Community Dent Oral Epidemiol 1998; 26: 310–15
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COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY
ISSN 0301-5661

Dental fluorosis in Chilean children: evaluation of risk factors

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Villa AE, Guerrero S, Icaza G, Villalobos J, Anabalón M: Dental fluorosis in Chilean children: evaluation of risk factors. Community Dent Oral Epidemiol 1998; 26: 310–15. © Munksgaard, 1998

Abstract – The purpose of this case-control study was to determine the association between very-mild-to-moderate enamel fluorosis and exposure during early childhood to fluoridated water, mainly through ingestion of powdered milk. Analysis was performed on 136 residents of the optimally fluoridated community of San Felipe in the Chilean Fifth Region, who were categorised into one of three groups according to their age when water fluoridation was introduced in 1986: Group I was born after 1986; Group II was 16–24 months old in 1986; and Group III was >24 months of age. The case and control subjects were selected on the basis of a clinical examination given in July 1996. Dean's scoring system was used to determine fluorosis status. Risk factor exposure was ascertained by a questionnaire used in interviews with mothers of participating children. Logistic regression analysis, after adjustment for confounding variables, revealed that very-mild-to-moderate enamel fluorosis of permanent central maxillary incisors (CMI) was strongly associated both with the age of the subjects when water fluoridation began and with breast-feeding duration for children belonging to Group I. Subjects in Group I were 20.44 times more likely (95% CI: 5.00–93.48) to develop CMI fluorosis than children who were older than 24 months (Group III) when fluoridation began. Subjects who were between 16 and 24 months old when water fluoridation began were 4.15 times more likely (95% CI: 1.05–16.43) to have CMI fluorosis than children older than 24 months. An inverse association was found with breast-feeding duration (OR=0.86, 95% CI: 0.75–0.98) among Group I subjects but not in Groups II and III. Results obtained suggest that the current fluoride concentration in drinking water may be contributing to fluorosis. Further studies will be necessary to determine the relative competing risks of dental fluorosis and dental caries in Chilean children in order to establish the most appropriate water fluoridation level in Chile.

Key words: Chilean children; dental fluorosis; risk factors

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Accepted for publication 1 May 1998

The increase of dental fluorosis prevalence in North America during the last decades is well documented (1). Several factors have been identified as possible sources for this undesirable trend: water supplies fluoridated above optimum concentrations (2), dilution of concentrated and powdered infant formula with fluoridated water (3), inappropriate use of fluoride dietary supplements (4), ingestion of fluoridated toothpaste during brushing (5), and possible dietary practices of high consumption of fish or tea (6). A high retention of fluoride by infants was recently reported (7) and the use of fluoride-free water for infant formula preparation was also suggested (8). The National Complementary Feeding Program (PNAC), which delivers free powdered milk and milk derivatives to all children from birth to 6 years old, has operated in Chile since the 1950s. PNAC has ample coverage nation-wide (9) and its powdered products are prepared with tap water before ingestion. Fluoride ingestion among infants and young children might be increased through the preparation of these powdered milk products with fluoridated tap water.

Fluoridation of potable water was initiated in San Felipe, a city located in the Fifth Region of

Chile, in January 1986. Higher than usual prevalence and severity of dental fluorosis among Chilean children from different socio-economic status (SES) residing in coastal cities of the Fifth Region were recently reported (9). The prevalence and severity of enamel fluorosis in the permanent teeth of 8-year-old children from low socio-economic status (LSES) were found to be higher than those of children belonging to high socio-economic status groups (9).

This study was undertaken to identify the source(s) of excess fluorides associated with dental fluorosis on early forming enamel surfaces in a child population born and reared in the optimally fluoridated city of San Felipe, and to determine whether an association could exist between age and initiation of fluoridated water exposure. The present study also aimed to establish if the socio-economic status of children had a significant influence on enamel fluorosis prevalence. Taking into account previous data (7, 8), the possibility that breast-feeding duration, as a protective factor mimizing the effects of fluoridated water exposure, could be associated with fluorosis of early forming enamel surfaces was also examined.

This work is part of a broader comparative study on caries experience and dental fluorosis prevalence in five Chilean communities with different fluoride concentration in their tap water, the results of which are reported in a separate paper (10).

Material and methods

Water fluoridation was implemented on January 2 1986 in San Felipe, a city of 44 500 inhabitants, located in the valley of the Aconcagua River at 630 m above sea level with an average maximum annual temperature of 22°C. The mean fluoride (F) water concentration for this community in the last 10 years was 0.93 mg/L; extreme values were 0.65 and 1.42 mg/L. The range of fluctuation around the mean value was ±12% in 87% of the samples (11). The reported values come from daily samples at the waterworks facility serving San Felipe.

The study protocol was approved by the Ethics Committee of INTA, University of Chile. Enrolment of the study population was through and with the co-operation of the participating schools. Three age groups were selected for this study to compare children who were born after water fluoridation was introduced (Group I) and children who were 16–24-months old (Group II) or older than 24 months (Group III) when such intervention started. The numbers of children in Group I, and Groups II and III residing in San Felipe were estimated to be 1150 and 1000, respectively. The study population comprised Group I children (n=134) and Groups II and III (n=164), enrolled in two private and three publicly supported basic schools. Selection of the schools was made at random from: 1) the complete list of private schools that monthly charge more than USD 150 per child, and whose pupils are considered to have high socio-economic status (HSES) and 2) the complete list of publicly supported basic schools of San Felipe where children of low socio-economic status attend. This categorisation is based on the Chilean Ministry of Social Development criteria (9).

Clinical examinations were carried out in July–August 1996. The educational authorities of the selected schools notified parents that their children would receive a dental clinical examination related to a water fluoridation research study, and 97% of parents responded positively. Thus, all of the children in age groups I, II, and III who volunteered for the study and attended one of the five schools when the studies were done received an oral clinical examination that included enamel fluorosis evaluation of fully erupted permanent teeth. Enamel fluorosis was assessed and recorded using Dean's index (12) and Russell's criteria for differentiating fluoride and non-fluoride opacities (13). Teeth were not dried before inspection and were examined under tangential natural light. Each tooth was assigned an individual score to compare prevalence and severity of fluorosis in each group of teeth.

Only one examiner (SG) carried out fluorosis examinations, and approximately 12% of the children were re-examined after 4 weeks in a single-blind fashion to monitor diagnostic standards. The level of reproducibility was expressed using the kappa statistic (14). A slightly modified WHO form was used to accommodate individual tooth fluorosis scores (15).

A pre-tested questionnaire developed specifically for this study was used in personal interviews with the mothers of all clinically examined children. Through the questionnaires information was collected on children's breast-feeding habits, nursery school attendance and residence location histories, as well as on the frequency, extent, and duration of breast-feeding and toothbrushing practices. Exclusive breast-feeding is promoted by the Secretary of Health through educational campaigns. This implies that solid foods are incorporated in the infants' diets normally, but that their milk intake comes from breast-feeding as long as possible.

In order to minimize bias in the collection of the potential risk factors the interviewer was blind to the child's enamel fluorosis status and parents were not informed of the child's fluorosis status by study personnel.

Eligible subjects for the risk factor study were those who were permanent residents of San Felipe *and* whose mothers answered the questionnaire. After fulfilling these two criteria, a "case" was defined as any subject presenting a fluorosis score ≥1 in the central maxillary incisors (CMI). A "non-case" (control) was defined as any subject presenting a fluorosis score equal to 0, i.e. normal enamel for the same teeth. Subjects diagnosed as "questionable", i.e. with a score of 0.5, were not included in the risk factor study.

All data were entered into an IBM-compatible computer and analysed using the SAS statistical package (16). Basic descriptive and univariate statistics were used to initially categorise the data and help construct the multivariate analyses. Logistic regression analyses were used to develop a model of exposures associated with very-mild-to-moderate enamel fluorosis. Odds ratios from the regression coefficient were used to estimate the relative risk for each factor, adjusting for all other factors in the model.

Breast-feeding duration and age at the start of community water fluoridation were the independent variables of principal interest. Additional independent variables included in the model were sex, SES, nursery school attendance, age when toothbrushing was started, and tea ingestion. Ninety-five percent confidence intervals were generated for all adjusted odds ratios.

Results

Intra-examiner agreement for enamel fluorosis diagnoses was excellent with a kappa value of 0.87. Seventeen children were excluded from the study because of orthodontic attachments, CMI restorations, or unerupted teeth. Out of the total number (N=281) of examined children, 220 (78.3%) of their mothers answered the questionnaire. Thirty-six subjects were excluded for residence reasons and another 47 were not included in the study because their CMI fluorosis score was 0.5. There was a missing answer in relation to breast-feeding duration for one subject who was also excluded. Thus, the number of children included in the risk factor study was 136.

Bivariate analyses showed that several potential risk factors did not show an association with CMI enamel fluorosis. These included: SES, sex, nursery school attendance, tea ingestion, and age at which toothbrushing started.

Data collected through the interviews with mothers of participating children showed that common features for the three age groups were:

a) Toothbrushing started at an average age of 35 months (s=13 months).
b) After breast-feeding cessation, milk ingestion came from powdered milk during the first 6 years of life for 95.5% of the children.
b) Average breast-feeding duration was 5.5 months (s=4.3 months).
e) Forty-two percent of the subjects in the sample drank tea at pre-school age. Tea ingestion started at an average age of 32 months (s=8 months).
d) Less than 2% of the study population had occasionally used fluoride supplements.

The daily volume of milk ingested during infancy and early childhood could not be estimated from the questionnaires.

Table 1, which shows central maxillary incisors (CMI) enamel fluorosis status by the age of subjects when water fluoridation began in San Felipe, reveals that Groups I and II had a higher percentage of cases than Group III, i.e. five and three times more cases, respectively. The adjusted odds ratio estimates with 95% confidence intervals for CMI

Table 1. Enamel fluorosis status of central maxillary incisors (CMI) by subject age when water fluoridation began in January 1986 in San Felipe

Age group	Age (months) when water fluoridation began	Number of cases	Number of controls	N	% of cases in group
Group I	Unborn	36	32	68	52.9
Group II	16–24	12	26	38	31.6
Group III	More than 24	3	27	30	10.0
Total		51	85	136	

Table 2. Adjusted* odds ratios (OR) with 95% confidence interval (CI) for central maxillary incisors enamel fluorosis, by varying fluoride exposures

Age group	Age (months) when water fluoridation began	Adjusted OR	95% CI
Group I	Unborn	20.44	5.00–83.48
Group II	16–24	4.15	1.05–16.43
Group III	More than 24	1.00†	

* Each variable was adjusted for all of the other variables in the table: sex, SES, toothbrushing, and dietary habits.
† Reference category.

enamel fluorosis are presented in Table 2. This table shows that the Group I children, who were born after water fluoridation started in San Felipe, presented a statistically significant 20.44 increase in the odds of CMI fluorosis compared with children who were older than 24 months (Group III) when drinking water fluoridation was implemented. Those children who were 16–24 months old (Group II) when water fluoridation started presented a statistically significant 4.15 increase in the odds of CMI fluorosis compared to those who were older than 24 months.

The only other statistically significant odds ratio related to CMI was the variable of exclusive breast-feeding. When exclusive breast-feeding is taken as a continuous independent variable, the logistic model shows that exclusive breast-feeding duration becomes a protective factor in the Group I children, showing a statistically significant decrease of the likelihood of CMI fluorosis by 14% (OR=0.86; CI: 0.75–0.98).

Analysis of the association of the above factors with the prevalence of enamel fluorosis in the posterior teeth (first molars excluded) of children in Groups II and III showed that an increase of prevalence of enamel fluorosis was apparently related to the amount of tea ingested and to an increased daily frequency of toothbrushing when subjects were pre-schoolers, but no significant associations were found.

Discussion

Previous work on dental fluorosis risk factors employed several fluorosis scoring systems. Pendrys' Fluorosis Risk Index was used in US and Canadian studies (3, 17, 18), while the Thylstrup and Fejerskov Index (19) was used in a study from East York, Canada (5). Several investigations used Dean's scoring system on certain teeth (20) or groups of teeth chosen for chronological assessments (4, 21). Previous studies on dental fluorosis prevalence carried out in Chile (9, 10, 22, 23) used Dean's scoring system. Thus, in order to obtain comparable results at the local level, our study employed Dean's scoring system.

In a previous study carried out in Valparaíso and Viña del Mar, two coastal cities of the Chilean Fifth Region (9), it was found that children with LSES presented a higher prevalence of enamel fluorosis than children with high socio-economic status. In the present study, no significant difference was found when comparing fluorosis prevalence by socio-economic status. A possible explanation for this contradictory finding might be related to the finding in the present study that HSES children did not show a significant difference in their use of powdered milk compared with LSES children, while in the previous study (9) HSES children had a higher intake of cow's milk with low fluoride concentration than LSES children, who consumed powdered milk prepared with tap water.

Given that the data of the present study indicate that tea ingestion and use of fluoridated dentifrice started at similar average ages of 32 and 35 months, respectively, and that fluoride supplement use was almost negligible among participating subjects, present results suggest that increased odds for CMI fluorosis (OR=20.44) for children born when the drinking water was already fluoridated in comparison to those older than 24 months when water fluoridation was implemented may be associated with ''optimally'' fluoridated water intake in Chile via a prolonged use of powdered milk during their first years of life. This conclusion is further substantiated by the finding that an extended period of exclusive breast-feeding appears to be a protective factor for the Group I children, while this factor is not significant for Group III children (taken as reference category in Table 2), who did not ingest fluoridated water during their first 24 months of life. These findings are in agreement with previous results on prolonged use of milk and soy-based infant formula (3, 5).

It is well known that central incisors are susceptible to fluoride challenge during the first years of life (18, 20, 21). Previous studies (20, 24) suggested that maxillary central incisors, on the whole, are most susceptible to fluorosis in children younger than 22 months. Our finding on the increased odds of CMI fluorosis (OR=4.15) for children aged 16–24 months when water fluoridation was introduced, as compared with those older than 24 months, appears to support those previous findings.

Traditional recommendations for optimal fluoride water concentrations in the range 0.7–1.2 mg/L (25, 26) come essentially from studies on fluid consumption among young children residing in areas with different mean annual maximum temperatures, which were carried out 30 and 40 years ago (25–27) when water consumption constituted approximately 35% of total fluid ingestion among children studied (25).

The use of powdered milk in Chile is an old and lasting dietary habit. Results obtained in this study regarding the high percentage (95.5%) of powdered milk use until school age are similar to those of a recent epidemiological study (28), which showed that more than 90% of Chilean children up to 6 years old use powdered milk and milk derivatives. Thus, tap water consumption either directly or indirectly through the preparation of powdered milk and milk derivatives and other beverages such as tea, soups and water-diluted powdered juices, constitutes nearly all of the fluid consumption of infants after breast-feeding cessation and extends through their first years of life. Results from this study suggest that under Chilean conditions the prevalence of CMI fluorosis may be associated to the ingestion of water with a fluoride concentration of 0.9 mg/L during the first 2 years of life.

The habit of tea drinking among Chilean preschool children, specially those with medium-low and low socio-economic status (28), and the use of fluoridated toothpastes would likely increase fluoride ingestion among young children. The additional risks of dental fluorosis of teeth other than CMI (and first molars) that mineralise later in life, and which might be associated with tea ingestion and frequent toothbrushing with fluoridated toothpaste, could not be evaluated in the present work.

Acknowledgements

The technical support of Ms L. Cabezas is gratefully acknowledged.

This study was financially supported through Grant 1960993 from FONDECYT – CHILE.

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