 100% en zonas donde el agua era fluorada de manera natural y de 52 a 82% en zonas donde se consumía sal fluorada. La mayoría de los 14 estudios se realizaron en áreas donde el nivel de fluoruros en el agua era superior al óptimo y los casos de fluorosis informados en esos artículos se clasificaron entre "moderados" y "graves". Desde que se introdujo la fluoración de la sal en México en 1991 se han informado muy pocos casos de fluorosis dental. Sin embargo, en algunos de estos estudios se encontraron prevalencias mayores que las esperadas, si se tienen en cuenta los datos históricos de comunidades con fluoración óptima en otros países.

Conclusión. Debido a lo limitado de la información no es posible determinar si hay un aumento de la prevalencia de fluorosis dental en México o si esta afección constituye un problema de salud pública. Para responder objetivamente a estas interrogantes se requieren estudios más controlados en zonas donde se distribuya sal fluorada, donde los niveles de fluoruros en el agua sean superiores al óptimo y en poblaciones situadas a mayor altura sobre el nivel del mar.

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