

Caries and fluorosis in the Santiago metropolitan region in Chile: The impact of the fluoridation of the water

Cárie e fluorose na região metropolitana de Santiago, Chile: impacto da fluoretação da água

Abstract

Purpose: To assess the damage and the prevalence of caries and fluorosis in children and adolescents in the metropolitan area after 8 years of drinking water fluoridation and to compare them with the baseline study.

Methods: This was a prevalence study. The sample was selected using two-step probability sampling and stratified according to socioeconomic level. Subjects included 2,323 schoolchildren aged 6 to 8 years and 12 years living within the metropolitan region. The parents of all students provided consent and were previously included in the study. The subjects were clinically examined by calibrated dentists, who used World Health Organization (WHO) screening criteria and indicators to determine the presence of caries and dental fluorosis.

Results: No cavity damage was found in 23.68% of the children. The average dmft was 3.18 for children aged 6 to 8 years. The DMFT was 0.59 in children aged 6 to 8 years and 2.6 in children 12 years compared with the baseline study. These differences were statistically significant. There were also significant differences in the DMFT index for each socioeconomic status group. The average number of dams was higher among children of low socioeconomic status. Of the studied children, 14.3% of children had dental fluorosis. Fluorosis was very mild in 12.35% of the cases, mild in 1.98% and moderate in 0.26%. There were no cases of severe fluorosis (classified according to Dean's index).

Conclusion: We conclude that after 8 years drinking water fluoridation in the metropolitan area, the number of children with no history of caries has increased by approximately 100%. The number of cases significantly affected by caries has also decreased significantly. The incidence of dental fluorosis has increased, but to milder degrees.

Key words: Dental caries; dental fluorosis; cross-sectional study; water fluoridation

Resumo

Objetivo: Avaliar o dano e a prevalência de cárie e fluorose em crianças e adolescentes na região metropolitana do Chile, após oito anos de fluoretação da água potável, em comparação com o estudo de base em 1996.

Metodologia: Desenho: estudo de prevalência. A amostra probabilística, estratificada por nível socioeconômico, constituiu-se de 2.323 escolares de 6-8 e 12 anos na Região Metropolitana. Todos os alunos foram clinicamente examinados por dentistas calibrados, utilizando critérios de seleção e indicadores propostos pela OMS para determinar cárie e fluorose dentária.

Resultados: Cerca de 24% das crianças estavam livres de cáries. A média de CPOD foi de 3,18 em escolares de 6 a 8 anos. O CPOD foi de 0,59 em crianças de 6 a 8 anos e de 2,6 em crianças de 12 anos em relação ao estudo de base, sendo essas diferenças estatisticamente significativas. Houve diferenças significativas devido ao nível socioeconômico, sendo que os valores médios foram maiores em crianças de baixo nível socioeconômico. Cerca de 14% das crianças apresentaram fluorose dentária, em geral de grau muito leve.

Conclusão: Após 8 anos de fluoretação da água potável na região metropolitana, observou-se um aumento de 100% de crianças sem história de cárie e significativa diminuição de danos. A fluorose dentária aumentou, mas em graus mais leves.

Palavras-chave: Cárie dentária; fluorose dentária; estudo transversal; fluoretação da água

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Introduction

Dental caries is a multifactorial infectious disease that affects most people in both industrialized and developing countries (1). The principal public health measure taken to prevent dental caries is water fluoridation (2). Fluoride (F-) reduces the incidence of dental caries and delays or reverses the progression of incipient lesions. It has been an important factor in reducing the incidence and severity of dental caries (1).

Because fluoride has been added to the drinking water in Santiago, Chile, since 1996, it has been necessary to evaluate the water's fluoride levels. A considerable amount of fluoride can prevent and eliminate dental caries. However, fluoride consumed during tooth development can also create a range of visible changes. These changes are known as enamel fluorosis, and their extreme expressions are aesthetically unpleasant (3). Severe fluorosis only occurs when children consume excess fluoride during critical periods of tooth maturation (4). That is to say, the risk of enamel fluorosis is limited to children younger than 8 years old because the enamel is very vulnerable before it reaches pre-eruption maturity (5). Considerable controversy surrounds the use of F- in drinking water to control dental caries (6). It is generally agreed that F- effectively controls dental caries and decreases its incidence (7). However, its critics have pointed to some harmful side effects. Many of these effects are related to abnormalities in mineralized tissues (including dental fluorosis) that result from the accumulation of fluoride in the hard tissue (8).

Normally, enamel fluorosis has been seen as a reasonable trade-off for the substantial protection against dental caries provided by an optimal concentration of natural or introduced fluoride (5). In Chile, despite the existing controversies, more than half of the population lives in communities whose drinking water contains F- concentrations regulated at the optimum values established by the country (9).

The prevalence and severity of dental caries in developed and developing countries have been substantially reduced after such preventive measures as drinking water fluoridation have been adopted. Furthermore, the increased use of topical fluoride use has increased the incidence of dental fluorosis. Consequently, this study aimed to document the prevalence and severity of dental caries and the presence of fluorosis in the Santiago metropolitan region after eight years of fluoridation.

Methods

Study design and sample

The study employed a probabilistic design that was two-phased and stratified by socioeconomic level, in accordance with the Commune Poverty Ranking established in the 2003 CASEN survey. The sample was composed of 2,323 children attending school in 26 different fluoridated urban communities in the metropolitan region. Of these participants, 1,757 children were between the ages of 6- to 8-years-old, and 566 were 12-years-old. This study was approved by the Ethics Committee of the Faculty of Dentistry of the University of Chile, and the parents of all children agreed to their participation in the study and signed an informed consent form. This study was conducted between 2005 and 2006. Table 1 shows the distribution of the children by age, sex and socioeconomic level.

Clinical evaluation

The prevalence of dental caries and the number of caries-free children was determined using the World Health Organization (WHO) methodology for epidemiological studies described in the *Health Survey Basic Methods*, Fourth Edition, Geneva, 1997 (10).

The dmft index was used to determine the frequency of decayed (d), filled (f) and missing (m) teeth due to dental caries in primary teeth. The DMFT index was used for permanent teeth.

The Dean index was used to quantify the prevalence and severity of dental fluorosis. The Russell criterion was used to differentiate fluorosis from other diseases or defects of the dental enamel. An excerpt from "Dental fluorosis. Codes and criteria for its diagnosis of the Oral Health Survey Basic Methods. 4th Edition, Genoa. 1997" was used (10).

Calibration of dental caries and medical examination

The four examiners were trained by the project advisor regarding the forms, codes and diagnostic criteria used in the study. Oral examinations were performed in a classroom, with the children lying on a desk. Light was provided by a desk lamp with a 100-watt bulb, and the surgeon stood behind the patient's head (12 o'clock position). A group of 10 patients was examined twice by the same examiner on alternate days. Before the clinical examination, the children

Table 1. Distribution of the study population by age, sex and socioeconomic level.

Age (years)	Sex				Socioeconomic level						Total	
	Male		Female		High		Middle		Low		n	%
	n	%	n	%	n	%	n	%	n	%		
6 to 8	858	48.83	899	51.17	323	18.38	571	32.49	863	49.13	1757	100
12	270	47.70	296	52.30	75	13.25	210	37.10	281	49.65	566	100
Total	1128	48.56	1195	51.44	398	17.13	781	33.62	1144	49.25	2323	100

were asked to brush their teeth. The statistical calibration study showed kappa coefficients of 0.90 for interexaminer agreement and 0.90 for intraexaminer agreement.

Calibration of Fluorosis Assessment

During this stage, 30 children between the ages of 6- to 12-years-old with different degrees of fluorosis, as determined by the Dean index, were examined with and without dental light. The statistical calibration study showed a Kappa coefficient of 0.86 for interexaminer agreement. For the intraexaminer calibration, the Kappa test concordance was significant ($P < 0.001$).

Determination of Fluoride Concentrations in Water

Drinking water was collected by the researchers during the visits, in two different phases. These samples were stored in a cooler with ice at temperatures near ± 4 °C. The fluoride in water was determined potentiometrically with an ion-specific electrode, according to the technique described by Villa (11) and modified by Yévenes et al. (12). Five milliliters of filtered water were added to 5 ml of TISAB II and read directly with a previously calibrated ion meter. Readings were obtained as mg/L (parts per million [ppm]) of fluoride.

Results

The average fluoride concentration measured in water samples obtained from the schools of different communities showed a value $0.58 \text{ ppm} \pm 0.013$.

Table 2 indicates that 24.62% of children were caries-free, including 25.38% of the 6- to 8-year-old group and 22.26% of the 12-year-old group. The difference between the age groups was not statistically significant ($P > 0.05$).

The distribution of caries-free children according to socioeconomic level revealed that the caries-free percentage was significantly different for the three socioeconomic levels, with the highest percentage of caries-free children in the higher stratus ($P < 0.05$) (Table 3).

In the 6- to 8-year-old group, the DMFT index was $0.59 (\pm 1.1)$. All the DMFT elements were significantly lower in this group than in the 12-year-old group, which had a DMFT index of $2.56 (\pm 2.4)$ ($P < 0.05$). The DMFT scores showed an increasing trend with age. The proportion of decayed (D), missing (M) and filled (F) teeth was 0.37, 0.21 and 0.01, respectively, for the 6- to 8-year-old group and 1.10, 1.36 and 0.10 for the 12-year-olds. In contrast, the dmft index was higher among the 6- to 8-year-old children ($3.16 [\pm 2.9]$) than the 12-year-olds ($0.23 [\pm 0.8]$). The differences between the groups were significant ($P < 0.05$). The components of dmft index were 1.49 (d), 0.16 (m) and 1.51 (f) for the 6- to 8-year-olds and 0.10, 0.03 and 0.1 for the 12-year-olds.

In terms of socioeconomic level, significant differences were found in the DMFT indexes of the 6- to 8-year-olds in different socioeconomic strata ($P < 0.05$). Children in the lower stratus had the highest DMFT values ($P < 0.05$). Only children in the highest stratus showed no evidence of tooth loss. For the primary teeth, the dmft index showed significant differences between the socioeconomic levels ($P < 0.05$),

Table 2. Percentage of caries-free children by group (ages 6- to 8-years-old and 12-years-old).

	6- to 8-years-old		12-years-old		Total	
	n	%	n	%	n	%
Caries free	446	25.38	136	22.26	572	24.62
With history of caries	1311	74.62	440	77.74	1751	75.38
Total	1757	100	566	100	2323	100

Table 3. Percentage of caries-free children 6- to 8- years and 12-years-old, according to socioeconomic level.

	Socioeconomic level	6- to 8-years-old			12-years-old		
		n Dental caries free	% Dental caries free	Total	n Dental caries free	% Dental caries free	Total
Socioeconomic level	High	103	31.89	323	25	33.33	75
	Middle	163	28.55	571	44	20.95	210
	Low	180	20.86	863	57	20.29	281
	Total	446	25.38	1757	126	22.26	566

Table 4. Dental caries history of permanent teeth in 6- to 8-year-old and 12-year-old children grouped according to socioeconomic level.

Age	Socioeconomic level	D	M	F	DMFT	SD	d	m	f	dmft	SD	n
6 a 8	High	0.20	0.90	0.00	0.29	0.8	1.10	0.09	1.10	2.29	2.7	323
	Middle	0.37	0.15	0.01	0.53	1.1	1.46	0.17	1.20	2.80	2.9	571
	Low	0.42	0.30	0.01	0.73	1.2	1.63	0.18	1.79	3.60	2.9	863
12	High	0.68	1.06	0.00	1.74	3.4	0.14	0.01	0.08	0.23	0.7	75
	Middle	0.93	1.40	0.08	2.41	0.4	0.10	0.03	0.11	0.24	0.8	210
	Low	1.30	1.40	0.10	2.80	0.4	0.14	0.04	0.11	0.29	0.8	281

SD = Standar Desviation; n = number of examined children

with the lowest stratus presenting the highest values. This was also true for incidence of diseased teeth (value d). At the same time, the 12-year-olds in the lower stratum had higher values than the 6- to 8-year-olds ($P<0.05$), as expected. The 12-year-old group's history of dental caries in the primary teeth was higher in the lowest stratus; however, these differences were not significant in relation to the other socioeconomic levels ($P>0.05$) (Table 4).

Table 5 shows that 69.87% of the children did not present dental fluorosis, and 30.13% presented dental fluorosis that corresponded to the "questionable" and "very slight" categories. Very few cases exhibited mild and moderate levels of fluorosis, and no severe cases were found. It was not possible to register dental fluorosis in children whose upper incisors had not yet erupted; consequently, the number of children in each socioeconomic status group differed from the numbers for each group shown in the dental caries tests.

Analyzing the results according to age revealed a significantly higher ($P<0.05$) fluorosis prevalence in the 6- to 8-year-olds (32.27%) compared with the 12-year-olds (23.5%). When analyzed according to socioeconomic levels, the fluorosis results showed that children in the low stratus (24.48%) presented lower values than children in the middle (35.6%) and high strata (35.68%). This was a statistically significant difference ($P<0.05$). These values were unexpected results of the analysis (Table 6).

Discussion

Caries prevalence

The present study showed a significant decrease in the prevalence of dental caries associated with the fluoridation of the regional water supply. The study described a 25.38% prevalence of caries-free 6- to 8-year-olds, compared with 12.6% in the study by Urbina et al., Metropolitan Region – 1996 (13). These results also showed a decrease in the caries-free prevalence among 12-year-olds (22.26% in the present study, compared with 10.8% in the 1996 study) (13).

Internationally, a 2004 study in Brazil showed a higher prevalence of dental caries in 5-year-olds (60%) compared with the present study (14). However, better results were obtained in 2000 in Switzerland, where 48% of 7-year-old children and 59% of 12-year-old children were caries-free (15). Such differences can be attributed to cultural, social, economic and technical factors.

The average number of caries-free children in both age groups examined in the present study differed significantly among the three socioeconomic levels. The highest stratus children had the greatest percentage of caries-free children. National and international studies have shown significant differences in the caries-free status of children at different socioeconomic levels (13).

Table 5. Dental fluorosis prevalence and severity in 6- to 8-year-old and 12-year-old children in the Santiago metropolitan region, Chile.

Level	6- to 8-years-old		12-years-old		Total	
	n	%	n	%	n	%
Normal	1,190	67.73	433	76.50	1,623	69.87
Questionable	287	16.33	74	13.07	361	15.54
Very Light	234	13.32	53	9.36	287	12.35
Light	41	2.33	5	0.88	46	1.98
Moderate	5	0.28	1	0.18	6	0.26
Severe	0	0.00	0	0.00	0	0.00
Total	1,757	100	566	100	2,323	100

Table 6. Dental fluorosis prevalence and severity in all children according socioeconomic level (Santiago metropolitan region).

Grade	Socioeconomic Level							
	High		Middle		Low		Total	
	n	%	n	%	n	%	n	%
Normal	256	64.32	503	64.40	864	75.52	1,623	69.87
Questionable	92	23.11	121	15.49	148	12.94	361	15.54
Very Light	46	11.56	128	16.39	113	9.88	287	12.35
Light	1	0.25	26	3.33	19	1.66	46	1.98
Moderate	3	0.76	3	0.38	0	0.00	6	0.26
Severe	0	0.00	0	0.00	0	0.00	0	0.00
Total	398	100	781	100	1,144	100	2,323	100

Caries severity

Caries severity was reflected by a DMFT index of 0.59 for 6- to 8-year-old children, which was lower than the value Urbina et al. described in 1996 (13). In 1996, before the fluoridation of the public water supply began, the DMFT index was 1.10 in the metropolitan area. A comparison of these values shows a 50% decrease in caries severity. For primary teeth, the dmft index in the present study was 3.16, compared with the 1996 (13) value of 4.29. This indicates a nearly 30% decrease in the history of dental caries, with a very significant reduction in decayed teeth and teeth indicating missing or filled teeth.

The caries history and severity results for the 12-year-old children in the present study were lower than those described in 1996 (13) (DMFT index=3.13). However, the global dental caries situation reflected by the DMFT index (2001) showed that the estimated global average was 1.74, and 70% of the countries included had an index ≤ 3 . Although the present study shows that the DMFT values have decreased in the metropolitan area since fluoridation began, they remain higher than the worldwide average.

In the present study, the total dmft index was 0.23 for the 12-year-old children, which is lower than the 1996 (13) value of 0.32. Our result was in the line with previous studies that showed that fluoride in drinking water decreases the caries index in children (16,17). The dmft index values obtained in the metropolitan region were higher than the index value of 2.45 for 7-year-olds found in Zurich in 2000.

The analysis of the children's dental caries history in relation to their socioeconomic level revealed an inverse relationship between the DMFT index and socioeconomic status. The same was true for the dmft index ($P < 0.05$), the highest value of which was found in the lowest socioeconomic stratum. This difference between socioeconomic levels has been reported in the literature (13,16,18). Moreover, a recent study (2010) found that socioeconomic level and fluoridation status were the strongest predictors of primary caries (19).

Dental fluorosis

The prevalence and severity study of dental fluorosis in 6- to 8- and 12-year-old children in the Santiago metropolitan region showed the following results: 69.67% of children did not present fluorosis, and 30.33% of the children who presented fluorosis fell into the "questionable" or "light" categories.

Compared with the results reported in previous publications, data from the year 1996 showed a low prevalence of 3.7%. When evaluating the literature, Fomon et al. (20) indicated that dental fluorosis had increased in the United States over the last 30 years in communities with fluoridated water as well as those with nonfluoridated water; infant feeding practices and the production of

fluoridated products for infants and young children have modified the fluoride intake. The study's authors predicted that dental fluorosis and the prevalence of enamel fluorosis will continue to increase unless intervention measures are established.

In a United States study conducted between 1999 and 2002, Beltran-Aguilar et al. (21) noted that light dental fluorosis was observed in 32% of the 6- to 39-year-old population, along with a 9% increase in the fluorosis prevalence.

The 1996 data for the Santiago metropolitan region (13) show a low prevalence of dental fluorosis (4.2% of 6- to 8-year-olds and 2.3% of 12-year-olds). The current data indicate an increase in the prevalence of dental fluorosis to 32.53% of 6- to 8-year-olds and 23.53% of 12-year-olds, for a total prevalence of 30.33%.

Our analyses revealed differences in the prevalence and severity of dental fluorosis in the Santiago metropolitan region according to socioeconomic level. Children in the low stratus presented lower values, followed by higher values in the middle and the highest values among children in the high stratus. The differences between socioeconomic strata were statistically significant ($P < 0.05$).

The NHANES 1999-2002 (United States) report showed that the highest socioeconomic class presented a higher average of dental fluorosis, usually in the "questionable" category (21). The increase in "moderate" fluorosis in recent years was attributed to children's cumulative fluoride intake during the dental development phase, although the severity of dental fluorosis depends not only on the dose, but also on the timing and duration of fluoride consumption (22). However, it is believed that water fluoridation is not the major cause of fluorosis (23). This is why countries that use drinking water fluoridation, such as the United States, have a fluorosis prevalence of 22% among 9- to 19-year-olds, with most cases belonging to the "light" or "very light" category and only 1% representing the "moderate" or "severe" category (24).

When we analyzed the fluorosis prevalence, we found a significant increase in the metropolitan region, which was an expected result of the increase of the fluoride in the drinking water from 0.21 mg/L (25) to 0.60 mg/L. However, the resulting increase in fluorosis severity for both studied age groups is generally accepted as a reasonable consequence and of minor importance, given the substantial protection against dental caries provided by drinking water containing an optimal fluoride concentration.

Conclusions

After eight years of water fluoridation in the metropolitan region of Chile, the prevalence and severity of dental caries has decreased; however, the presence of fluorosis has increased (Table 7).

Table 7. Comparison of data on the impact of water fluoridation.

Year	Water % F-mg/L	% Dental caries free	6- to 8-years-old			12-years-old			
			dmft	DMFT	% fluorosis	% Dental caries free	dmft	DMFT	% fluorosis
1996*	0.21	12.6	4.29	1.10	4.2	10.8	0.32	3.13	2.3
2006	0.60	24.7	3.16	0.59	32.27	22.3	0.23	2.56	23.5

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