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Enamel fluorosis in 12- and 15-year-old school children in Costa Rica. Results of a National Survey, 1999

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In 1987, Costa Rica implemented a national salt fluoridation programme using sodium fluoride (225-275 mg F^-/kg). ***Objective***: To evaluate the prevalence and severity of enamel fluorosis (EF) in Costa Rican schoolchildren as part of the biological monitoring of the salt fluoridation programme. ***Basic research design:*** In 1999, eight calibrated examiners (interexaminer Kappa=0.73) recorded EF in the maxillary anterior teeth and first bicuspids (FDI's teeth 14 to 24) using Dean's Index and artificial light without drying. The multistrata probability sample included 12 and 15-year-old schoolchildren (n=2,499), representing seven regions of the country. Data were analyzed in SAS and SUDAAN to account for sampling design. ***Setting***: Costa Rican schoolchildren. The 12-year-old cohort was born when salt fluoridation started. ***Participants***: 3,758 children in selected age groups. ***Main outcome measures:*** Dean's index was calculated for cuspid to cuspid (teeth 13 to 23) and premolar to premolar (teeth 14 to 24). ***Results:*** Prevalence of EF (very mild or higher) at age 12 years was 17% for teeth 13 to 23 and 32% when teeth 14 and 24 were included. At age 15 years, the prevalence was 12% for teeth 13 to 23 and 25% when teeth 14 and 24 were included. Large regional differences were observed: from 10% to 76% among 12-year-old children and from 6% to 50% among 15-year-old children. ***Conclusions:*** In the aggregate, EF prevalence is within the range expected for a salt fluoridation programme, but regions with higher severity need further investigation on additional sources of fluoride including environmental sources. Prevalence figures were higher in the cohort born at time of fluoridation.

Key words: Costa Rica, dental fluorosis, enamel fluorosis, oral epidemiology, prevalence and severity, salt fluoridation, survey methods.

In 1987, the Costa Rican Ministry of Health and the Research Institute in Education, Nutrition, and Health (*Instituto Costarricense de Investigación en Nutrición y Salud,* INCIENSA) implemented the National Salt Fluoridation Programme of Costa Rica (*Programmea de Fluoruración de la Sal de Costa Rica,* PFSCR) as a nationwide intervention to prevent dental caries. The PFSCR was designed, coordinated, and implemented with the participation of all major Costa Rican salt producers. The PFSCR received technical support from the Pan American Health Organization (PAHO) and financial support from the W. K. Kellogg Foundation. The initial dosage, 250 mg F^-/kg salt, with an acceptable range between 225 and 275 mg F^-/kg, was decided based on experience from other countries (Marthaler, 1986; Mejía, 1986) and urinary fluoride excretion studies conducted in Costa Rica. In 1987, Costa Rica became the first country in America and third in the world, after Switzerland and France, to initiate a national programme to prevent dental caries using salt fluoridation.

In 1994, as part of surveillance activities, the PFSCR implemented an epidemiological investigation of enamel fluorosis in children age 6 to 20 years living in two Costa Rican populations (San Ramón at 1,100m over sea level and 0.13 mg F^-/L and Jacó at sea level and 0.18 mg F^-/L) (Salas-Pereira *et al*., 1995). The investigators used Horowitz' Tooth Surface Fluorosis Index (TSIF). In the sample, only children age 8 years or younger were fully exposed to fluoridated salt since birth. Children ages 9 through 13 years were partially exposed, and children older than14 had their teeth formed when fluoridation started. The use of the TSIF and the age groups used in the study (6 to 12 and 13 to 20 years) makes the analysis and interpretation of its results difficult. The investigators reported a larger percentage of surfaces with no fluorosis in Jacó, the sea level community (8.4% at age 6 to 12 years and 5.5% at age 13 to 20 years) than in San Ramón (3.7% at age 6 to 12 and 1.8% at age 13 to 20 years). Later, in 1998 a group of experts appointed by the Pan American Health Organization, including two coauthors of this report, visited two Costa Rican communities, Tierra Blanca and Jacó. In Jacó, the experts identified enamel fluorosis in the premolars and second molars among children who were 3-years of age in 1987, when salt fluoridation started, suggesting that it was caused by the ingestion of fluoridated salt.

In 1999, the PFSCR implemented a national survey to assess the prevalence and severity of dental caries, enamel fluorosis, and dentofacial anomalies in children age 12 (born when salt fluoridation started) and 15 years. This report describes the results of the enamel fluorosis assessment. Results for dental caries have been reported elsewhere (Solórzano *et al*., 2005).

Methods

Sample design

The 1999 national survey was designed as a multistrata

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probability sample with fixed random allocation representing school children from three age groups, 6–8, 12, and 15 years, at the national level and for each of seven Costa Rican administrative regions: Gran Area Metropolitana (GAM, which includes San José, the capital), Central, Chorotega, Pacífico Central (P. Central), Huetar Norte (H. Norte), Huetar Atlántica (H. Atlántica), and Brunca.

In the first stage of selection, 126 schools were selected as primary sampling units (PSU) from a total of 2,621 elementary and 546 secondary schools. The number of PSUs in each region (strata) was proportional to the population of schoolchildren in that region. In the second stage, 10 children from each PSU were selected for each of the three age groups using a systematic random selection approach. The study targeted a fixed number of children in each age group (180) in each region, for an estimated a total sample size of 3,780 children. The final sample sized was 3,758 children (over 99 per cent response rate) who represented 286,434 school children in selected age groups.

Diagnostic criteria

The 1999 National survey used a modified version of the World Health Organization (WHO) (1997) diagnostic criteria to assess dental caries, treatment needs, enamel fluorosis, and dentofacial anomalies. The modification of the protocol consisted in the recording of tooth-specific information on enamel fluorosis–using Dean's diagnostic criteria and coding–on the maxillary anterior teeth and first bicuspid.

Training and standardization procedures

Two experienced epidemiologists (HH and EB-A) served as reference examiners in the training and calibration of eight teams consisting of examiners (dentists) and recorders (dental assistants). Each team was sent to one region and one served as back-up. A five-day training and standardization workshop was implemented two weeks before data collection started, to allow retraining. One hundred and sixty volunteer children with different levels of enamel fluorosis participated in the workshop. Kappa values for inter-examiner reliability ranged from 0.42 to 0.70. Three of the eight examiners were retrained the following week until their kappa values reached 0.70 or above. Kappa values for intra-examiner reliability ranged from 0.7 to 0.8.

Survey implementation and data analysis

Permission for the study was obtained from INCIENSA's Ethics Committee. Written authorization and consent were obtained from the Ministry of Education and parents. Data collection took place between May 3 and June 4 of 1999. Clinical examinations were administered at the school using a portable chair. Each participating child was asked to toothbrush his/her own teeth and provide verbal assent prior to examination. Examiners were instructed to keep the surfaces wet before coding. All examination areas and instruments were reprocessed following recommended procedures (CDC, 1993; Summers *et al.,* 1994).

Data were collected in paper forms and later entered into an electronic data file using an error check programme. Data cleaning and variable transformation were done in the SAS statistical package (version 6.12) (SAS, 1999). An individual score was assigned based on Dean's criteria for the "two most affected teeth" (Dean, 1942). The final dataset was analyzed in SUDAAN version 7.5 (Shah *et al.*, 1997) to obtain unbiased estimates and standard errors. Unless noticed, prevalence figures were calculated including very mild and higher severity. In addition, Dean's Community Fluorosis Index (CFI) (Dean, 1942) was calculated for each administrative region. In all figures, non-overlapping error bars represent statistical differences in the point estimate at α=0.05 (i.e., error bound= $\pm$ 1.96 x standard error of the estimator)

Results

Table 1 displays the sample and population distribution by age group and region. In the table, percentages reflect the population represented by each region. No differences in enamel fluorosis by gender were observed, thus all figures combine the information for both genders.

Figure 1 depicts the prevalence and severity of enamel fluorosis by age. Around 32 per cent of school children age 12 years and 25 per cent of age 15 years had enamel fluorosis when assessed including maxillary anterior teeth and first bicuspids. Prevalence figures were much lower when only anteriors were included: 17 per cent at age 12 years and 12 per cent at age 15 years. Overall, school children at age 12 years had higher severity of enamel fluorosis than school children at age 15 years whether the first bicuspids were included or not. However such

Table 1. Sample size and population represented by region and age group. National oral health survey of schoolchildren, Costa Rica, 1999.

	Age 12 years		*Age 15 years*	
Region	*N(n)**	*%*	*N(n)**	*%*
Gran Area Metropolitana	21,422 (180)	45.3	20,144 (178)	58.7
Central	6,696 (180)	14.1	3,918 (177)	11.4
Chorotega	3,488 (172)	7.4	2,591 (180)	7.5
Pacífico Central	2,774 (178)	5.9	1,817 (178)	5.6
Huetar Norte	3,810 (178)	8.0	1,571 (180)	4.6
Huetar Atlántica	4,826 (174)	10.2	2,183 (176)	6.4
Brunca	4,300 (188)	9.1	2,109 (180)	6.1
Costa Rica	47,316 (1,250)	100	34,333 (1,249)	100

* "N" is the population represented and "n" the sample size

tendency reached statistically significant levels only in the very mild and moderate categories and when bicuspids were included.

Figure 2 depicts the distribution of enamel fluorosis by region among 12-year-old children for anterior teeth and first bicuspids. Large differences by region were observed: Chorotega showed the highest prevalence (75.5 per cent) followed by four regions: H. Atlántica (50.4 per cent), Brunca (43.3 per cent), Central (40.6 per cent), and H. Norte (40.2 per cent). The lowest prevalence and severity were observed in P. Central (9.6 per cent) and GAM (16.5 per cent). Children with moderate fluorosis were observed in all regions except in P. Central and GAM. Children with severe fluorosis were observed only in H. Norte, Central and Brunca regions. Overall, lower prevalence and severity figures were observed when only anterior teeth were included (Figure 3).

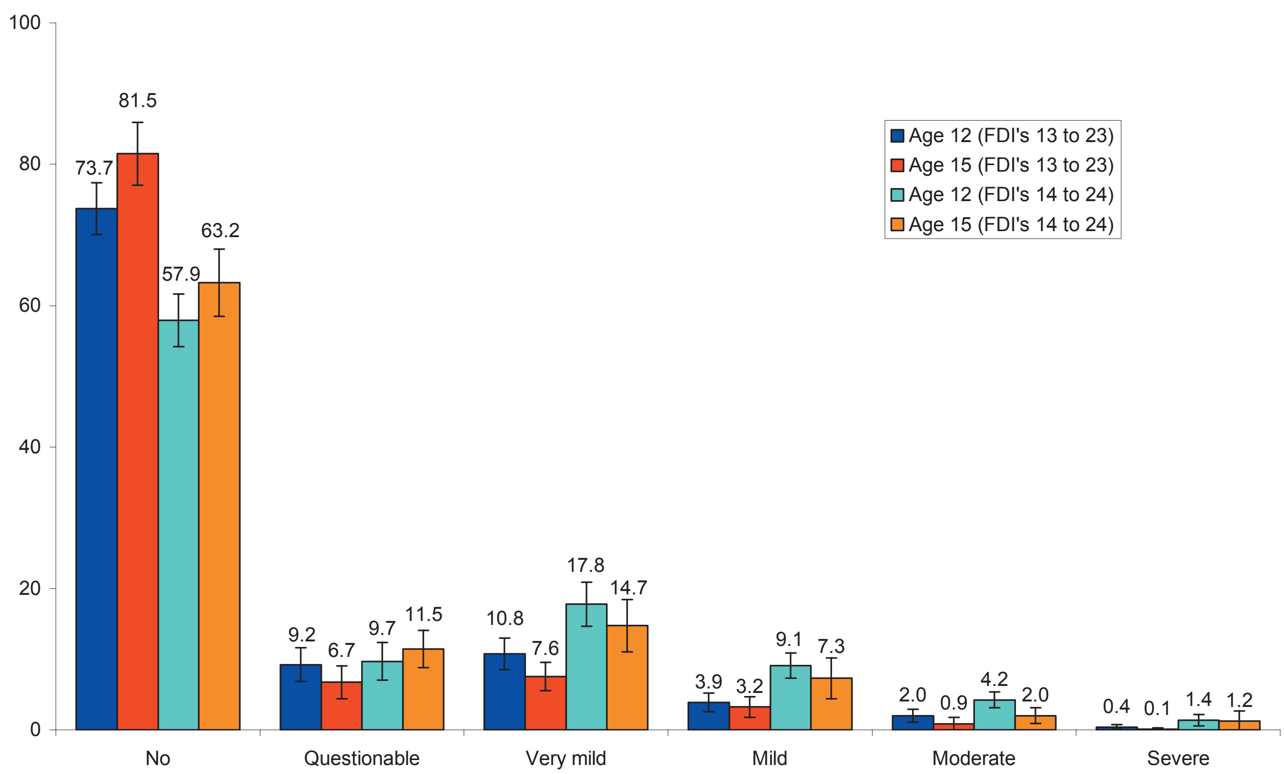
Figures 4 and 5 depict regional data for 15-year-old children. H. Norte, Central and H. Atlántica showed the highest prevalence and severity when bicuspids were included (Figure 4) and Central, H. Norte, and Chorotega when only anterior teeth were included (Figure 5).

Figure 6 shows CFI values by region for both age groups including maxillary anterior teeth and bicuspids. Chorotega had the highest CFI scores (0.96 at age 15 years and 1.25 at age 12 years). The lowest CFI scores were in P. Central (0.17 at age 15 years and 0.14 at age 12 years). Assuming Dean's arbitrary value of 0.6 (Dean, 1946) all regions except P. Central and GAM have fluorosis levels of borderline public health importance. Using the same Dean's scale, Central, H. Norte, H. Atlántica and Brunca have fluorosis levels at "slight," and Chorotega at "medium" public health significance.

Discussion

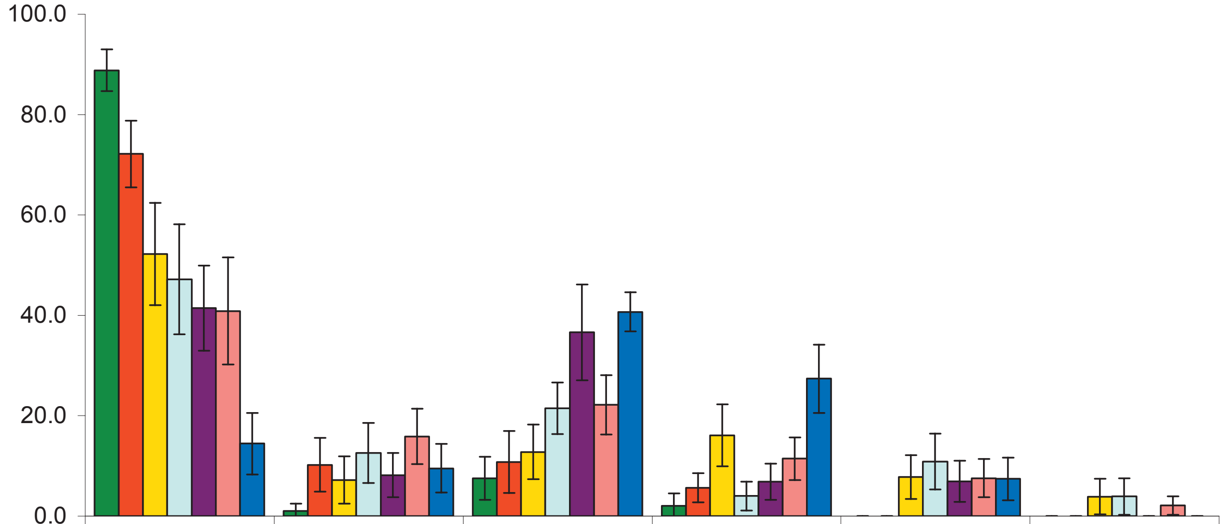
Enamel fluorosis is a side effect in preventive schemes using systemic fluorides. In the 1930s, Dean reported that 12 per cent of the children in Kewanee, Illinois, who drank water with 0.9 mg F^-/L had very mild and mild fluorosis, and an additional 35 per cent had a questionable level of fluorosis. In the absence of other fluoride vehicles, fluoride in the water, at that time, was the main and probably the most important source of systemic fluoride. Dean's studies lead to establishing 1 mg F^-/L (1 ppm) as the "optimal" level, where the preventive effects against dental caries are maximized, while the side effects of fluorosis are minimized. Such value was later expressed as a range (0.8 to 1.2 mg F^-/L) to take into account the variations in the drinking patterns based on climate.

The use of salt as an alternative vehicle to deliver systemic fluoride was first proposed by Wespi in the late 1940s, who was originally interested in preventing goiter among his patients. In 1946, after receiving information on the fluoridation community trials in North America, he envisioned the use of salt as a vehicle to deliver fluoride to prevent dental caries. Fluoridated salt was distributed first in 1955 in the city of Zürich at a concentration of 90 mg F^-/kg, and later to the entire canton. By 1960 fluoridated salt was commercialized in 20 of the 25 Swiss cantons. In the late 1960s the Canton of Vaud opted for salt fluoridation using 250 mg F^-/kg due to the limited effects reported in a retrospective study on children and adolescents using fluoridated salt at 90 mg F^-/kg (Marthaler and Schenardi, 1962). In 1964 a community trial was started in four Colombian communities which compared the preventive effects of



* All percentages are weighted estimates representing 12 and 15-year-old school children in Costa Rica. There were 1,250 children representing 47,300 12-year-old school children, and 1,249 children representing 34,300 15-year-old school children.

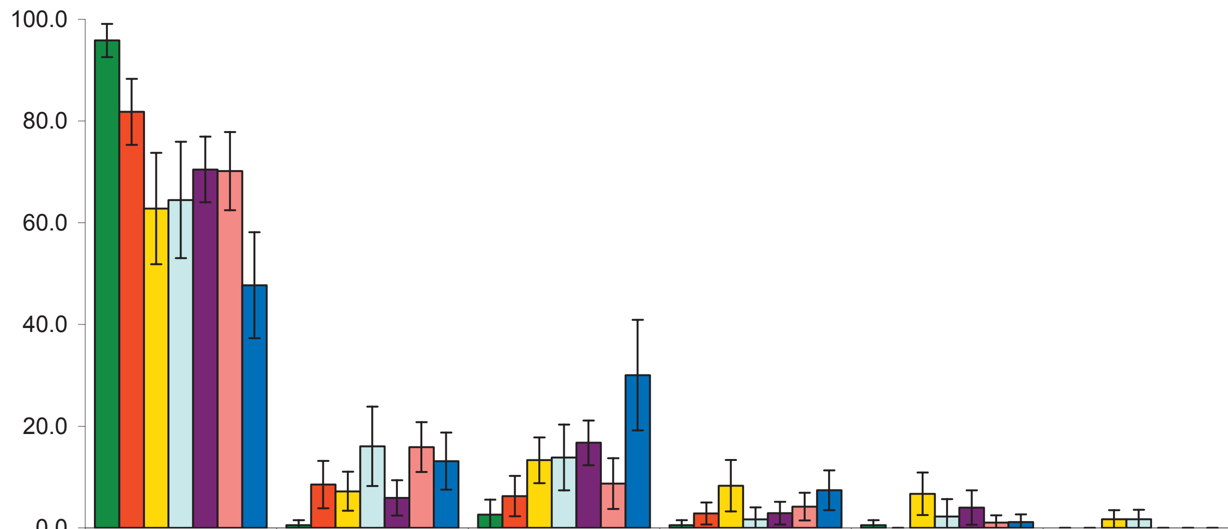
Figure 1. *Prevalence and severity of enamel fluorosis using Dean's fluorosis index applied to maxillary anterior teeth and first premolars among 12- and 15-year-old school children. National oral health survey. Costa Rica, 1999.*



	No	Questionable	Very mild	Mild	Moderate	Severe
P. Central	88.8	1.0	7.5	2.1	0.0	0.0
GAM	72.2	10.2	10.8	5.7	0.0	0.0
Central	52.2	7.2	12.8	16.1	7.8	3.9
H. Norte	47.2	12.6	21.5	4.0	10.8	3.9
H Atlantica	41.5	8.2	36.6	6.8	6.9	0.0
Brunca	40.9	15.9	22.2	11.4	7.6	2.1
Chorotega	14.5	9.5	40.7	27.4	7.4	0.0

* All percentages are weighted estimates representing 12 and 15-year-old school children in Costa Rica. There were 1,250 children representing 47,300 12-year-old school children, and 1,249 children representing 34,300 15-year-old school children.

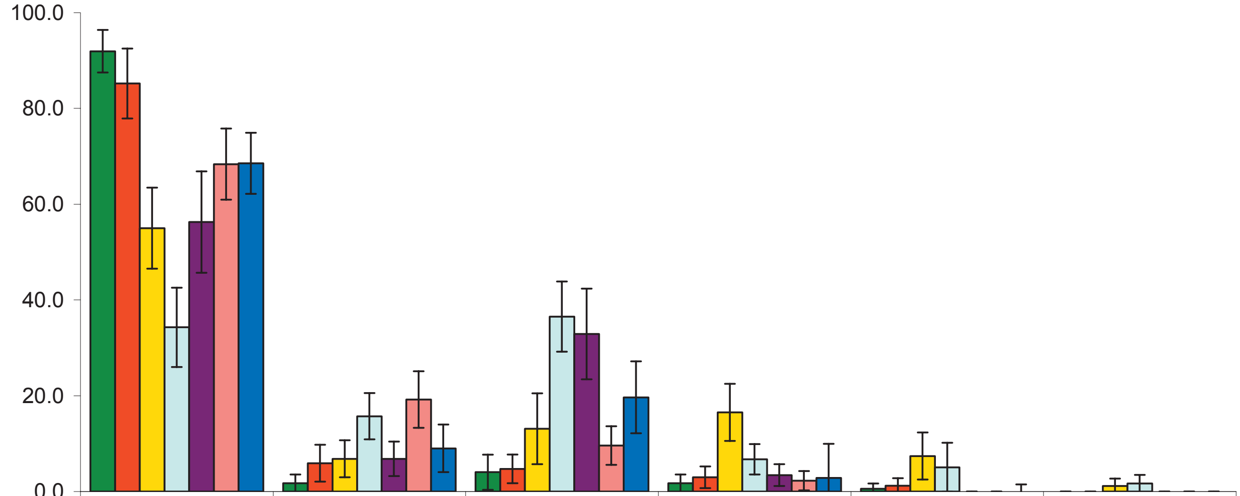
Figure 2. *Prevalence and Severity of enamel fluorosis using Dean´s fluorosis index applied to maxillary anterior teeth and first premolars among 12-year-old school children, by region.* National oral health survey. Costa Rica, 1999.*



	No	Questionable	Very mild	Mild	Moderate	Severe
P. Central	95.8	0.5	2.6	0.5	0.5	0.0
GAM	81.8	8.5	6.3	2.8	0.0	0.0
Central	62.8	7.2	13.3	8.3	6.7	1.7
H. Norte	64.5	16.0	13.9	1.7	2.2	1.7
H. Atlantica	70.5	5.9	16.7	2.9	4.0	0.0
Brunca	70.2	15.9	8.7	4.2	1.1	0.0
Chorotega	47.7	13.1	30.0	7.4	1.1	0.0

* All percentages are weighted estimates representing 12 and 15-year-old school children in Costa Rica. There were 1,250 children representing 47,300 12-year-old school children, and 1,249 children representing 34,300 15-year-old school children.

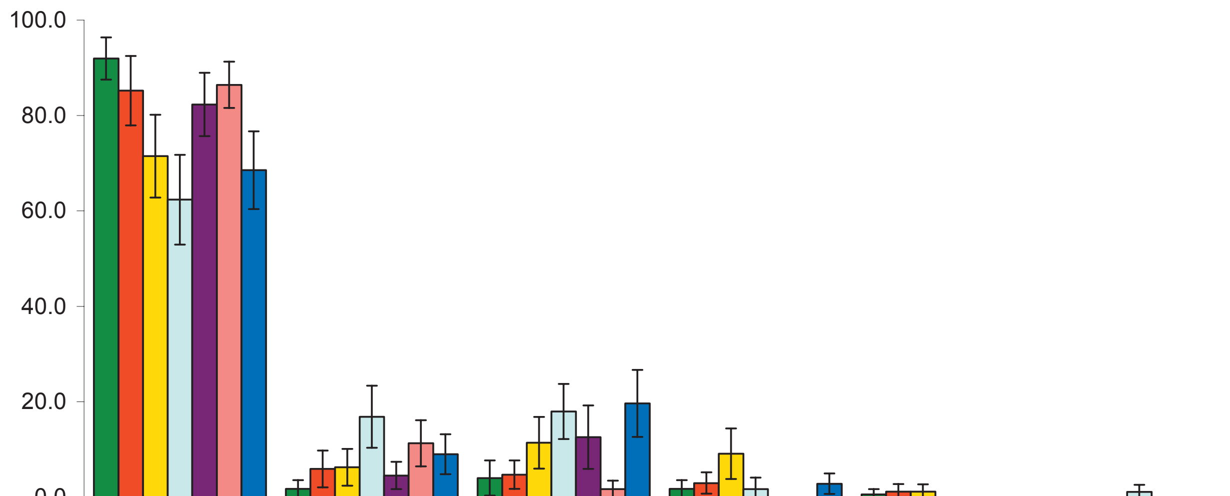
Figure 3. *Prevalence and severity of enamel fluorosis using Dean's fluorosis index applied to the maxillary anterior teeth among 12-year-old school children, by Region.* National oral health Survey. Costa Rica, 1999.*



	No	Questionable	Very mild	Mild	Moderate	Severe
P. Central	92.0	1.7	4.0	1.7	0.6	0.0
GAM	85.2	5.9	4.7	3.0	1.2	0.0
Central	55.0	6.8	13.1	16.5	7.4	1.1
H.Norte	34.3	15.7	36.5	6.7	5.1	1.7
H.Atlantica	56.3	6.8	32.9	3.4	0.0	0.0
Brunca	68.4	19.2	9.6	2.3	0.0	0.0
Chorotega	68.5	9.0	19.7	2.8	0.0	0.0

* All percentages are weighted estimates representing 15 -year-old school children in Costa Rica and each administrative region. Each region was represented by approximately 180 participants (total 1,249 representing 34,300 15-year-old school children in Costa Rica)

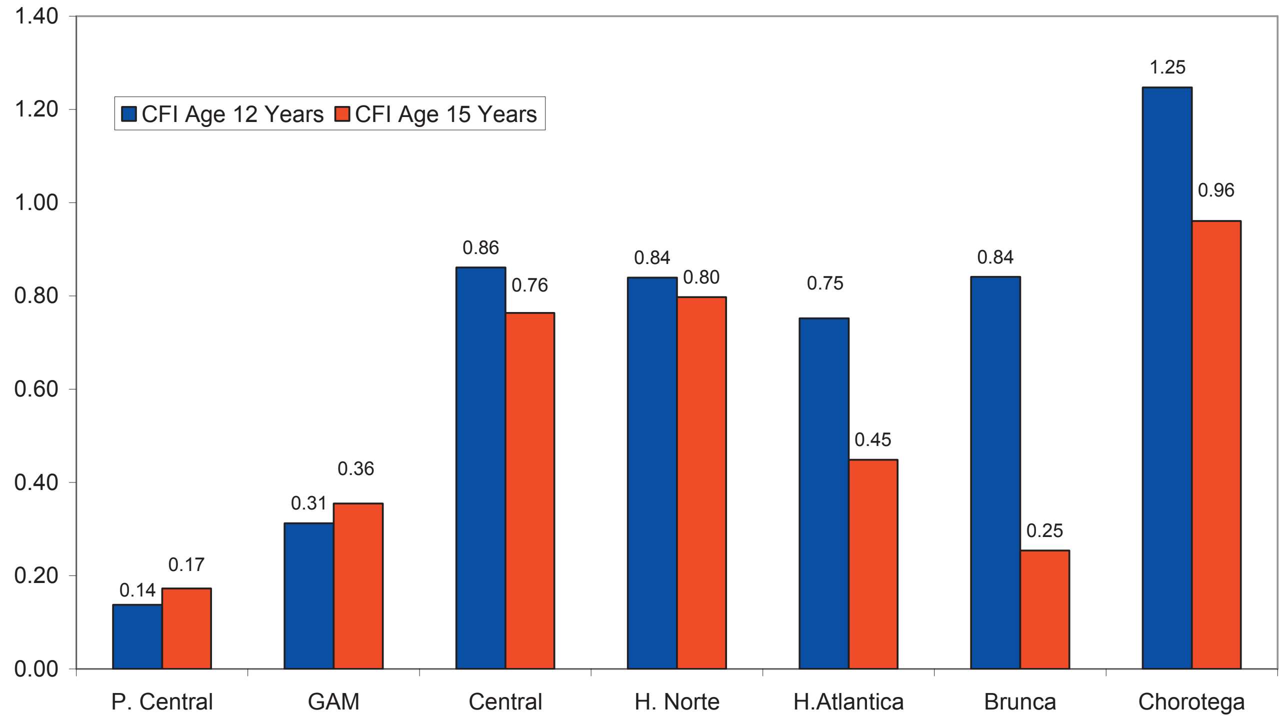
Figure 4. *Prevalence and severity of enamel fluorosis using Dean´s fluorosis index applied to maxillary anterior teeth and first premolars among 15-year-old school children, by region.* National oral health survey. Costa Rica, 1999.*



	No	Questionable	Very mild	Mild	Moderate	Severe
P.Central	92.0	1.7	4.0	1.7	0.6	0.0
GAM	85.2	5.9	4.7	3.0	1.2	0.0
Central	71.5	6.3	11.4	9.1	1.1	0.0
H. Norte	62.4	16.9	18.0	1.7	0.0	1.1
H.Atlantica	82.3	4.6	12.6	0.0	0.0	0.0
Brunca	86.4	11.3	1.7	0.0	0.0	0.0
Chorotega	68.5	9.0	19.7	2.8	0.0	0.0

* All percentages are weighted estimates representing 15 -year-old school children in Costa Rica and each administrative region. Each region was represented by approximately 180 participants (total 1,249 representing 34,300 15-year-old school children in Costa Rica)

Figure 5. *Prevalence and severity of enamel fluorosis using Dean's fluorosis index applied to maxillary anterior teeth among 15-year-old school children, by region.* National oral health survey. Costa Rica, 1999.*



* CFI was calculated for each age-group in each region (approximately 180 children).

Figure 6. *Community fluorosis index (CFI) applied to maxillary anterior teeth and first premolars among 12- and 15-year-old school children, by region.* National oral health survey. Costa Rica, 1999*

fluoridated salt at 200 mg F^-/kg–using two different fluoride chemicals–against an optimally fluoridated (1 mg F^-/L) and a non-fluoridated community (Restrepo *et al*, 1972). The idea of salt fluoridation resurfaces in Latin American in the late 1987s when Costa Rica opted for a national salt fluoridation scheme to prevent dental caries (Ministerio de Salud,1991). Before salt fluoridation was introduced, the PFSCR conducted feasibility studies focused on salt consumption and urinary excretion and a surveillance system to monitor efficacy and side effects of the intervention.

The data presented in this study indicate that, as expected, once a source of systemic fluoride is introduced in the population, enamel fluorosis becomes evident. Twelve-year old children who were born at the time salt fluoridation started had higher levels of enamel fluorosis than 15-year-old children. Furthermore, the prevalence and severity of fluorosis from cuspid to cuspid among 15-year-old children is lower than when biscuspids were included, suggesting that salt fluoridation had a higher effect on late-forming teeth–in this cohort early-forming teeth completed most of their maturation when fluoridation started.

Comparisons with data from other countries are difficult because few of them have reported national data on enamel fluorosis, and those reporting data sometimes have used different indices applied to different set of teeth. Furthermore, countries had used different dosages (e.g., 90, 200, 250 mg F^-/kg). In Jamaica, where salt fluoridation started also in 1987 using 250 mg F^-/kg, less than five per cent of the 6–8, 12 and 15-year-old children were reported to have enamel fluorosis in a national survey conducted in 1995 (Estupiñan-Day *et al.*, 2001). This study used Dean's index applied to maxillary anterior teeth–cuspid to cuspid; thus, most of these children's teeth at risk (biscuspids and second molars) were not included in the assessment, thus the low prevalence reported.

In 1994, the PFSCR reduced the dosage from 225-275 mg F^-/kg to 180-220 mg F^-/kg, in part due to the observed levels of fluorosis observed in 1994 (Salas-Pereira *et al.*, 1995). Children born in 1995 were four years of age at the time data was collected for the present study (1999). Thus, any effect due to the lower dosage should be evaluated in 2006, when the first cohort born and raised with the reduced dosage reach age 12 and had both anterior and posterior teeth available for assessment.

The present study reports strong regional variation in the prevalence and severity of enamel fluorosis, reflecting different fluoride exposures. Two such sources may explain the difference between regions. The first source is natural fluoride levels in water. In 1988, the PFSCR collected samples of drinking water and identified two communities with natural fluoride levels between 0.8 and 1.4 mg F^-/L where non-fluoridated salt was distributed complemented with a strong campaign supported by the salt industry and public officials. In 1995, ten additional communities were identified containing drinking water with natural fluoride levels from 0.4 to 1.9 mg F^-/L. In these communities, children have been exposed to fluoridated salt and fluoride in drinking water.

The second source is the environmental exposure from volcanic fumes containing fluoride. Volcanic emissions have been shown to contain fluoride (Delmelle *et al.*, 2003) which, breathed from the air or deposited in natural grasses, could affect animals and humans (Cronin and Sharp, 2002). Costa Rica has many active volcanoes and some of them, for example the Irazú volcano in Cartago could be partially responsible for the high natural water fluoride levels in Tierra Blanca and Llano Grande. An environmental investigation of fluoride exposure in animals and pastures could help to determine if such exposures are significant contributors to total fluoride exposure. Unfortunately, there is no historical record of the gases released when children in these regions were at risk of fluorosis. Other sources of fluoride exposure, such as fluoride supplements and ingestion of fluoride toothpaste play a minor role in Costa Rica. Supplements are rarely used and require a prescription, and most dentifrices in Costa Rica are fluoridated. Thus, neither could explain the level of regional differences observed. Furthermore, the areas where these vehicles should pose a greater risk, urban areas and higher income populations, have lower levels of enamel fluorosis. Finally, it is possible that some regional variations may be caused by the amount of salt used in the diet. Costa Rica has many microclimates and it is possible that in some communities, salt could be used earlier in life and in greater amount than in others.

The 1999 results were part of the PFSCR's surveillance system. The system includes the biological monitoring of dental caries, enamel fluorosis, urinary fluoride excretion, the chemical monitoring of the fluoride concentration in water and salt. Fluoridated salt quality control includes an internal control at the salt plant laboratory, an external control at INCIENSA's laboratory, and market surveys. A full detail of these studies are available in Spanish upon request.

In assessing the public health importance of the levels of enamel fluorosis reported in this study, it should be taken into account the beneficial effects on caries prevalence and severity. Dental caries prevalence in Costa Rica has declined dramatically over the past 15 years from a DMFT 9.13 in 1984 to 2.46 in 1999 (Salas-Pereira *et al.,* 2001). This decrease in almost seven teeth has been attributed mainly but not exclusively to the introduction of salt fluoridation.

These data have some limitations and advantages. The most important limitation is the lack of data for smaller geographical areas. The regions included in the sampling, represented administrative aggregates with complex and diverse microenvironments. In 2003, the PFSCR started a plan to identify and monitor smaller communities where exposure to fluoride from multiple sources may be higher, i.e., those in the regions showing higher levels of fluorosis in 1999. Additional cases of fluorosis and additional communities with natural fluoride levels in their water were identified. In some of these communities, the recommendation was to change to a different source of drinking water. The cross-sectional nature of the data, on the other hand, is an advantage, because it allowed identifying the cohort effect produced by the initiation of fluoridated salt.

In conclusion, this study reports an increase in the prevalence and severity of enamel fluorosis in cohorts born after salt fluoridation. Such occurrence is within the expected levels at the aggregate level and should be reduced in cohorts born after the reduction in the fluoride dosage; but in some regions the prevalence and severity is higher demanding further epidemiological investigations and surveillance. Finally, in assessing enamel fluorosis using modification of the Dean's index, it is important to include first or second premolars to account for a longer period of exposure.

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