UPDATE

Epidemiology of Dental Fluorosis in 12-year-old adolescents: Systematic review

Epidemiologia de la Fluorosis Dental en adolescentes de 12 años: Revisión sistemática

Epidemiologia da Fluorose Dentária em adolescentes de 12 anos: Revisão sistemática

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Abstract

The prevalence of dental fluorosis presents great variability worldwide. Its analysis is necessary as part of epidemiological surveillance

Objective: To know the available literature on the prevalence of dental fluorosis among 12 years-old in relation to the community fluoridation method used.

Methodology: Two researchers carried out a systematic review of the literature without time limits following the PRISMA guidelines, using the Pubmed, Cochrane, Scopus, BVS and Google Schoolar databases in English, Spanish, Portuguese and Italian.

Results: 19 cross-sectional articles were included, 16 belonging to communities that use fluoridated water, one that use fluoridated salt and 2 that compare results between communities that use fluoridated water or salt.

Conclusions: there is great variability in the reports of prevalence of dental fluorosis. Regardless of the community fluoridation method used, fluorosis lesions of mild severity are the most prevalent.

Keywords: Dental fluorosis, Fluorides, fluoridated salt, fluoridated water, adolescents.

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Resumen

La prevalencia de fluorosis dental presenta una gran variabilidad a nivel mundial. Es necesario su análisis como parte de la vigilancia epidemiológica.

Objetivo: Conocer la literatura disponible sobre prevalencia de fluorosis dental a la edad de 12 años en relación con el método de fluoruración comunitario utilizado.

Metodología: Dos investigadoras realizaron una revisión sistemática de la literatura sin límites temporales siguiendo las pautas PRISMA, utilizando las bases de datos Pubmed, Cochrane, Scopus, BVS y Google Schoolar en idioma inglés, español, portugués e italiano.

Resultados: Fueron incluidos 19 artículos de diseño transversal, 16 pertenecientes a comunidades que utilizan agua fluorurada, uno que utiliza sal fluorurada y 2 que comparan resultados entre comunidades que utilizan agua o sal fluorurada.

Conclusiones: existe gran variabilidad en los reportes de prevalencia de fluorosis dental. Independientemente del método de fluoruración comunitario utilizado las lesiones de fluorosis de severidad leve son las más prevalentes.

Palabras clave: Fluorosis dental, Fluoruros, sal fluorurada, agua fluorurada, adolescentes.

Resumo

Os relatos sobre a prevalência de fluorose dentária aos 12 anos apresentam grande variabilidade, não havendo unificação quanto ao uso Sua análise é necessária no âmbito da vigilância epidemiológica.

Objetivo: Conhecer a literatura disponível sobre prevalência de fluorose dentária aos 12 anos em relação ao método comunitário de fluoretação utilizado.

Metodologia: Dois pesquisadores realizaram uma revisão sistemática da literatura sem limites de tempo seguindo as diretrizes PRISMA, utilizando as bases de dados Pubmed, Cochrane, Scopus, BVS e Google Schoolar em inglês, espanhol, português e italiano.

Resultados: Foram incluídos 19 artigos transversais, sendo 16 pertencentes a comunidades que utilizam água fluoretada, un sal fluoretada e 2 que comparam resultados entre comunidades que utilizam água ou sal fluoretado.

Conclusões: Há grande variabilidade nos relatos de prevalência de fluorose dentária. Independentemente do método de fluoretação comunitária utilizado, as lesões de fluorose de gravidade leve são as mais prevalentes.

Palavras-chave: Palavras-chave: Fluorose dentária, Fluoretos, sal fluoretado, água fluoretada, adolescentes.

Introduction and Background

The mechanism of action of fluorides is based on regulating the mineral balance between the tooth and oral fluids, with their bioavailability at low concentrations in the oral environment being fundamental [1]. Strategies to deliver fluorides to the oral cavity are classified as: community (water, salt, milk), individual (toothpastes and mouthrinses), professional (gels, varnishes, foams, etc.), or a combination of these [2]. The community-based strategies are directly related to a progressive decrease in the prevalence of caries worldwide.

Community access to fluoride, through artificially fluoridated drinking water and salt, has proven to be an efficient public health measure to globally reduce dental caries [2]. Regarding

fluoridated milk, the Cochrane review conducted to evaluate the available evidence up to 2014 concluded that it could be beneficial in reducing caries levels in schoolchildren. However, more high-quality studies are needed to reach a definitive conclusion regarding the degree of benefit of this measure [3].

Sustained exposure to excess fluoride (beyond the recommended dose according to the World Health Organization) can be harmful, causing dental fluorosis (DF).

DF is a qualitative structural defect of enamel. It is a form of hypomineralization where the enamel exhibits more porous areas with a higher protein content [4,5]. Clinically, the characteristic lesions of DF appear opaque and calcareous, reflecting the increased porosity of the affected enamel. Its prevalence varies between 13.4% and 76.4% worldwide, and specifically in Latin America, it ranges from 29.42% to 63.7% [6–9]. It appears in its mildest severity levels across all program reports utilizing community fluoridation as a strategy [10–14].

Since 1991, Uruguay has implemented a table salt fluoridation program with a concentration of 250 mg/kg of sodium fluoride. However, we have no available reports of its monitoring [15].

Two recently published studies have raised concerns within the scientific community of our country. One of them reports a high prevalence of fluorosis among 12-year-old schoolchildren in the Department of Montevideo (84.8%), where 98.8% of cases were classified as very mild or mild fluorosis, and only 1.2% as moderate or severe fluorosis [9]. The second study highlights the wide variability in fluoride concentrations found in the analysis of domestic salt packages marketed in Montevideo, revealing the lack of program surveillance [16]. Periodic monitoring of both the quality of fluoridation and its impact on the population would optimize the benefits and enhance the safety of this Public Health measure.

This study aimed to analyze the scientific evidence on the prevalence and severity of dental fluorosis among 12-year-old adolescents in relation to the community fluoridation method used.

Methodology

In 2022, a systematic review of the literature in Spanish, English, Portuguese, and Italian was conducted, identifying epidemiological studies on DF among 12-year-old adolescents in communities with salt or water fluoridation programs. The study followed PRISMA guidelines for design and publication [17] and was registered in the PROSPERO registry.

Search strategies were created to cover the following databases without time restrictions: PubMed (Medline, NCBI, USA), Cochrane Library (Cochrane Collaboration, including Cochrane Oral Health's Trials Register and the Cochrane Central Register of Controlled Trials (CENTRAL)), Scopus (via Timbo foco, the academic access platform of the University of the Republic of Uruguay and the National Agency for Research and Innovation), and the Virtual Health Library (PAHO/WHO) were utilized. The gray literature database Scholar Google was also included *(Table 1)*.

All articles providing epidemiological data on fluorosis among 12-year-olds in communities with water fluoridation (WF) or salt fluoridation (SF) were included. Articles from communities with naturally fluoridated water were excluded.

Two reviewers (IG, SA) independently evaluated the identified publications. Duplicate papers were excluded, and selection by title and abstract was performed. After full-text reading, the final selection of articles was made according to the eligibility criteria. In cases of disagreement, two expert reviewers (LA, JL) solved the issue.

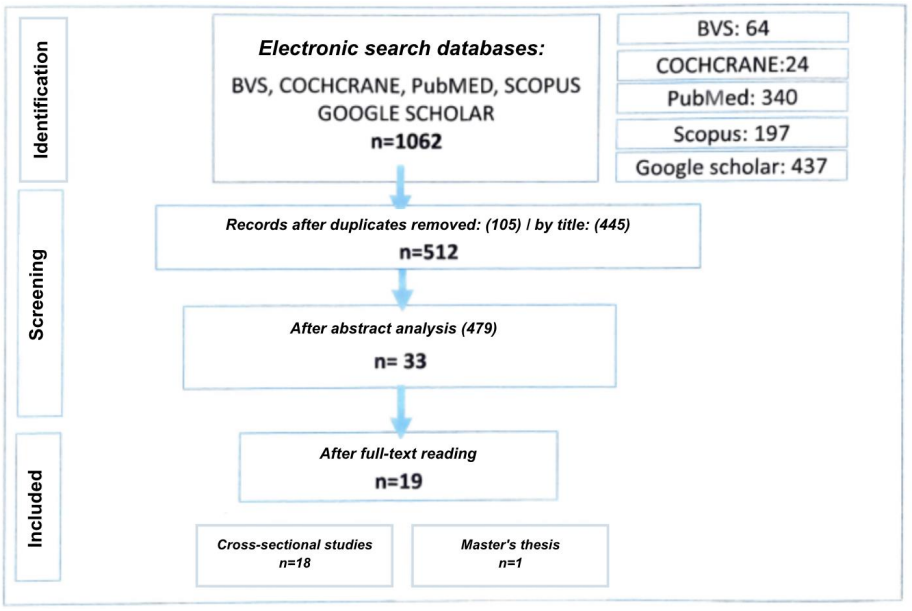
Table 1. Search criteria and results.

DATABASE	STRATEGY	RESULTS LINK
Pubmed (MEDLINE)	(Fluoride[All fields] OR Fluoridation[All fields] OR fluoridated[All fields]) AND (salt[tiab] OR water[tiab]) AND (epidemiology[All fields] OR prevalence[tiab] OR epidemiologic[All fields] OR statistics[All fields] OR "numerical data"[All fields]) AND hasabstract[text] (((12 AND child*) OR school*) AND fluorosis) Filters: from 1000/1/1 - 2021/4	340
Cochrane Library	#1 fluoride OR fluoridation OR fluoridated #2 salt OR water #3 epidemiology OR prevalence OR epidemiologic #4 statistics #5 "numerical data" #6 child OR school #7 fluorosis #8 #3 OR #4 OR #5 #9 #1 AND #2 AND #8 AND #6 AND #7	24
Scopus (via Timbo Foco)	TITLE-ABS-KEY (((fluoride OR fluoridation OR fluoridated) AND (salt OR water) AND (epidemiology OR prevalence OR epidemiologic OR statistics OR "numerical data") AND (child OR school) AND fluorosis)) AND NOT INDEX (medline) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010) OR LIMIT-TO (PUBYEAR, 2009) OR LIMIT-TO (PUBYEAR, 2008) OR LIMIT-TO (PUBYEAR, 2007) OR LIMIT-TO (PUBYEAR, 2006) OR LIMIT-TO (PUBYEAR, 2005) OR LIMIT-TO (PUBYEAR, 2004) OR LIMIT-TO (PUBYEAR, 2003) OR LIMIT-TO (PUBYEAR, 2002) OR LIMIT-TO (PUBYEAR, 2001) OR LIMIT-TO (PUBYEAR, 2000) OR LIMIT-TO (PUBYEAR, 1999) OR LIMIT-TO (PUBYEAR, 1998) OR LIMIT-TO (PUBYEAR, 1997) OR LIMIT-TO (PUBYEAR, 1996) OR LIMIT-TO (PUBYEAR, 1994) OR LIMIT-TO (PUBYEAR, 1988) OR LIMIT-TO (PUBYEAR, 1985) OR LIMIT-TO (PUBYEAR, 1981) OR LIMIT-TO (PUBYEAR, 1980) OR LIMIT-TO (PUBYEAR, 1976) OR LIMIT-TO (PUBYEAR, 1975))	197
BVS	fluor* AND (agua OR sal) AND (comuni* OR poblac* OR zona OR región OR personas OR demogra*) AND (epidemiol* OR estadíst* OR datos* OR preval*) AND fluorosis AND (niño OR adolescente) AND (db:("LILACS" OR "BBO" OR "BINACIS" OR "IBECS" OR "LIPECS" OR "CUMED"))	64
Scholar Google (Literatura gris)	(((fluoride|fluoridation|fluoridated) AND (salt|water) AND (epidemiology|prevalence|epidemiologic|statistics|"numerical data") AND (child|school) AND fluorosis))) AND (child|adolescent|12)	436

Results

The search strategy retrieved 1062 articles (437 from Google Scholar, after screening until no significant new words were found; 340 from PubMed; 197 from Scopus; 64 from BVS; 24 from Cochrane), of which only 512 were considered for abstract reading after eliminating duplicates and reviewing titles. To avoid overlapping data, only the most recent publication from the same research team was included. After reading the abstracts, 479 articles were excluded, resulting in 19 articles being included after full-text reading *(Figure 1).*

Figure 1: Flow chart of the search strategy



The included articles were all cross-sectional studies: 14 from Brazil, two from Europe (Switzerland and Ireland), one from Uruguay, one from the USA, and one from Asia (Singapore). Of all the included studies, 16 were conducted in communities using water fluoridation, one used fluoridated salt, and two compared communities using water or salt.

Fluorosis prevalence showed a very broad range between 0.5% and 84.1% globally and in Latin America between 0.5% and 58.9% [19,20].

Variations were observed in the indices used across the selected studies, each applied with different criteria. Thirteen studies employed the Dean index (DI) [18–30], while five utilized the Thylstrup Fejerskov index (TFI) [7,31–34], with one study comparing both [35]. Among those employing the DI, 10 merged the "healthy" and "questionable" categories to signify the absence of DF [18,20–26,28,29], while 3 interpreted the "questionable" category as indicative of DF [27,30,33], 1 provided no specifications [19]. A study correlated the TFI with the DI, considering the "questionable" category as indicative of DF [34].

Consensus among studies reporting on fluorosis severity indicates that mild and moderate lesions predominate, regardless of the community fluoridation method or index utilized [7,18,31,32,34,36,20–22,24,26,27,29,30] *(Table 2)*.

Discussion

This review aimed to assess available literature concerning epidemiological data on DF and the diagnostic indicators used at the age of 12.

Community water and/or salt fluoridation is a universal measure for preventing dental caries (DC) [37–39]. It represents an equitable, cost-effective public health measure, offering lifelong oral health benefits to all community members and reducing disparities. The systematic review conducted by Iheozor-Ejiofor et al. in 2015, aimed at assessing the effects of fluoridated water on the prevention of DC and DF, concluded that the implementation of WF resulted in a 35% reduction in the extent of DC in primary dentition (DFT) and 26% in permanent dentition (DMFT) [40]. The benefits of using SF in DC prevention were firmly established in the early 1980s, following numerous successful implementations of this measure in European and American countries [37].

Table 2. Selected articles regarding dental fluorosis at 12 years of age.

AUTHOR YEAR	COUNTRY	INDEX	FLUORIDATED COMMUNITY MEASURE	FLUORIDE CONCENTRATION	RESULTS
LEVERETT D. 1986	U.S.A.	DI	WF	Optimal = 1.0 ppm*	1. Prevalence at 12 years: 23.7% 2. Mild lesion most prevalent
LO GL & COL. 1996	Singapore	DI	WF	0.7 mg/L	1. Prevalence at 12 years: 84.1% 2. Mild lesion most prevalent
MOYSÉS S & COL. 2002	Brazil	DI	WF	(not specified) **	1. Prevalence: 23% 2. Severity: 20% ML and L/2% M/0.6 S 3. No aesthetic concern
PROVENZANO MG, 2003	Brazil	TFI/ DI	WF	0.8 mg/L	1. Prevalence: TFI 49.39% / DI 49.12% 2. Affected teeth: 53.6% 3. Most prevalent TFI:1 / DI: ML 4. More prevalent in males
CYPRIANO S. 2003	Brazil	DI	WF	(not specified) **	1. Fluorosis prevalence at 12 years: 14.9% 2. Severity: ML 8.2% / L 2.2% / M 0.8% / S 0.1%
SAGHERI D. 2007	Ireland	DI	WF / SF	WF: 1 ppm SF: 200 ppm	1. Dublin prevalence: 25.5% 2. Severity: C 11.7% / ML 9.8% / L 3.7% / M 0.3% 3.Fribourg prevalence: 19.4% 4.Severity: C 10.9% / ML 4.0% / L 3.4% / M 0%
RAMIRES I & COL. 2007	Brazil	TFI	WF	0.8 mg/L	1. Prevalence: 37.36% 2. Severity: TFI 1 most prevalent 28% 3. Most affected upper PM
DITTERICH R. 2008	Brazil	DI	WF	0.7 ppm	1. Prevalence: 24.4% 2. Severity: ML 17.1% / L 7.3% / 3. No differences between sexes
MORO L & COL. 2009	Brazil	DI	WF	0.7 to 1.1 ppm	1. Prevalence: 12.9% 2. Severity: ML 8.8% / L 1.1% 3. More prevalent in the private healthcare sector
FRANZOLIN S & COL. 2010	Brazil	TFI	WF	(not specified) **	1. Prevalence: 39.45% 2. Higher prevalence in regular fluoridation 3. Higher prevalence of TFI 1 and 2 lesions
RIGO L & COL. 2010	Brazil	DI	WF	0.6 to 0.9 ppm	1. Prevalence: 36.2% 2. Severity: C 8.7% / ML 78.4% / L 11.1% / M 1.9% 3. Association between DF frequency and low risk of CA
BUTCHEL K & COL. 2011	Switzerland	TFI	WF / SF	WF: 0.8 to 1 ppm SF: 250 ppm	1. Prevalence: 31.9% WF and SF 2. Severity: 90% presents TFI 1 and 2 3. Most affected tooth is MCI, followed by MLI
ANGULO & COL. 2011	Uruguay	TFI	SF	250 mg/Kg	1. Prevalence: 45% 2. Severity: Higher prevalence of TFI 1 and 2
BENAZZI A & COL. 2012	Brazil	TFI	WF	0.7 ppm	1. Prevalence: 29.4% 2. Severity: Higher prevalence TFI 2 followed by TFI 1

AUTHOR YEAR	COUNTRY	INDEX	FLUORIDATED COMMUNITY MEASURE	FLUORIDE CONCENTRATION	RESULTS
NARVAI PC & COL. 2013	Brazil	DI	WF	(not specified) **	1. Prevalence: 1998: 43.8% / 2002: 33.7% / 2008: 40.3% / 2010: 38.1% 2. Severity: ML / 1998: 28.7% / 2002: 24.9% / 2008: 29.8% / 2010: 29%
AZEVEDO M & COL. 2014	Brazil	DI	WF	0.6 to 0.9 mg/L	1. Prevalence: 8.53% 2. Severity: ML 13.7% / L 2.5% / M and S 1.88%
JORDÃO L & COL. 2015	Brazil	DI	WF	0.7 mg/L	1. Total prevalence: 58.9% 2. Severity: ML 44% / L 11.9% 3. Association between F^- and presence of DF
JORDÃO L & COL. 2015	Brazil	DI	WF	(not specified) **	1. Prevalence: 18.7% 2. Severity: ML 11.2% / L 4.4% / M 2.6% / S 0.5% 3. No impact on quality of life
FIRMINO R & COL. 2018	Brazil	DI	WF	0.6 to 0.8 ppm	1. Prevalence between 0.5% and 45.8% according to region of the country

*International measurement system 1mg/L is equivalent to 1ppm.
** Brazil has had a water fluoridation program since 1974 with a concentration of 0.7 mg/L (Ministerio Da Saude 2009)

Concerns about the emergence of DF have always accompanied community fluoride measures. Dean's studies, conducted in US populations with varying concentrations of natural fluoride in water, demonstrated a clear correlation between fluoride concentration and the occurrence of DF with varying degrees of severity [41,42]. The concentration recommended by the US Department of Health and Human Services in 1962, and internationally followed, ranged from 0.7 to 1.2 mg/L. Currently, this recommendation has been set at the lower limit of 0.7 mg/L, as evidence suggests that preventive benefits against dental caries remain intact while minimizing the risk of DF [43,44]. The findings from the systematic review published in 2015 by the Cochrane group on water fluoridation suggest that at a fluoride level of 0.7 ppm, there is a 12% probability of developing DF [40]. In this review, the prevalence of fluorosis exhibits a broad spectrum, ranging from 0.5% to 84.1% [18,19], and particularly in Latin America, from 0.5% to 58.9% [19,20]. Such wide-ranging data, primarily sourced from Brazil, a nation employing WF as a community fluoridation method, may stem from variations in the criteria applied to the utilized indexes.

It is pertinent to consider the imperative of standardizing the use of indexes that are universally applicable and sensitive for coding DF. Such standardization would facilitate comparisons with reduced bias risks. Through a literature review, it became evident that the choice of indexes used exhibits significant variability: thirteen studies employed DI, five utilized TFI, one employed TFI while establishing a correlation with DI, and one utilized both, comparing them. This comparative analysis indicates that both indexes can identify DF prevalence similarly, with TFI demonstrating greater specificity in recording the severity of DF [35]. Additionally, among the studies conducted with the DI, ten merge the "healthy" and "questionable" categories as the absence of DF, two consider the "questionable" category as the presence of DF, and one does not specify the criterion used. These variations in the assessment and classification of DF determine numerous limitations

in terms of prevalence data and comparison of findings. This complexity impedes the collaborative efforts of scientific communities in analyzing and measuring the impact, thus hindering the achievement of standardized preventive measures considered universal.

SF has been demonstrated to have a comparable impact on oral health as the aforementioned method, with the added advantage of its elective incorporation into the diet. However, its consumption may face certain limitations related to its vehicle, considering the WHO recommendations for cardiovascular disease prevention [37,39]. The recommended fluoride concentration for salt intended for human consumption ranges from 200 to 250 mg/kg [37]. In this review, prevalence data of DF in studies conducted in communities using SF vary between 19.4% and 45% [27,34]. Regarding this variation, it is important to note that the study reporting a lower prevalence only evaluates the anterior teeth, while the other includes all dental pieces. Thus, this variation is expected because at the age of 12, natural wear on the anterior teeth may lead to underestimated prevalence. Studies evaluating DF based on TFI report a higher prevalence [32,34] compared to those using DI [27]. This difference could be attributed to the prophylaxis and drying procedures carried out prior to TFI evaluation, which are not conducted with DI, potentially leading to an underestimation of DF presence.

It can be asserted that DF in its very mild and/or mild degrees is the sole undesirable effect of community fluoride use measures [14]. Eighteen studies included in this review indicate that the mildest forms of DF are the most prevalent. When comparing severity reports based on the index used, it is notable that "very mild" fluorosis is reported as the most prevalent in ten studies utilizing DI [20–23,26–30,35], while studies employing TFI identify TFI 1 and 2 as the most prevalent severity levels [7,31–35].

Nine studies conclude that due to the way DF presents itself, it is not self-perceived as an aesthetic issue and thus is not considered a public health concern [20,22,25-27,29,31,32,45].

Conclusions

Analysis of the studies included in this review reveals considerable variability in reporting the prevalence of DF. One possible explanation for this finding is the lack of standardized criteria regarding the index used or its application method, which hinders the comparison of study results.

Mild DF is consistently the most prevalent form, irrespective of the community fluoridation method or the index employed. Since this mild presentation of DF is generally not perceived as an aesthetic problem, it is unlikely to impact individuals' quality of life significantly.

Joint efforts among scientific communities are imperative in analyzing and assessing the impact of this public health intervention to maximize its benefits and ensure safety.

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The authors declare no conflict of interest in the publication of the article.

Authorship and Collaboration Contributions Statement

a) Study conception
b) Data acquisition
c) Data analysis
d) Results discussion
e) Manuscript drafting and revision
f) Approval of the final version of the manuscript

IG has contributed to: a, b, c, d, e and f
MSA has contributed to: b, c, d, e and f
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