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Danilo Bonadia Catani[I]

Fernando Neves Hugo[I]

Silvia Cypriano[II]

Maria da Luz Rosário de Sousa[I]

Jaime Aparecido Cury[I]

Relationship between fluoride levels in the public water supply and dental fluorosis

ABSTRACT

OBJECTIVE: To assess the prevalence of dental fluorosis among schoolchildren subjected to different fluoride concentrations in the public water supply of their cities.

METHODS: The sample comprised 386 seven-year-old schoolchildren living in two municipalities in the State of São Paulo that practiced external control over the fluoridation of the water from 1998 to 2002: one with homogenous fluoride concentration and the other with oscillating concentration. Dental fluorosis was determined by dry examination of the upper permanent incisors using Dean's index. Scores classified as questionable were considered to represent fluorosis. Sociodemographic variables and questions regarding oral health were assessed using a structured questionnaire sent to the children's parents or the adults responsible for these children. Correlates of fluorosis were assessed using multivariate logistic regression ($p<0.05$).

RESULTS: Both municipalities presented a mild degree of fluorosis. The prevalence of fluorosis in the municipality with oscillating fluoride content in the water was 31.4%, and it was 79.9% in the municipality with homogenous fluoride content. The prevalence of fluorosis was associated with the municipality with homogeneous fluoride levels in the water (OR=8.33, 95% CI: 5.15;13.45) and with not owning a car (OR=2.10, 95% CI: 1.27;3.49).

CONCLUSIONS: The prevalence of dental fluorosis was higher in the city with better control of fluoride levels in the water supply, however, this higher prevalence was not related with children's satisfaction with the appearance of their teeth.

KEY WORDS: Fluorosis, dental, epidemiology. Fluorosis, dental, prevention & control. Child. Water supply, analysis. Fluoridation.

INTRODUCTION

Fluoridation of the public water supply is still an important public health measure in many countries.[20]

Since the discovery of the importance of adding fluoride in water treatment for reducing the prevalence of caries at population level,[9] its risks in terms of dental fluorosis development have been minimized through maintaining a so-called "optimal" concentration of fluoride in water.[17] This concentration depends on the temperature in the environment and, for most Brazilian regions, it is set at 0.7 ppm F (mg F/L), with a tolerance ranging from 0.6 to 0.8.* Thus, concentrations

[I] Faculdade de Odontologia de Piracicaba. Universidade Estadual de Campinas. Piracicaba, SP, Brasil

[II] Faculdade de Odontologia. Pontifícia Universidade Católica de Campinas. Campinas, SP, Brasil

Correspondence:
Maria da Luz Rosário de Souza
Faculdade de Odontologia de Piracicaba
Av. Limeira, 901, Cx. Postal 52
13414-903 Piracicaba, SP, Brasil
E-mail: luzsousa@fop.unicamp.br

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above 0.6 would ensure the benefits of caries reduction, while it would be important not to exceed 0.8 in order to maintain acceptable levels of dental fluorosis. This situation makes operational control essential, and this is implemented by the municipal sanitation company in order to assure the quality of the water provided to consumers, as required by the legislation.[13]

Dental fluorosis is a deficiency in tooth enamel mineralization caused by daily intake of fluoride during tooth development.[1] Since there is a linear dose-response relationship in dental fluorosis,[7] the consequences depend on the fluoride concentration and the length of time for which this concentration remains constant in tissue fluids during tooth enamel mineralization. Thus, the prevalence of dental fluorosis in populations supplied with fluoridated water will depend on the length of time for which a given concentration is kept constant during tooth development. However, epidemiological data on this matter are still scarce in the literature.

There has been increasing prevalence of dental fluorosis over recent decades, both in cities with and without fluoridated water, because of the widespread use of other forms of fluoride.[3] Prevalences of 54% and 23% have been described in the permanent incisor teeth of children aged 8-9 years old living in communities supplied with fluoridated and non-fluoridated water, respectively.[16]

Thus, the objective of the present study was to investigate the prevalence of dental fluorosis among schoolchildren in two municipalities that had different standards with regard to controlling the optimal fluoride concentration in the water supplied to the population.

METHODS

This cross-sectional study was carried out in 2004, among a population sample composed of seven-year-old schoolchildren who were enrolled in public and private schools in two municipalities in the State of São Paulo. The results from the external control over the fluoride concentrations in the water of these municipalities between 1998 and 2002 were known only to one of the author of this study, thus ensuring that the study was conducted in a blind manner.

The inclusion criteria for the children in the study were that they had to have lived in the municipality since birth; had to present at least 50% of their homologous permanent upper incisors erupted; and had to have been authorized to take part in the study by their parents, by means of signing a free and informed consent form.

The sample size was calculated on the basis of the previous estimate of the prevalence of fluorosis from the World Health Organization,[15] and accepting losses of 20%, which resulted in 924 children. The sample was selected by a systematic randomized sampling method, from lists furnished by the teaching institutions.

The examinations were performed by four dentists who were public employees in the municipalities where the study took place. They underwent prior training consisting of theoretical discussions, slide presentations and oral examinations in order to characterize the different degrees of fluorosis. The children who took part the training for the dentists (N=80) did not form part of the final study sample. The inter-examiner concordance among the team, during the calibration period, ranged from 90% to 100%, with kappa coefficients of 0.6 to 1.0. The intra-examiner concordance ranged from 88% to 100%, with kappa coefficients of 0.6 to 0.8.

The examinations were performed in August and September 2004. Children were analyzed under artificial lighting, after supervised toothbrushing. The teeth were isolated and allowed to dry for at least 100 seconds before defining the degree of fluorosis using the Dean Index.[19] The criterion used to define prevalent fluorosis was the presence of questionable, very mild, moderate or severe degrees of fluorosis in at least one of the teeth examined. In each municipality, 10% of the sample was re-examined in order to assess the reliability of the data, and among these, the intra-examiner concordance ranged from 89 to 94%, with kappa coefficients of 0.7 to 0.9.

A questionnaire was applied to the parents or other adults responsible for the children, to investigate the fluoride intake from sources other than the fluoridated water supply and to obtain sociodemographic and other variables. The following were investigated: parents' professional occupation, parents' schooling (up to eight years, from eight to 12 years, or more than 12 years), number of people living in the home, household status (owned, rented, assigned or lent), ownership of a computer and a car (yes or no), visit to the dentist during the year prior to the study (yes or no), reason for that visit (routine or maintenance visit, motivated by pain, motivated by dental caries, or other reasons), fluoride intake from other water sources (filtered water, bottled water, water taken from a well, or other sources), daily frequency of toothbrushing, amount of toothpaste used when toothbrushing (one third of the length of the bristles, half of the length of the bristles, or the full length of the bristles), consumption of fluoride supplements during pregnancy (yes or no), guidance received regarding oral hygiene (yes or no), socioeconomic level (improved, stable or worsened over the year prior to the study) and family income. In addition, at the time of the examination, the schoolchildren were asked how they rated their own oral health (liked or disliked). The ethnic group was assessed by the examiner, using the criteria recommended by the *Instituto Brasileiro de Geografia e Estatística* (IBGE – Brazilian Institute

for Geography and Statistics): yellow, white, black or *pardo*. This variable was later dichotomized into whites or non-whites (yellow, *pardo* and black) to enable the statistical analysis.

Among the schoolchildren examined, 92% came from public schools and 8% from private schools. In each municipality, 462 children were selected for the sample, comprising 924 participants. Of these, 17 were not present on the day of the examinations and 521 did not fulfill the inclusion criterion of having lived in the municipality since birth or their parents or the other adults responsible for them had not answered the questionnaire. Thus, out of the probabilistic calculated sample, only 386 children (42%) were examined and made up the final sample for the study. There were 172 from the municipality with oscillating fluoride levels and 214 from the municipality with homogenous fluoride levels in the water.

The data on the fluoride concentrations in the public water supply were obtained monthly from representative collection points, covering the period from 2001 to 2002. Both municipalities used fluorosilicic acid for fluoridating their public water supplies. The external control data available regarding fluoride levels in the two municipalities presented different dosage patterns over this period. These data were provided by the Oral Biochemistry Laboratory of the Faculdade de Odontologia de Piracicaba, of Universidade Estadual de Campinas.

One of the municipalities, in which 98.9% of the dwellings were supplied with treated water, presented sample homogeneity that was within the sanitary surveillance standards of the State of São Paulo (ranging from 0.6 to 0.8 ppm F). In the other municipality, 96.5% of the homes were supplied with water, but there was a large variation in concentrations, from 0.3 to 1.2 ppm F. This variation was not in accordance with the lower and upper fluoride concentrations that are considered optimal by Brazilian legislation. It is suggested that such problems may have also occurred in previous years, which could not be evaluated precisely due to insufficient sampling.

The categorical variables were evaluated using the Chi-square test and continuous variables were evaluated using Student's t test or the Mann-Whitney test. The value for rejecting the null hypothesis was set at $p \leq 0.05$.

The statistical analysis was carried out using the SPSS 12.0 software. All independent variables with $p \leq 0.25$

Table 1. Distribution of schoolchildren according to sociodemographic characteristics and frequency of fluorosis. Municipalities in the State of São Paulo, 2004.

Variable	Category	Municipality with oscillating fluoride levels		Municipality with homogenous fluoride levels		p
		%	N	%	N	
Sex	Male	44.8	77	44.4	95	0.98
	Female	55.2	95	55.6	119	
Ethnic group	White	69.2	117	23.4	50	0.00
	Non-white	30.8	52	76.6	164	
School	Public	93.0	162	90.2	193	0.21
	Private	7.0	10	9.8	21	
Father's profession	Non-manual	25.0	40	19.6	36	0.28
	Manual	75.0	120	80.4	203	
Mother's profession	Non-manual	20.5	33	22.0	44	0.83
	Manual	79.5	128	78.0	156	
Socioeconomic level	Maintained or improved	73.9	122	74.2	155	0.96
	Worsened	20.1	43	25.8	54	
Fluorosis	Normal	68.6	118	20.1	43	0.00
	Questionable	7.0	12	6.1	13	
	Very mild	17.4	30	55.6	119	
	Mild	7.0	12	15.9	34	
	Moderate	-	-	2.3	5	
	Severe	-	-	-	-	

Table 2. Bivariate analysis on demographic, economic, social and behavioral characteristics associated with fluorosis among schoolchildren. Municipalities in the State of São Paulo, 2004.

Variable	Dental fluorosis		Unadjusted OR (IC 95%)	p
	Absent (N)	Present (N)		
Municipality				0.00
With oscillating fluoride levels	118	54	1.00	
With homogenous fluoride levels	43	171	8.69 (5.47;13.82)	
Ethnic group				0.00
White	94	73	1.00	
Non-white	63	151	3.09 (2.02;4.72)	
Car ownership				0.10
Yes	93	102	1.00	
No	32	120	1.37 (0.95;1.96)	
Computer ownership				0.10
Yes	40	41	1.00	
No	117	184	1.53 (0.94;2.51)	
Father's profession				0.51
Non-manual	35	41	1.00	
Manual	112	156	1.19 (0.71;1.98)	
Mother's profession				0.19
Non-manual	37	40	1.00	
Manual	112	172	1.42 (0.86;2.36)	
Father's schooling				0.43
9 years or more	60	85	1.00	
Up to 8 years	82	109	0.94 (0.61;1.45)	
Mother's schooling				0.53
9 years or more	67	97	1.00	
Up to 8 years	76	109	0.99 (0.65;1.52)	
Reason for last visit to dentist				0.06
Routine/maintenance	77	88	1.00	
Caries or pain	40	73	1.60 (0.98;2.61)	
Type of water most frequently consumed by the child				0.92
From the public supply	83	117	1.00	
Bottled, from a well or other sources	77	104	0.96 (0.64;1.44)	
Does your child drink tea?				0.89
No	126	174	1.00	
Yes	30	40	0.97 (0.57;1.63)	
Does anyone supervise your child's toothbrushing?				0.35
Yes	125	183	1.00	
No	34	38	0.76 (0.46;1.28)	
Amount of toothpaste used by your child when toothbrushing				0.61
Up to 1/3 of the bristles	37	45	1.00	
Half of the bristles or more	116	165	1.17 (0.71;1.92)	
Did the mother use fluoride supplements during pregnancy?				0.65
No	27	24	1.00	
Yes	15	17	1.27 (0.53;13.09)	
Have you received any oral hygiene advice?				0.06
Yes	128	157	1.00	
No	32	63	1.60 (0.99;2.61)	

in the bivariate analyses, and also those variables with clinical-epidemiological relevance according to data in the literature were candidates for the multivariate model and were analyzed using the Enter method (10). The variables that were not significantly associated with the outcome ($p<0.25$) were eliminated and a new model was calculated. This new model was always compared with the previous one using the likelihood ratio test. Unadjusted and adjusted odds ratios (OR) are shown with the respective 95% confidence intervals (95% CI).

RESULTS

The prevalence of fluorosis found in the municipalities with oscillating and homogenous fluoride levels in the water supply were 31.4% and 79.9%, respectively.

In Table 1, the characteristics of the samples from the two municipalities were similar, with the exception of the variable of ethnicity: in the municipality with oscillating levels, the percentage of white schoolchildren was greater (69.2%) than in the municipality with homogenous levels (23.4%), and this difference was statistically significant ($p<0.001$).

The descriptive statistics of dental fluorosis prevalence in its different degrees is presented in Table 1. The percentages of children with fluorosis in the municipalities with oscillating and homogenous fluoride levels in the water supply were 31.4% and 79.9%, respectively, and this difference was statistically significant ($p<0.001$). On the other hand, very mild fluorosis was the most frequent degree of fluorosis observed in both municipalities.

With regard to the perception of the impact of fluorosis on the children's satisfaction with their own teeth, 99.4% of the children in the municipality with oscillating fluoride levels in the water supply, and 99.5% of those living in the municipality with homogenous fluoride levels reported being satisfied with their own teeth.

The community fluorosis index showed a "negative" value (0.4) in the municipality with oscillating fluoride levels in the water supply, while in the municipality with homogenous fluoride levels the value was 1.0, which is classified as mild in public health terms.

All the independent variables in Table 1 were used in the bivariate analyses. Schoolchildren living in the municipality with homogenous fluoride levels were more likely to present fluorosis than were the children living in the municipality with oscillating levels (OR=8.69; 95% CI: 5.47;13.82). According to ethnic group, non-white schoolchildren were three times more likely to develop fluorosis (OR=3.09; 95% CI: 2.02;4.72) (Table 2).

After multivariate logistic regression analysis, the variables that showed statistical associations with dental fluorosis were: living in the municipality with homogenous fluoride levels (OR=8.33; 95% CI: 5.15;13.45) and not owning a car (OR = 2.10; 95% CI: 1.27;3.49) (Table 3).

DISCUSSION

Although the percentage of children with fluorosis in the municipality with homogenous fluoride levels in the water supply was higher than the percentage in the municipality with oscillating levels, no high percentages of moderate or severe fluorosis were found. Very mild fluorosis was the predominant degree of fluorosis observed, as expected for localities with adequate fluoride levels in the water supply.[8]

Addition of fluoride to the public water supply is considered necessary because of its anti-caries effect. Moreover, the widespread use of different forms of fluoride has contributed towards greater occurrence of fluorosis, particularly in localities that maintain constant and optimal fluoride levels in their water supplies. However, the present study did not find any associations between fluorosis and exposure to other sources of fluoride.

Table 3. Risk variables for fluorosis among schoolchildren according to multiple regression analysis. Municipalities in the State of São Paulo, 2004.

Variable	Unadjusted OR	p*	Adjusted OR	p**
Municipality				
With oscillating fluoride levels	1.0			
With homogenous fluoride levels	8.69 (5.47 – 13.82)	0.00	8.33 (5.15 - 13.45)	0.00
Car ownership				
Yes	1.00			
No	1.37 (0.95 – 1.96)	0.10	2.10 (1.27 - 3.49)	0.00

-2 Log likelihood = 408.008
* value relating to bivariate analysis
** p-value for the variable after adjustment for other variables in the model
OR = odds ratio

The children living in the municipality with homogenous fluoride levels were eight times more likely to have fluorosis than were the children living in the municipality with oscillating fluoride levels. Fluorosis occurred predominantly to a very mild degree and thus, 99.5% of the schoolchildren living in the municipality with homogenous fluoride levels reported satisfaction with their own oral situation. This suggests that the resultant fluorosis is a consequence of the "biological effect", caused by the systemic effect of fluoride intake from the public water supply,[11] but without any esthetically compromising effect.

Regarding the prevalence of fluorosis in the two municipalities (31% and 80%), these values are within the variation from 35% to 60% reported from fluoridated communities in the United States.[4] In municipalities with fluoridated water supplies in the State of São Paulo, Brazil, Forni (2000)* reported a large variations in the prevalence of fluorosis among children aged six to 12 years: 49.2 % in Santos, 49.4% in the city of São Paulo, 54.8% in São Vicente, 59.4% in São Caetano, 84.0% in Ribeirão Pires and 95.4% in Rio Grande da Serra (all in State of São Paulo). The reason for these variations have not been explored, and the data from the present study suggest that the variations might be related to controlling for the optimal fluoride concentration in the public water supply of these different municipalities.

The only socioeconomic indicator significantly associated with fluorosis in the present study was car ownership, which suggests higher socioeconomic status and greater access to other sources of fluoride. However, a single indicator does not precisely reflect an individual's socioeconomic level, and there is no consensus in the literature regarding the association between socioeconomic status and dental fluorosis.[5,12,14,18]

With regard to sociodemographic characteristics, the two municipalities studied were homogenous, with differences observed only in relation to the ethnic classification of the children (white and non-white). However, this variable was not significantly associated with fluorosis in the final logistic regression model. The larger percentage of non-white children in the municipality with homogenous fluoride levels might explain the greater prevalence of fluorosis if this were associated with lower socioeconomic status. However, the opposite has been reported.[12]

The fact that only the permanent incisors were examined in estimating the prevalence of dental fluorosis is considered not to constitute a limitation on the present study. According to Clark & Berkowitz,[3] there is no difference in investigating the prevalence of fluorosis between doing this for the whole dentition or just for part of it.

Some authors have estimated that the transition and early maturation phases of the dental enamel (when the teeth are more susceptible to dental fluorosis) occur between the ages of 20 and 36 months in the case of the upper permanent incisors.[6] However, according to a systematic review,[2] the length of the exposure to a given fluoride concentration is more relevant than a particular risk period. Thus, the present study sought to give support to this hypothesis, since the children studied had been subjected to fluoride concentrations for more than seven years.

One limitation of the present study was the fact that less than 50% of the calculated population sample was made use of in the final study, mainly because of losses among schoolchildren who did not meet the criterion of having lived in the municipality since birth.

Despite this limitation, the data from the present study suggest that there is an association between regular maintenance of optimal fluoride concentrations in the water supply and increased prevalence of dental fluorosis, which is in accordance with the mechanisms for fluorosis development.[1] On the other hand, research on laboratory animals that are exposed to oscillating fluoride concentrations in water is suggested in order to confirm the observed results.

* Forni, TIB. Caracterização de levantamentos epidemiológicos de fluorose dentária no Estado de São Paulo. [Master's dissertation] São Paulo: Faculdade de Saúde Pública da USP; 2000.

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