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ORIGINAL ARTICLE

Dental fluorosis prevalence and severity using Dean's index based on six teeth and on 28 teeth

Carlo Eduardo Medina-Solis · América Patricia Pontigo-Loyola · Gerardo Maupome · Hector Lamadrid-Figueroa · Juan Pablo Loyola-Rodríguez · Jesús Hernández-Romano · Juan José Villalobos-Rodelo · Ma. de Lourdes Marquez-Corona

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Abstract To contrast the sensitivity, specificity, and positive–negative predictive values between dental fluorosis prevalence scored on 28 (DF28) and on six permanent teeth (DF6), we undertook a cross-sectional study on 1,538 adolescents (12 and 15 years old) residing in Hidalgo State, Mexico, a naturally fluoridated (>0.7 ppm) area at an elevated altitude (>2,500 m above sea level). Dental fluorosis was scored using Dean's modified index. Using the scores obtained for all teeth present (DF28) as a gold standard, we calculated the sensitivity, specificity, positive–negative predictive values, and receiver operating characteristic and concordance index pertaining to the scores based on six teeth (upper incisors and canines). DF28 fluorosis prevalence was 81.7%; based on DF6, it was 58.7% (23% difference). Among 12 year olds, the difference between DF28 and DF6 was 20.1% (84.5 vs. 64.4%); among 15 year olds, it was 25.4% (79.4 vs. 54%). Among girls, it was 23.2% (81.1 vs. 57.9%) and among boys, 22.8% (82.2 vs. 59.4%). The fluorosis community indices were 1.75 (DF28) and 1.11 (DF6). All positive predictive values reached 100% while negative predictive values were below 45%. Concordance between DF28 and DF6 was 53.9%, and kappa coefficient was 0.40. Partial scoring of fluorosis based on esthetically important permanent teeth underestimated prevalence, compared to full-mouth scoring. The decision to use an abridged Dean's index protocol

C. E. Medina-Solis · A. P. Pontigo-Loyola · M. L. Marquez-Corona
Área Académica de Odontología del Instituto de Ciencias de la Salud, Universidad Autónoma del Estado de Hidalgo, Pachuca, Hidalgo, Mexico

G. Maupome
Oral Health Research Institute, Indiana University/Purdue University at Indianapolis School of Dentistry, Indianapolis, IN, USA

G. Maupome
The Regenstrief Institute, Inc., Indianapolis, IN, USA

H. Lamadrid-Figueroa
Dirección de Evaluación de Programas y Bioestadística, Centro de Investigación en Evaluación y Encuestas del, Instituto Nacional de Salud Pública, Cuernavaca, Morelos, Mexico

J. P. Loyola-Rodríguez
Facultad de Estomatología, Universidad Autónoma de San Luís Potosí, San Luis Potosi, Mexico

J. Hernández-Romano
Universidad Politécnica del Estado de Morelos, Cuernavaca, Morelos, Mexico

J. J. Villalobos-Rodelo
Facultad de Odontología, Universidad Autónoma de Sinaloa, Culiacán, Sinaloa, Mexico

C. E. Medina-Solis (✉)
Privada de Altillo s/n entre Av. Central y Pedro Moreno. Colonia San José, CP. 24040 Campeche, Campeche, Mexico
e-mail: cemedinas@yahoo.com

must take into account the number of teeth examined, and which specific teeth are examined, to appraise the benefit of reduced data collection effort against possible information loss.

Keywords Oral health · Fluorosis · Prevalence · Epidemiology · Mexico

Introduction

Fluoride has been used for many years in caries prevention, mainly as community water fluoridation, whereby 1 ppm of fluoride in drinking water leads to a reduction in dental caries with minor side effects—such as (largely negligible) dental fluorosis [2, 3, 20]. Over the past few decades, however, wide availability of fluoride in multiple presentations (e.g., treatment applied by dental professionals, oral health programs, fluoride supplements, and fluoride in food and beverages, drinking water, domestic salt, toothpastes, and food grown in soil containing fluoride or irrigated with fluoridated water) has exposed people to higher fluoride doses than strictly needed for preventive purposes. This evolving situation has increasingly contributed to dental fluorosis [1, 5, 7, 8, 13, 16, 18, 20] due to increased exposure to fluoride when permanent teeth are more susceptible to be affected [2, 12]—by and large before the age of 6 years (susceptibility window) [7, 19]. The early maturation stage of enamel development is more critical for fluorosis than is the earlier, secretory stage [4, 18, 19].

Around the world, fluorosis prevalence varies depending on diverse characteristics of the community under study: fluoride present naturally in drinking water [14, 17, 23, 33], public health fluoridation programs [1, 27, 30], as well as the altitude of the community above sea level where study subjects reside [15, 26]. For example, estimated fluorosis prevalence ranges between 30% and 80% in fluoridated and 10–40% in non-fluoridated areas of the US [25]. In Mexico, the prevalence of dental fluorosis ranges from 30% to 100% in areas where water is naturally fluoridated, to 52% to 82% in areas where fluoridated salt is used [28]. Not surprisingly, the system used to diagnose or score dental fluorosis also plays a role in driving the stated prevalence of fluorosis higher or lower along the scales; as the definitions of severity or cases change, the proportion that is considered to have fluorosis (persons or teeth) also changes.

Several diagnostic scoring systems have been proposed for assessing the prevalence and severity of dental fluorosis. Although each system is used to evaluate the clinical effects of fluoride exposure on tooth structure, the focus of each approach is specific to the purposes it was originally designed to address [9]. They include the Thylstrup–Fejerskov Index [29], the Tooth Surface Index of Fluorosis [6], and the Fluorosis Risk Index [18]. However, one of the longest standing indices, very commonly used in epidemiological studies, is the index created by Dean in 1934, the Dean's Fluorosis Index and its subsequent modifications [24]. This index is often used by the Word Health Organization [34] and remains as the gold standard index in the public health armamentarium. While the widespread use of the Dean's Fluorosis Index makes it a common choice among competing indices, it is not well established whether scoring only esthetically important and easier-to-access teeth (upper anteriors) makes it less reliable than the more conservative, yet time consuming approach of scoring every tooth in the mouth. The possible impact of this economy of effort on epidemiological data gathering has not been quantified in a population exposed to high levels of fluoride in drinking water, at a high altitude above sea level (a likely risk factor for dental fluorosis) [15, 26]. We carried out the present study to contrast the diagnostic tests' values between fluorosis prevalence scored on 28 teeth and on six teeth (upper permanent incisors and canines), using Dean's modified index.

Materials and methods

Study design and population

The study design followed the ethical guidelines laid out to protect participants' individual rights during biomedical studies at the School of Dentistry, Universidad Nacional Autónoma de México. An informed written consent from parents was obtained prior to clinical examination according to the ethical guidelines of the Helsinki Declaration (1975).

Tula de Allende is one municipality in the State of Hidalgo with six locales: Tula Centro, El Llano, San Marcos, Santa Ana Ahuehuepan, San Miguel Vindhó, and Bomintzha. The first two are located at 2,040 m of altitude (6,690 ft) and the third one at 2,050 m (6,725 ft.). Weather is mild, semi-wet with rain in summer and semi-dry throughout the remainder of the year, with an average temperature of 17°C (63°F). Average fluoride concentrations in drinking water were obtained from the Drinkable Water Commission and Tula's Sewer System; readings for Tula Centro were 1.42 F ppm, San Marcos 1.38 F ppm, and El Llano 3.07 F ppm. Hidalgo is one of the states in Mexico that is part of the fluoridated domestic salt program implemented at the national level in 1991.

A detailed description of "Materials and methods" has been published elsewhere [21, 22]. Briefly, this cross-sectional investigation studied a pool of 1,768 schoolchildren, 12 and 15 years of age, from all of the elementary and junior high schools in Tula Centro, San Marcos, and El Llano. Seven schools did not participate in the study due to logistic limitations, leading to 139 schoolchildren being out of the study (7.9%). A total of 1,629 schoolchildren attending the remaining 25 schools participated in the study in 1999 and received an oral exam, except for 91 schoolchildren that were excluded (43 used fixed orthodontics appliances; two had full crowns; 40 left school before the exam took place; and six refused to be examined). The final study sample was 1,538 individuals. Basic variables collected were sex and age.

Dental examination

Dental examinations were performed by two examiners previously trained and standardized (kappa interexaminer=0.85; intraexaminer=0.97). A pilot study was conducted beforehand to standardize fluorosis criteria, and to verify the duration of the examination procedures. The modified Dean's index was used, where 0=no fluorosis or questionable, 1=very mild, 2=mild, 3=moderate, and 4=severe. Fluorosis was differentiated from other opacities [24].

Dental exams were carried out using a mirror, under daylight, after plaque removal was completed using a toothbrush. Teeth were not dried prior to the administration of the index; every permanent tooth present was included in the exam as long as it had at least 50% of the clinical crown erupted. The index was calculated based on 28 teeth and six teeth (upper incisors and canines). The two teeth with the worst score were used for the person-level score. Where two teeth were not affected to the same degree, we used the criterion often used in recent years: to assign a category based on the less involved tooth of the two exhibiting the worst scores—in other words, to assign a person-level score based on the less severe of the two worst scores [24].

Data analysis

A dataset was constructed and analyzed with the statistical program STATA 8.2®. Our data analysis plan started with the determination of simple absolute frequencies and their distributions. Frequency and distribution of fluorosis values by age and sex were obtained. In the bivariate analysis, Spearman's correlation test was used to compare the correlation in the severity of fluorosis. We calculated the sensitivity (proportion of diseased cases correctly identified), specificity (proportion of healthy cases correctly identified), the positive predictive value (probability of a subject having the disease given a positive diagnostic test), the negative predictive value (probability of a subject not having the disease given a negative diagnostic test), and the receiver operating characteristic area (ROC curve, the average combined sensitivity and specificity for a simple test). As the gold standard, we used the index based on the scores recorded for the 28 teeth—or as many as were present in the mouth. Because these are census data (we targeted the entire population of the municipality), we did not calculate *p*-values or 95% confidence intervals.

Table 1 Fluorosis prevalence by age and sex using DF28 (index scored on 28 teeth) and DF6 (index scored on six teeth) measurements

Variables	DF28	DF6	Difference
Age			
12 years (*n*=688)	84.5%	64.4%	20.1%
15 years (*n*=850)	79.4%	54.0%	25.4%
Sex			
Girls (*n*=768)	81.1%	57.9%	23.2%
Boys (*n*=770)	82.2%	59.4%	22.8%
All (*n*=1583)	81.7%	58.7%	23.0%

Concordance agreement=77.0%; Kappa coefficient=0.48

DF28 Prevalence of dental fluorosis, as derived from an index scored on 28 teeth *DF6* prevalence of dental fluorosis, as derived from an index scored on six teeth.

Results

Included in the analysis were 1,538 adolescents; 49.9% were women; 44.7% were 12 years old and 55.3% were 15 years old. Table 1 shows dental fluorosis prevalence by age and sex; overall prevalence of fluorosis was 81.7% using DF28 and 58.7% with DF6. The difference in dental fluorosis prevalence between DF28 and D6 ranged across various subgroups from 20.0% to 25.4%. When dental fluorosis was analyzed as a dichotomous variable (0=no fluorosis, 1=any fluorosis), concordance agreement between DF28 and DF6 was 77.0%, while Kappa coefficient was 0.48.

Table 2 presents contrasts of the DF6 against the DF28 ("gold standard"), stratifying by age and sex. All specificity values were as high as 100% while sensitivity values were below 80%. ROC values were generally high, between 0.840 and 0.881. All positive predictive values were high (100%), with negative predictive values below 45%. Table 3 presents the distribution of dental fluorosis across DF6 and

Table 2 Sensitivity, specificity, positive and negative predictive values, comparing DF6 against DF28 in each subgroup studied

Variable	Sensitivity	Specificity	ROC area	PPV	NPV
Age					
12 years (*n*=688)	76.2	100	0.881	100	43.7
15 years (*n*=850)	68.0	100	0.840	100.0	44.8
Sex					
Girls (*n*=768)	71.4	100	0.857	100	44.9
Boys (*n*=770)	72.2	100	0.861	100	43.8
	71.8	100	0.859	100	44.3

PPV Positive predictive value; *NPV* negative predictive value; *DF28* gold standard

Table 3 Comparison of dental fluorosis levels derived from DF6 and DF28 fluorosis scores

28 teeth index (DF28)	Six teeth index (DF6)					Total
	No-fluorosis	Very-mild	Mild	Moderate	Severe	
No-fluorosis	282	0	0	0	0	282 (18.3)
Very-mild	294	281	0	0	0	575 (37.4)
Mild	34	90	102	0	0	226 (14.7)
Moderate	12	36	46	67	0	161 (10.5)
Severe	14	37	55	91	97	294 (19.1)
Total	636 (41.4)	444 (28.9)	203 (13.2)	158 (10.2)	97 (6.4)	1538

Note: percentages in parentheses. Community Fluorosis Index 28 teeth=1.75, Community Fluorosis Index six teeth=1.11, Spearman's correlation: $r=0.7919$, concordance agreement=53.9%, Kappa coefficient=0.40

DF28 scores, suggesting that only limited agreement was found between the DF6 and DF28 (concordance agreement 53.9%, Kappa coefficient 0.40). The fluorosis community indices were 1.75 (DF28) and 1.11 (DF6).

At the individual tooth level, the teeth that were more often bilaterally affected by fluorosis (any severity) were the lower second molars, followed by the upper second molars, and the upper second premolars (Table 4). The teeth that were more commonly affected by severe dental fluorosis were the upper second molars, followed by the upper first molars, and the upper first premolars. The teeth least likely to be affected by severe dental fluorosis were the lower lateral incisors. In both upper and lower arches, fluorosis was more severe in posterior than in anterior teeth.

Discussion

Several indices, focused on either a description of the condition or its etiology, have been proposed for measuring fluorosis. This multiplicity of measurement tools has made comparisons among studies complex and assessment of fluorosis prevalence sometimes unreliable [32]. Dean's index provides a valuable perspective of fluorosis prevalence [11], as opposed to severity or etiological considerations. Because fluorosis prevalence has increased over the last few decades as a consequence of improved fluoride availability impacting developing enamel, fluorosis prevalence has increased in many populations [25]; considering the likely public health impact of this trend, there is a need to examine the competing advantages of various data collection and examination protocols to document fluorosis. The present report examined one aspect of the protocol concerning Dean's index—that of scoring the index on the entire permanent dentition or using an abridged version of the protocol.

Because of its simplicity, the Dean's Fluorosis Index and its subsequent modifications [16] have been used as a common tool in epidemiological studies in which the entire dentition was scored, and where only partial dentition scoring was employed. Our results have quantified the extent of the disagreement between the two approaches. Differences did exist between DF6 and DF28, and they were substantial. It has been reported that the longer maturation process of premolars and molars and their thicker enamel structure could be the likely explanation for the higher occurrence of dental fluorosis in posterior teeth [10, 31]; our findings confirmed that those teeth that appeared to be affected more severely and more often seemed to have the longest developmental maturation interval. The fact that certain teeth showed increased evidence of fluorosis suggests that information loss is not only important when an abridged version of Dean's index is used, but it is also affected by teeth that are included in such abridged protocol. These observations are in agreement with the (anatomically more detailed) results offered by Levy et al. [11] using the Fluorosis Risk Index. Even

Table 4 Bilateral agreement across fluorosis statuses per tooth

	% Agreement			
	Sound to severe[a]	Excluded sound[b]	No fluorosis[c]	Severe fluorosis[d]
Upper teeth				
Second molars	93.3	93.3	28.5	9.9
First molars	93.4	91.8	49.9	8.8
Second bicuspids	92.5	90.6	37.5	7.3
First bicuspids	93.6	92.7	38.8	8.3
Canines	94.1	92.2	46.7	4.4
Lateral incisors	95.5	94.1	48.4	1.7
Central incisors	97.0	95.4	50.4	4.2
Lower teeth				
Second molars	93.2	93.2	27.7	7.9
First molars	95.0	92.4	53.7	6.3
Second bicuspids	94.9	94.1	43.1	4.8
First bicuspids	93.3	91.8	43.5	4.5
Canines	94.3	92.2	53.1	3.0
Lateral incisors	97.6	95.9	63.7	1.2
Central incisors	98.6	96.3	64.7	1.5

[a] Included all teeth: sound, and with very mild, mild, moderate, and severe fluorosis
[b] Included only teeth with very mild, mild, moderate, and severe fluorosis
[c] Included only sound teeth
[d] Included only teeth with severe fluorosis

though their report was focused more specifically on the anterior teeth, both studies agree that readings derived from different teeth offer varying prevalence figures—bilateral symmetry in fluorosis occurrence notwithstanding.

While it is generally agreed that the choice of a fluorosis index should take into account the primary purpose of the research effort (descriptive, analytic, treatment, esthetic, and/or etiological), a prevalence study and a study of fluorosis esthetics may use appropriately different examination protocols. Additionally, the features of the community or population under study should also be considered during the research design stage. The presence of fluoride in drinking water (naturally available or adjusted by means of public health measures), the reliance on food and drinks manufactured in fluoridated areas, the altitude above sea level, and the total exposure to various fluoride sources at the individual level (e.g., school programs for fluoride rinses) or throughout the community (e.g., fluoridation of domestic salt) should guide the decision of which index, and which index protocol, would be appropriate to maximize the value of information collected while minimizing the effort and time involved. Although more researchers and public health workers are starting to use photographic methods for recording changes in fluorosis over time, inclusion of 28 teeth in photographic assessments poses additional complexities. A methodological shortcoming in the present study was that the dental exam was carried out using only daylight; examining the teeth (in particular molars) might have been more reliable if artificial light had been used as well.

An interesting contrasting framework would be afforded by replicating the present investigation in a setting at reduced risk of fluorosis or at least lower than the relatively high experience that has been reported for the Hidalgo municipality where the present study was carried out.

While Dean's index was not originally designed to address the differences derived from measuring fluorosis based on a full-mouth or six-teeth basis, it has become the recommended index by WHO for epidemiological data collection studies. Based on our findings, we concluded that partial scoring of fluorosis limited to esthetically important permanent teeth underestimated prevalence, compared to full-mouth scoring. The decision to use an abridged Dean's index protocol must take into account the number of teeth examined, and which specific teeth are examined, to appraise the benefit of reduced data collection effort against possible information loss.

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