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Dental fluorosis and associated factors among Colombian schoolchildren: A Mixed Methods Study

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Abstract

Objective: To identify the prevalence and factors associated with dental fluorosis (DF) among schoolchildren and to understand parent/guardian perception and knowledge concerning this condition.

Methods: In this mixed methods study, researchers conducted clinical examinations on schoolchildren, as well as surveys and semi-structured interviews with parents/guardians in Nariño, Colombia, during 2023. The researchers analyzed data using descriptive statistics and multivariate analysis (quantitative), with the dependent variable fluorosis measured using Dean's Index. Data was categorized according to content analysis (qualitative). The analysis of narratives and triangulation of the findings followed principles of grounded theory.

Results: Using Dean's index, the adjusted model found that prevalence of fluorosis increased with age among individuals with "very mild" versus "mild" levels (aOR = 1.85; 95%CI = 1.24-2.75) or in men (aOR = 3.08; 95% CI = 1.06-8.90) and was lower in those individuals who lived in urban areas (aOR = 0.21 95%; CI = 0.06-0.71) or among subjects who had a dental checkup three or more times per year (aOR = 0.12; 95% CI = 0.02-0.83). Prevalence also increased with age in individuals with very mild versus moderate levels (aOR = 2.21; 95% CI = 1.10-4.42) or in those whose parents reported knowing about fluorosis (aOR = 35.58; 95% CI = 3.50-361.14) and was lower in individuals who consumed the most popular salt brand in the area (aOR = 0.41; 95% CI = 0.002-0.90). Ten individuals participated in the semi-structured interview; a lack of knowledge was observed, and participants perceived DF as a natural or teeth-strengthening process. Through triangulation, age was identified as a factor interacting with fluorosis. **Conclusion:** The findings of this study suggest that frequency of dental checkups, age, sex, place of residence, parent/guardian knowledge and perception, and diet were associated with presence of DF.

-----**Keywords:** Health education, dental fluorosis, nutrition, oral health, children's health

Fluorosis dental y factores asociados en escolares colombianos: un estudio de métodos mixtos

Resumen

Objetivo: Identificar la prevalencia y los factores asociados con la fluorosis dental (FD) en escolares y comprender la percepción y el conocimiento de los padres/tutores sobre esta condición.

Métodos: En este estudio de métodos mixtos, los investigadores realizaron exámenes clínicos a escolares, así como encuestas y entrevistas semiestructuradas con padres/tutores en Nariño, Colombia, durante 2023. Los investigadores analizaron los datos mediante estadística descriptiva y análisis multivariado (cuantitativo), con la variable dependiente fluorosis medida mediante el índice de Dean. Los datos se categorizaron según el análisis de contenido (cualitativo). El análisis de narrativas y la triangulación de los hallazgos se basaron en los principios de la teoría fundamentada.

Resultados: Utilizando el índice de Dean, el modelo ajustado encontró que la prevalencia de fluorosis aumentó con la edad entre individuos con niveles “muy leves” versus “leves” ($RDa = 1,85$; $IC\ 95\% = 1,24-2,75$) o en hombres ($RDa = 3,08$; $IC\ 95\% = 1,06-8,90$), y fue menor en aquellos individuos que vivían en áreas urbanas ($RDa = 0,21$; $IC\ 95\% = 0,06-0,71$) o entre sujetos que tenían un chequeo dental tres o más veces al año ($RDa = 0,12$; $IC\ 95\% = 0,02-0,83$). La prevalencia también aumentó con la edad en individuos con niveles muy leves versus moderados ($RDa = 2,21$; $IC\ 95\% = 1,10-4,42$) o en aquellos cuyos padres reportaron saber sobre la fluorosis ($RDa = 35,58$; $IC\ 95\% = 3,50-361,14$) y fue menor en individuos que consumían la marca de sal más popular en el área ($RDa = 0,41$; $IC\ 95\% = 0,002-0,90$). Diez individuos participaron en la entrevista semiestructurada; se observó una falta de conocimiento sobre la fluorosis dental y los participantes la percibieron como un proceso natural o de fortalecimiento de los dientes. A través de la triangulación, se identificó la edad como un factor que interactúa con la fluorosis.

Conclusión: Los hallazgos de este estudio sugieren que la frecuencia de los controles dentales, la edad, el sexo, el lugar de residencia, el conocimiento y la percepción de los padres / tutores y la dieta se asociaron con la presencia de fluorosis dental.

-----*Palabras clave:* Educación en salud, fluorosis dental, nutrición, salud bucal, salud de los niños

Fluorose dentária e fatores associados entre escolares colombianos: um estudo de métodos mistos

Resumo

Objetivo: Identificar a prevalência e os fatores associados à fluorose dentária (FD) em escolares e compreender a percepção e o conhecimento dos pais/responsáveis sobre essa condição.

Métodos: Neste estudo de métodos mistos, pesquisadores realizaram exames clínicos em escolares, além de questionários e entrevistas semiestructuradas com pais/responsáveis em Nariño, Colômbia, durante o ano de 2023. Os pesquisadores analisaram os dados por meio de estatística descritiva e análise multivariada (quantitativa), com a variável dependente fluorose sendo medida pelo Índice de Dean. Os dados foram categorizados de acordo com a análise de conteúdo (qualitativa). A análise das narrativas e a triangulação dos achados seguiram os princípios da teoria fundamentada.

Resultados: Usando o índice de Dean, o modelo ajustado descobriu que a prevalência de fluorose aumentou com a idade entre indivíduos com níveis “muito leves” versus “leves” ($RDa = 1,85$; $IC\ 95\% = 1,24-2,75$) ou em homens ($RDa = 3,08$; $IC\ 95\% = 1,06-8,90$) e foi menor naqueles indivíduos que viviam em áreas urbanas ($RDa = 0,21$; $IC\ 95\% = 0,06-0,71$) ou entre indivíduos que faziam check-up odontológico três ou mais vezes por ano ($RDa = 0,12$; $IC\ 95\% = 0,02-0,83$). A prevalência também aumentou com a idade em indivíduos com níveis muito leves versus moderados ($RDa = 2,21$; $IC\ 95\% = 1,10-4,42$) ou naqueles cujos pais relataram saber sobre fluorose ($RDa = 35,58$; $IC\ 95\% = 3,50-361,14$) e foi menor em indivíduos que consumiam a marca de sal mais popular na área ($RDa = 0,41$; $IC\ 95\% = 0,002-0,90$). Dez indivíduos participaram da entrevista semiestructurada; foi observada falta de conhecimento, e os participantes perceberam a DF como um processo natural ou de fortalecimento dos dentes. Por meio da triangulação, a idade foi identificada como um fator que interage com a fluorose.

Conclusão: Os achados deste estudo sugerem que a frequência de exames odontológicos, idade, sexo, local de residência, conhecimento e percepção dos pais/responsáveis e dieta foram associados à presença de DF.

-----*Palavras-chave:* Fluorose dentária, Criança, Escolar, Estudo de métodos mistos, Pesquisa qualitativa, Estudos transversais

Introduction

Dental fluorosis (DF) is an endemic condition characterized by hypomineralization and occasional structural change of dental enamel [1]. It is a chronic, fluoride-induced aesthetic condition, in which the enamel becomes more porous [2]. Severity depends on the concentration of fluoride in tissue fluids during odontogenesis. This process occurs during growth, which in the case of teeth ends around age 12 with permanent dentition [3,4], the most critical period for the development of fluorosis and the early maturation phase of dental development [5]. DF often shows symmetrical and bilateral distribution due to simultaneous tooth development, and systemic fluoride is the same for all teeth in formation [6].

The World Health Organization (WHO), the Pan American Health Organization (PAHO) and the World Dental Federation (FDI) recognize water fluoridation and fluoridated toothpaste as measures to reduce the prevalence and incidence of dental caries [7]. However, WHO also recommends the surveillance of fluorosis in the population due to potential systemic effects beyond aesthetics, including skeletal fluorosis, renal impairment, neurotoxicity, and endocrine disruption [6].

In low- or middle-income countries, nutritional status and type of diet are associated with an increased risk of fluorosis. There are communities in which drinking water has a high fluoride concentration [8]. Furthermore, certain foods that are rich in fluoride, foods grown locally in areas where the concentration of fluoride in the water used for irrigation is high, and oral hygiene products such as toothpaste can affect health conditions and play an important role in developing fluorosis [9]. Also, areas that are geographically close to volcanoes present an alteration in the levels of fluoride in their water [10]. Knowledge about the condition is important, and parent's education levels and income have been associated with higher prevalence. Understanding these sociodemographic factors is crucial to assessing the perception and awareness of DF across different populations [11].

In Chile, the prevalence of DF ranges from 7.7% to 80.7% in areas with fluoridated water. In contrast, it is between 2.9% and 42% in areas where fluoride comes from other sources, with mild severity being more common [12]. In Colombia, according to the latest National Oral Health Surveys (ENSAB IV) in 2014, the prevalence of DF is 8.43% in 5-year-old children, 62.15% at 12 years of age, and 56.05% at 15 years of age. The prevalence is higher in dispersed rural areas (64.87%) and the Pacific region (78%). In 2018, 'severe' fluorosis cases were reported in the departments of Caldas (4.1%), Sucre (2.8%), Antioquia, Nariño, and Casanare (2.6%) [7]. However, prevalence rates in the country are wide-ran-

ging, varying from 0 to 98% in different areas [13,14]. Notably, 14 municipalities showed fluoride concentrations >4 ppm in drinking water, exceeding the recommended 0.7–1.2 ppm by WHO and Colombia's Ministry of Health [9,15].

Fluoride is present in seawater, the atmosphere, vegetation, different foods and drinks, soil, and volcanic rocks [7,15]. These naturally emit fluorides into the air, transported by wind and rain, finally depositing them in the soil, water, and food sources [15]. As a result, these are ingested daily and directly, in greater proportion in rural areas. However, it is important to clarify that they are not constituent elements of the human body.

The amount of fluoride in water in the department of Nariño, Colombia, has occasionally alerted the country's public health authorities; concentrations higher than 4 ppm have occurred. Due to this, Nariño was the department with the highest number of municipalities at serious risk. The municipalities of La Cruz, La Unión, Olaya Herrera, Imués, and San Pablo in the Nariño department exhibited fluoride concentrations between 1.01 and 4 ppm, placing La Cruz at medium risk for DF [15].

Particularly, in Nariño, there are three neighboring volcanoes to La Cruz: the Doña Juana Animas, and Petacas volcanoes, located at 4200 mts, 4300 mts, and 4500 mts, respectively. This proximity could result in fluorides being released into the air by the volcano, later to be transported by wind and rain to the surrounding soils and waters, which could explain the high fluoride concentrations in the water [16]. Volcanoes represent a natural source of fluoride and are the primary source of drinking water for daily consumption [16]. Thus, the objective of the present study was to identify the prevalence and factors associated with dental fluorosis among schoolchildren and understand the perception and knowledge about it among parents and guardians of a school population in La Cruz, Nariño, Colombia.

Methods

This mixed methods study aims to answer the research question: What are the prevalence and factors associated with dental fluorosis among schoolchildren, as well as the perception and knowledge about dental fluorosis of parents or guardians in La Cruz Nariño, Colombia? This study followed a quantitative, observational study methodology to identify the prevalence and factors associated with the development of DF and a qualitative methodology to understand the perception and knowledge of parents or guardians.

The study consisted of three phases. Phase one involved a clinical evaluation of schoolchildren. Phase two consisted of a survey administered to parents/guardians to assess variables such as sociodemographic status, oral care, diet, and knowledge, which were considered for

quantitative analysis. For the purposes of quantitative analysis, the researchers conducted semi-structured interviews with parents/guardians during the third phase to determine their knowledge and perceptions.

Quantitative Study

This cross-sectional analytical study followed the Equator Network's standards for reporting observational studies (STROBE). The target population included schoolchildren aged 8–12 years who attended two existing educational institutions in La Cruz, Nariño, Colombia, between July and December 2023.

According to the Colombian National Institute of Health's fluoride exposure report, the prevalence of DF in 2017 was 0.10%. The prevalence in women was 0.12%, and, in men, 0.09% [17]. Additionally, according to ENSAB IV [18], mild fluorosis had a prevalence of 12%.

Therefore, this study calculated the sample size based on the proportion of 12%. The sample size calculation considered a school population of 396 individuals, a prevalence of 12% of DF, and a confidence interval of 95%, resulting in a sample size of 116 individuals.

The inclusion criteria were schoolchildren who did not use fixed appliances and had mixed and permanent dentition. Among the exclusion criteria were schoolchildren with teeth that had fractures of >50% of the surface, caries lesions that prevented the correct diagnosis of DF, and a school population with dental or joint lesions that prevented intraoral examination.

The researchers used lists of students enrolled in grades two through six, selecting those who met the criteria and had their parents/guardians consent to participate. Random numbers were generated from these lists using Excel, and the sample was selected (Annex 1).

Clinical examination

The researchers who collected the data performed a clinical examination standardization by an expert. They reviewed the topic, identified fluorosis in photographs, and performed a clinical evaluation of six schoolchildren outside the sample size in which the examiners observed the teeth present and classified DF. The level of agreement between researchers was represented by Cohen's Kappa index.

The researchers clinically examined the schoolchildren under the same conditions for approximately 15 minutes. Before the assessment, food residue, plaque, or substances that could interfere with the visualization of the teeth were removed by brushing, and the researchers recorded the data using Dean's index as the dependent variable, identifying the prevalence as normal, questionable, very mild, mild, and severe fluorosis moderate.

The presence of DF was observed on the vestibular surfaces, and the presence and severity of fluorosis were determined considering the highest level of severity recorded in a tooth. The code 0 meant normal; 1 meant questionable or doubtful fluorosis; 2 was very mild fluorosis; 3 was mild fluorosis; 4 was moderate fluorosis; finally, 5 represented severe fluorosis [14].

Parent/guardian survey

The researchers surveyed parents/guardians to collect information on sociodemographic characteristics (age in years, sex, ethnicity, place of residence, parental occupation), oral care of schoolchildren (frequency of brushing, type of toothpaste, toothpaste intake, fluoride application, frequency of dental care, knowledge of fluorosis, consequences of fluorosis and previous diagnosis of fluorosis), and diet variables (type of salt, brand of salt, source of water consumption, frequency of consumption of legumes, cereals, vegetables, dairy products, red meat, chicken, fish, fruits and processed foods, as well as consumption of family crops and handling of agrochemicals by parents) (Table 1) [19, 20].

The researchers also asked questions regarding knowledge of fluorosis, its consequences, and whether the participant had previously been diagnosed with fluorosis. Likewise, they conducted a pilot study to evaluate the feasibility of the questionnaire questions. Data was collected using a form and consolidated in a database. Researchers double-checked the information to ensure quality. The sources of information for the quantitative section were the clinical examination and the parent survey.

Data analysis

The researchers conducted the data analysis using SPSS statistics software version 25 (IBM, Chicago, IL, USA). Analysis involved a descriptive analysis, calculating proportions and measures of central tendency and dispersion.

To avoid confounding factors, the researcher performed a multivariate analysis using multinomial logistic regression to estimate the unadjusted and adjusted Odds Ratio (aOR) with the corresponding 95% CI.

Data from participants with fluorosis (from very mild to moderate) were analyzed using multivariate model, and the "very mild" category was the reference group. First, unadjusted regression models were carried out. Any covariate with a *p* value less than 0.1 was a candidate to be included in the adjusted model considering the backward elimination method. Only covariates with a *p* value less than 0.05 in the final model indicated statistical significance.

The backward elimination method used potentially reduces multicollinearity. In addition, the researchers calculated the variation inflation factor (VIF) and the correlation between the variables to diagnose multicollinearity. The Akaike Information Criterion (AIC) verified the goodness of fit. Likewise, the researchers evaluated the model fit using Pearson's Chi-square and the deviation.

Qualitative study

The qualitative study followed the Equator Network's standards for reporting qualitative research. This method provides a wealth of detail and content through history, the universe, the meanings, motives, beliefs, values, and attitudes of social actors, which corresponds to a deeper space of relationships, processes, and phenomena that cannot be reduced to the operationalization of variables [21,22]. It is a methodology that facilitates understanding events considering people's life experiences [23]. The narrative in this study followed the established criteria for qualitative research [24].

Among the data production techniques, the researchers chose semi-structured interviews, in which questions can be formulated, resulting in information emerging more freely [24]. Using interviews to obtain data aims to understand the subjectivity of others through their stories [25]. The interviewee can take a favorable or unfavorable position on the topic without being tied to the question asked [25].

The qualitative study development involved (I) the preparatory/standardization phase (pilot study) and (II) the data collection phase (semi-structured interviews). During the pilot phase, an expert conducted five semi-structured interviews, with the main researcher present, to test and evaluate the understanding of the questions and adjust where necessary. These statements were not included in the study. After this phase, an experienced researcher performed standardization so that the main researcher conducted the interviews. The researchers carried out a prior discussion to align the research's development, the way of approaching the participants, and the conduction and moderation of the interview (Annex 2).

During the data collection phase, semi-structured interviews with the parents/guardians of the schoolchildren were conducted by an interviewer and an observer, exploring the topic of DF for approximately 15 minutes. The participants were informed about the research objectives, and the next motivating question was: Have you heard of DF? The interview continued with the following questions: Have you noticed if your child's (or children's) teeth have white or brown spots? The final question was: Do you believe that these stains make teeth weaker or stronger? The researchers recorded and

transcribed the interviews. Dean's Index was the theoretical support. The purpose of this procedure was to determine how parents/guardians of schoolchildren perceive and understand DF naturally, without prior theoretical preconceptions about the condition. The sample size for the qualitative part was related to the richness of data provided by the participants, using the speech saturation strategy (when no new data was identified, and the data found was satisfactory) to close group [26]. Therefore, in this study, the researchers approached 10 participants.

The researchers recorded the discussions on audio (tape recorder) and transcribed them in text format using identification codes (e.g., E1, E2) to ensure participant confidentiality. The transcribed material was subjected to exhaustive readings for better understanding [24]. The researchers categorized the data using the MAXQDA 12 software and interpreted the findings according to the content analysis proposed by Graneheim and Lundman [27]. The process involved identifying meaning units within the text, extracting each unit of meaning and its essence, obtaining the condensed unit of meaning, and interpreting the content to generate categories, which were subsequently grouped into topics.

The researchers analyzed the narratives and triangulated findings based on grounded theory, an appropriate research method for examining qualitative data to extract concepts organized around basic principles that can be integrated to develop a substantive theory about the studied phenomenon [8].

Method integration

The study employed a transformative convergent mixed-methods design, independently integrating qualitative and quantitative data sets and subsequently applying triangulation methods, contrasting and complementing the data findings [28-30]. DF remains highly prevalent despite implemented public policies and scientific findings. A mixed-methods design with a convergent approach allows for data to be collected within a previously established theoretical framework on DF, integrating population perceptions and knowledge of the topic.

Denzin discusses triangulation as a research validation strategy that can occur in four ways. The first refers to data triangulation or the use of different data sources; the second is researcher triangulation, which involves using different researchers to minimize subjective distortions; the third is theory triangulation; and the fourth is methodological triangulation [31].

For this study, data triangulation and researcher triangulation were used. Data sources included clinical assessments, surveys, and semi-structured interviews. Triangulation allowed for cross-comparison of the results from the sources during the analysis phase. The research used multiple observers or in-

interviewers (five researchers) to detect and minimize biased perspectives derived from the researcher's human nature.

This methodology was not limited to the division of labor during the research process; it was also used to systematically compare the data produced and the analyses prepared by the different researchers involved. The purpose of triangulation, in this sense, is to validate the research process, thus enriching and complementing the findings, and overcoming the always-limited epistemological potential of the individual method. Integration was achieved through narrative synthesis and a three-way table that identifies the prevalence and factors associated with DF in schoolchildren and the perception and knowledge of their parents or guardians. This strategy ensures the alignment of qualitative and quantitative results for comparability.

The Health Research Ethics Committee of Universidad del Valle approved the research protocols. All subjects participated voluntarily; they signed an assent and consent form, and the confidentiality of the data was guaranteed.

Results

Quantitative Study

The evaluated sample included 116 participants who met the inclusion criteria and were described using univariate analysis (Table 1). Data from participants with fluorosis was analyzed using multivariate models (Table 2). Clinical evaluation was performed with pre-calibrated examiners ($\kappa = 0.74$), ensuring consistency in applying Dean's index. The average age was 9.80 (1.38) years, with a predominance of the female sex (58.6%). The mean Dean's index was 2.36 (0.86), indicating very mild severity. Of the total sample, 101 participants (87%) were found to have very mild to moderate fluorosis. Only two participants (1.7%) exhibited normal results, while 13 (11.2%) showed questionable severity. The prevalence of very mild fluorosis was 44.8%, for mild fluorosis it was 33.6%, and for moderate fluorosis 8.6%. The researchers did not observe severe cases of fluorosis.

Regarding oral care, 79.3% used adult toothpaste; however, 91.4% did not ingest it. Concerning knowledge, 89.7% of parents/guardians did not know about fluorosis, 95.7% did not know its consequences, and 94% responded that in the dental checkup, they were not informed if the children had fluorosis. When investigating diet, 96.6% of the participants consumed the most popular salt brand, which is regulated by the Ministry of

Table 1. Characteristics of children.

Variables (N=116)	Frequency	%
Severity of fluorosis		
Normal	2	1.7
Questionable	13	11.2
Very mild	52	44.8
Mild	39	33.6
Moderate	10	8.6
Sex		
Female	68	58.6
Male	48	41.4
Place of residence		
Rural	28	24.1
Urban	88	75.9
Knowledge about fluorosis		
No	104	89.7
Yes	12	10.3
Salt brand		
Most popular brand of salt	112	96.6
Others	4	3.4
Frequency of dairy consumption		
Two or more times a week	70	60.3
Once a week	34	29.3
Never/occasionally	12	10.3
Frequency of red meat consumption		
Two or more times a week	45	38.8
Once a week	59	50.9
Never/occasionally	12	10.3
Frequency of fruit consumption		
Two or more times a week	89	76.7
Once a week	21	18.1
Never/occasionally	6	5.2
Variables	Mean (SD)	Min-Max
Age	9.80(1.38)	8-12
Dean's index	2.36(0.86)	0-4

Health of the country [32], and 72.4% reported tap water as their primary source of consumption (Table 1).

The researchers used a final multiple or adjusted model using a backward elimination method with nine variables (age, sex, place of residence, knowledge about fluorosis of parents or guardians, information of parents/

guardians about the previous diagnosis of fluorosis in their children, dental checkup, frequency of dental checkup, salt brand, and frequency of red meat consumption). The backward elimination method excluded previous diagnosis of fluorosis, dental checkup, and frequency of red meat consumption from the model because they were not significant.

The adjusted model identified that when comparing individuals with very mild (reference group) versus mild fluorosis, the researchers observed that for each additional year of age, the probability of presenting mild fluorosis increased by 85% (aOR 1.85; 95% CI: 1.24-2.75; p 0.002). On the other hand, male participants were 3.08 times more likely to present a mild score compared to female participants (aOR 3.08; 95% CI 1.06-8.90, p 0.038), and individuals living in urban areas were 79% less likely to have a mild score versus very mild compared to those living in rural areas (aOR 0.21; 95% CI 0.06-0.71, p 0.012). Regarding the frequency of dental

checkups, it was found that individuals who had dental checkups three or more times a year were 88% less likely to have mild fluorosis (aOR 0.12; 95% CI 0.02-0.83, p 0.032). The frequency also increased when individuals with a very mild (reference group) versus moderate fluorosis were compared. The likelihood of having a moderate (vs. very mild) score increased by 2.21 times (aOR 2.21; 95% CI 1.10-4.42, p 0.025). Similarly, individuals whose parents reported knowing about fluorosis were 35 times more likely to have moderate, rather than very mild fluorosis (aOR 35.58; 95% CI 3.50-361.14, p 0.003); however, this confidence interval shows a high dispersion in the data. Finally, consumption of the most commercial brand of salt in the area was associated with a 59% lower probability of having moderate rather than very mild fluorosis (aOR 0.41; 95% CI 0.002-0.90, p 0.043) (Table 2).

The researchers checked the goodness of fit by observing the decrease in the AIC with statistical signifi-

Table 2. Factors associated with dental fluorosis (Dean's Index) (N=101) in children

Variable	Unadjusted OR (95% IC) p value	Adjusted OR (95% IC) p value
Mild (N=39) vs. very mild (N=52)		
Age	1.653 (1.176 - 2.323) 0.004*	1.850 (1.245 - 2.750) 0.002*
Frequency of dental checkup		
Once or twice a year	1.200 (0.272 - 5.293) 0.810	0.882 (0.167 - 4.655) 0.882
Three or more times a year	0.217 (0.040 - 1.1781) 0.077	0.121 (0.018 - 0.831) 0.032*
Does not attend/Does not know	1	1
Place of residence		
Urban	0.291 (0.108 - 0.784) 0.015*	0.215 (0.065 - 0.710) 0.012*
Rural	1	1
Sex		
Male	2.625 (1.109 - 6.216) 0.028*	3.079 (1.065 - 8.898) 0.038*
Female	1	1

Variable	Unadjusted OR (95% IC) <i>p</i> value	Adjusted OR (95% IC) <i>p</i> value
Salt brand		
Most popular brand of salt	0.745 (0.045 - 12.295) 0.837	0.476 (0.015 - 15.101) 0.674
Others	1	1
Knowledge about fluorosis		
Yes	2.402 (0.538 - 10.730) 0.251	6.019 (0.883 - 41.040) 0.067
No	1	1
Moderate (N=10) vs. very mild (N=52)		
Age	2.001 (1.125 - 3.559) 0.018*	2.207 (1.103 - 4.418) 0.025*
Frequency of dental checkup		
Once or twice a year	0.320 (0.043 - 2.362) 0.264	0.165 (0.015 - 1.767) 0.136
Three or more times a year	0.348 (0.047 - 2.576) 0.301	0.124 (0.010 - 1.462) 0.097
Does not attend/Does not know	1	1
Place of residence		
Urban	0.424 (0.090 - 1.995) 0.278	0.368 (0.054 - 2.533) 0.310
Rural	1	1
Sex		
Male	0.964 (0.221 - 4.216) 0.961	1.028 (0.174 - 6.085) 0.976
Female	1	1
Salt brand		
Most popular brand of salt	0.078 (0.006 - 0.968) 0.047*	0.041 (0.002 - 0.899) 0.043*
Others	1	1
Knowledge about fluorosis		
Yes	7.000 (1.174 - 41.740) 0.033*	35.576 (3.505 - 361.143) 0.003*
No	1	1

Note: OR= Odds Ratio; CI= confidence interval; * $p < 0,05$

ficance. Likewise, the goodness of fit was evaluated using Pearson's Chi-square, and the deviation presented a *p value* of 0,95, indicating a good fit of the model. On the other hand, the Pseudo R square using the Nagelkerke correction showed that the final model explains 46% of the change in the dependent variable. The VIF values were all less than 2, while the correlation coefficient values were all less than 0.6, showing no collinearity problems.

Qualitative study

Participants included caregivers of the children included and clinically evaluated. These individuals were from the municipality of La Cruz, Nariño, and they were intentionally selected. Reading the narratives, the researchers observed a lack of knowledge among participants about DF. One participant (E3) stated, "Um... I don't know, maybe... is it genetics? I don't know, I couldn't say exactly." However, another interviewee (E2) obser-

ved the natural color change in children's teeth, stating, "Well, I check my daughter's teeth every day, and it has been about... she's had that little spot for about a year, so I go to the dentist, but no, he says, 'as she grows older, it's going to disappear,' but he also says it's because of what she eats... that's what I don't understand, but that's the type of answer that you get."

The perception of DF among the social actors in the study motivated further consideration of the idea of changes in dental enamel being caused by excess fluoride in the body during tooth formation, which, for the interviewees, is a natural or tooth-strengthening process. The analysis revealed that the perception of DF ranges from a lack of awareness that it is an oral condition affecting one's appearance and compromising the structure of the teeth, as indicated by one of the interviewees (E4) when referring to it: "Well, I think it weakens them because you have to keep an eye on it with the dentist" until to the point of thinking that color changes are nor-

Table 3. Three-way table. Data triangulation

Categories/ Constructs	Sources			Results
	Parents/Guardians		Children	
	Survey	Interview	Clinical evaluation	
Sociodemographic characteristics	Place of residence and age	Age – Role of Dentist in education.	Dean's index	Only one interview recognized the association with age. Place of residence was preconceived as an inclusion criterion; however, qualitatively, these geographical elements were not recognized as part of the risks.
Diet variables	Consumption of red meat, salt, dairy products and fruits	Diet was not identified; only one person said that the dentist reported the association between DF and diet and recognized it as a risk factor.	Dean's index	There is no evidence of a relationship between children's diet and the data gathered from the parents' interviews.
Oral care	There is no statistical significance	Oral hygiene, fluoride application, and toothpaste were identified. The dentists, their dental checkups, and their information were identified.	Dean's index	Participants relate dental hygiene to the appearance of DF, especially with poor hygiene.
Knowledge of DF	Knowledge and information specific to the condition of DF.	Interviews show a lack of knowledge.	Dean's index	In the quantitative analysis, 90% of the participants expressed that they do not know what DF is; similarly, the qualitative responses show a lack of knowledge.

DF: Dental fluorosis

mal. Table 3 shows the relationship between the qualitative and quantitative parameters found in the results, which allowed for adequate meeting points. The main interaction element observed was age. On the other hand, although the brand of salt was associated with dental fluorosis, parents did not identify nutrition as a relevant aspect related to fluorosis. For further details of the results, readers can contact the authors

Discussion

The relationship of DF with systemic conditions has been recognized; concentrations between 0.7 and 1.2 mg/L of fluoride in water are accepted [9]. Consumption toxicity appears due to the modification of additional fluoride consumption and sociodemographic conditions, resulting in a public health problem [33,34].

The findings show that 1 in 10 individuals reported ingesting toothpaste, and 3 in 10 were unaware of prior fluoride application. Although over 90% of participants regularly visited dental professionals, most of them had not been informed about DF, its consequences, or its presence in their children's teeth. This aspect that was also evident in the triangulation of findings and the qualitative analysis. These findings underscore the urgent need for educational actions for dental professionals and the general population [11]. The level of fluorosis was also associated with the knowledge of the population, especially when the knowledge is higher in the children and parents because they are aware that it is an abnormal condition. Individuals participating in the qualitative section of this study recognize the importance of this topic, leading to new approaches and improving the concept of education for health.

Reduction in fruit consumption and lower scores for Dean's index are associated with consumption of home-grown products, an association previously reported in Colombia, according to which fruit consumption among children in Villavicencio was found to be of 94.64%. However, this was not an association variable in the multivariate analyses [35]. Environmental factors, such as living near volcanic areas or consuming earth derivatives, may contribute to elevated fluoride exposure [36]; these factors should be evaluated in this region. Even aspects such as cooking in wood stoves have shown an OR of 9.34 and statistical significance, requiring further development [37].

Salt brands and reduced consumption of red meat, for the specific case of the study, had a low response frequency. High consumption of salt brands for which fluoride content is not regulated could lead to higher rates; the salt brand reported by most respondents has a fluoride content in the technical sheet of 175-225 ppm, which meets national standards [38]. The appropriate

values of fluoride consumption in salt are between 200 to 250 mg/kg [39]. In the case of diverse consumption of red meat, the findings show an association with the Dean index; however, they require additional analysis [40]. Some authors have found that there is not a relationship between protein consumption and the appearance of DF [40] or that no significant differences exist between protein-based or vegetarian diets [41]. One aspect that requires further consideration is how the decrease in protein diets and the increase in the consumption of fruits and vegetables in volcanic areas due to the fluoride conditions of the geographical region could influence the appearance of DF, especially when the amount of fluoride in meat varies greatly in composition (4–1.7 µg/g) [42]. According to the findings of this study, age is also an associated factor, as the condition becomes more prevalent with increasing age. This may be expected due to the prolonged exposure over time and the typical chronological progression of the condition's clinical manifestation [3,43].

Knowledge and perception of DF are related to higher scores for Dean's index; these findings are similar to those reported in the qualitative and quantitative literature [44]. The above could be because people do not recognize the appearance of the condition; however, if people had greater awareness of the condition, they could better perceive enamel alterations.

From a qualitative point of view, there are few approaches to understanding the problem; some endemic populations have defined DF as "bad teeth", the population with this condition being stigmatized, establishing water, tobacco, and poor hygiene as the main etiologies for its appearance [45]. These findings support the qualitative results found in the study, where water and poor hygiene were elements that the participants related to the condition. For this reason, education is important in generating different social structures, even more so in historical moments that require decisions in public health [46].

One of the main aspects of multimethod design is the possibility of creating new hypotheses while simultaneously integrating the processes to create a policy line. The findings here underscore the importance of implementing educational programs from a holistic perspective beginning with universities and dental schools, involving policymakers, and reaching families and children. The entire process must be approached transversally because problems and lack of education were identified as a result of the information given by the dentist and received by the person. Primary health care is vital in these processes and scenarios.

Previous analytical methodology approaches showed a relationship with susceptibility to dental caries, considering the extent of structural and chemical changes in the fluorotic enamel, eating habits, fluoride levels in one's diet and oral cavity, and the quality

of oral hygiene [47]. These factors are important for preventing both conditions; however, the general population understands both problems as if they were a single condition.

The convergence of models contributed to a deeper understanding of how DF is perceived and experienced by parents of affected children. Up to the appearance of this study, this is the only mixed-methodology study addressing how parents experience and understand DF within a clinical approach in children. More studies following this approach are necessary in other regions and among other populations, especially in the field of dental care [48].

This study has limitations, among them the cross-sectional design preventing follow-up or causal inference. A cohort or case-control study would allow for longitudinal observation. Furthermore, the qualitative section requires integrating political actors, educators, and decision-makers; their qualitative participation becomes very important. Additional studies are suggested to integrate fluoride concentrations in the foods consumed by children and the population under study. Furthermore, new qualitative approaches could be used with other actors. The specific analysis of the concentration of fluoride in hair or nails, which has shown a correlation with DF, could be investigated later [49].

This article has shown that clinical, sociodemographic, diet, knowledge- and perception- related factors are associated with the appearance of dental fluorosis, both from a qualitative and a quantitative perspective. These findings call for comprehensive public health strategies, including policies and analyses related to the cost/benefit of dental fluor. Greater health education for the general population is also necessary. As a final recommendation, fluoride consumption near volcanoes should be controlled. As previously reported in dentistry, oral health officials need to implement surveillance and control measures related to water and food, incorporating technology and differential epidemiological analysis. These actions, implemented in a continuous way, will generate future changes [50].

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Declaration of responsibility

The authors declare that they have all responsibility for the points of view expressed in the text. There is no responsibility for the institution of affiliation of the authors.

Contribution declaration by authors

All authors participated in the concept and design, acquisition of data, analysis and interpretation of data, writing of the manuscript and final approval

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Annex 1. Questionnaire on factors associated with dental fluorosis (quantitative study)

Preguntas relacionadas con datos personales (señala una opción):

1. ¿Cuántos años tiene el participante?: _____
2. ¿Qué género tiene?:
a) Femenino.
b) Masculino.
3. ¿Cuál es el lugar de residencia actual?:
a) Urbana.
b) Rural.
4. ¿A qué se dedican sus padres (ocupación)?:

5. ¿Cuánto tiempo lleva viviendo en la residencia actual?: _____

Preguntas relacionadas con hábitos (señala una opción):

6. ¿Cuántas veces se cepilla en el día?
a) 1 vez por día.
b) 2 veces por día.
c) 3 o más veces por día.
7. ¿Qué tipo de crema dental usa?
a) Niño.
b) Adulto.
8. ¿Ingiere crema dental mientras se cepilla?
a) Sí.
b) No.
9. ¿Le han aplicado flúor?
a) Sí.
b) No.
c) No sabe
10. ¿Con qué frecuencia asiste a atención odontológica?
a) 1 o dos veces por año.
b) 3 o más veces por año.
c) No asiste.

Preguntas relacionadas con la dieta (señala una opción):

11. ¿Qué tipo de sal consume?
a) Sal refinada.
b) Sal marina.
12. ¿Qué tipo de agua consume?
a) Agua de la llave.
b) Agua de botella o filtrada.
13. ¿Qué tan frecuente es el consumo de legumbres? (Arvejas, frijoles, lentejas, garbanzos, habichuelas).
a) 1 vez por semana.
b) 2 o más veces por semana.

- c) Ocasionalmente
d) Nunca
14. ¿Qué tan frecuente es el consumo de cereales? (Arroz, avena, trigo, pan, cebada, maíz, arepas, galletas, tortas, pasteles, pastas, hojuelas de maíz).
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
15. ¿Qué tan frecuente es el consumo de verduras? (Zanahoria, Papas, yuca, cebolla, remolacha, acelgas, apio, coliflor, repollos, espinacas, lechuga, calabacín, calabaza, pepino, pimentón, tomates).
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
16. ¿Qué tan frecuente es el consumo de lácteos? (Leche, Yogurt, Kumis, queso, otros derivados).
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
17. ¿Qué tan frecuente es el consumo de carnes rojas? (Carne de res, cerdo, salchichas, jamón, mortadela).
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
18. ¿Qué tan frecuente es el consumo de pollo?
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
19. ¿Qué tan frecuente es el consumo de pescado?
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
20. ¿Qué tan frecuente es el consumo de frutas?
a) 1 vez por semana.
b) 2 o más veces por semana.
c) Ocasionalmente
d) Nunca
21. ¿Consume alimentos procesados? (alimentos enlatados, embutidos, refrescos, comida chatarra que contengan productos químicos como sustancias artificiales, colorantes y saborizantes).
a) Sí.
b) No.

22. ¿Consume alimentos de cultivo familiar?
(Papa, yuca, café, fresas, maíz, arvejas, granadilla, olluco, plátano).

- a) Si.
- b) No.

23. ¿Los padres realizan manipulación de agroquímicos en sus cosechas? (Fertilizantes, insecticidas, fungicidas).

- a) Si.
- b) No

Annex 2. Semi-structured interview (qualitative study)

Semi-structured interview script

1. ¿Usted ha oído hablar de la fluorosis dental?
2. ¿Podría decirnos qué entiende por fluorosis dental?
3. ¿Usted ha notado si los dientes de su(s) hijo(s) tienen manchas blancas o marrones?
4. ¿Usted cree que esas manchas dejan los dientes más débiles o fuertes?

Interview number	Unit of meaning (US)	Condensed US Text-like description	Condensed US Interpretation of underlying meaning	Categories	Topic
E1	¿limpieza de los dientes? [...] desde que estaban que...tenían como unos 8 años. [...] si yo creo que los puede debilitar. [...] porque pues...no se actúa a tiempo se puede perder un diente ¿no?	Fluorosis dental si no actúa a tiempo se puede perder un diente	Puede perder un diente	Falta de conocimiento	Percepción de fluorosis dental
E2	“[...] no, en realidad no tengo conocimiento de ello. [...] pues, o sea, a mi criterio pienso que es como tenerle cuidado ¿no? de los dientes, estarle manejando como es la placa ¿no?, el esmalte dental, sobre eso, o sea, tener cuidado sobre eso y pues yo creo que ahí ya se le aplicaría el flúor, pues creo yo, ¿no? no sé. [...] eh, blancas, eso también, por ejemplo, eso era lo que le iba a comentar, por ejemplo, los dientes varían ¿no? hay manchitas, marrones no, pues lo que le he alcanzado a mirar no, blanquitas si o amarillitas, pienso que eso es de pronto. [...] pues yo todos los días le reviso a la niña y eso ya hace como unos... ya va para el año con esa manchita y voy al odontólogo y no, dice “eso es a medida que ella va creciendo se le va desapareciendo”, pero que de pronto por los alimentos eso es lo que yo no entiendo, pero así me han salido con esa respuesta. [...] a ver, verá ¿no?, tengo un primo que trabaja también en odontología, es auxiliar y a él le pregunte, le digo “a mí me dicen ya cuatro odontólogos que eso es normal, que a medida que ella va creciendo se le van desapareciendo que a veces por la comida, ósea los alimentos ¿no?”, entonces me dijo “no eso es problema” dijo de la, él me dijo un término pero no recuerdo ¿no? y que eso toca de tratarlo, o sea, eso pues es algo maleza para el diente, entonces es eso lo que quiero yo saber ¿qué se debe hacer ahí? ¿es bueno? ¿es malo que ella tenga esas cositas? porque no se le han desaparecido, ya un año, más de un año.”	No tengo conocimiento de fluorosis. El odontólogo dice que la manchita a medida que la niña va creciendo se le va desapareciendo y que puede ser por los alimentos	La fluorosis desaparece con el tiempo y puede ser por los alimentos	Falta de conocimiento	Percepción de fluorosis dental
E3	“lo que tengo entendido es que son manchas blancas en los dientes. [...] no, no tienen. [...] yo creo que debilidad [...] eh...no sé, por... ¿será por genética?, no sé, no sabría decirte exactamente.	Son manchas blancas en los dientes y creo que son debilidad, y puede ser genético.	Manchas blancas en los dientes que causan debilidad.	Debilitamiento de los dientes	Percepción de fluorosis dental

Interview number	Unit of meaning (US)	Condensed US Text-like description	Condensed US Interpretation of underlying meaning	Categories	Topic
E4	[...] no, la he escuchado pero que la entienda no. [...] mmm pues sí, o sea, entre amarillo y blanquito. [...] no pues yo creo que se los debilita, porque toca estar pendiente con el odontólogo.	Lo he oído, pero no lo entiendo. Son manchas entre amarillas y blancas que creo que debilitan el diente.	Son manchas que debilitan el diente.	Debilitamiento de los dientes	Percepción de fluorosis dental
E5	[...] que se le hacen como unos, unos, unos pedazos en los dientes o ¿desgaste de los dientes? [...] pienso que lo puede estar debilitando ¿no?, porque ya pues ya el exceso de ese líquido pues acabaría con los dientes.	Algunos pedazos en los dientes o desgaste en los dientes, que pueden ir debilitando, porque el exceso de ese líquido puede destruir los dientes.	Pienso que lo puede estar debilitando	Debilitamiento de los dientes	Falta de conocimiento de fluorosis dental
E6	'' no no, no lo sé. [...] están en perfecto estado. [...] debilitar. [...] no sé porque, pero sí sé que es maluco esas manchas.	Puede debilitarse, no sé porque, pero si sé que es maluco esas manchas	Puede debilitarse	Debilitamiento de los dientes	Percepción de fluorosis dental
E7	[...]no. [...] ¿cómo limpieza?, ¿es una limpieza? [...] mañones [...] pues de vez en cuando se las miro. [...] si, cuando comen, cuando se cepillan. [...] si, cuando comen, cuando se cepillan. [...] más débiles. [...] porque de pronto, o sea se le queda la comida ahí y eso le... ¿produce caries?	No había oído hablar de fluorosis. Las manchas hacen más débiles los dientes porque se queda comida y produce caries.	Manchas que debilitan los dientes.	Debilitamiento de los dientes	Falta de conocimiento de fluorosis dental
E8	'' no, nada porque no he escuchado hablar de eso. [...] débiles de pronto [...] porque son manchas que no, no se les ha visto en los dientes.	Nunca había oído hablar de esto, de repente puede debilitarse, porque son manchas que no se han visto en los dientes. Para prevenir la caries en los niños, y no la tienen.	Son manchas que no se veían en los dientes.	Debilitamiento de los dientes	Falta de conocimiento de fluorosis dental
E9	[...] si. [...] ¿es lo que le colocan a los niños, para evitar la caries? [...] no, no tienen. [...] mmm no se.	Para prevenir las caries en los niños	Para prevenir las caries en los niños	Prevención	Percepción de fluorosis dental
E10	'' no. [...] ¿tengo entendido que aplican un líquido en los dientes? [...] no, los de mis hijos no. [...] debilitar. [...] mmm pues pienso que unos dientes sanos deben tener su color, o sea su color blanco o el que sea, pero no cambiar de color.	Aplican un líquido en los dientes que pueden cambiar de color.	Aplican un líquido en los dientes	Falta de conocimiento	Percepción de fluorosis dental