Use of the Fluorosis Risk Index in a Cohort Study: The Iowa Fluoride Study

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Abstract

Objectives: *Several studies have used the Fluorosis Risk Index (FRI) to assess risk factors for dental fluorosis. This study reports fluorosis prevalence estimates in a birth cohort using the FRI in different ways.* ***Methods:*** *Subjects (n=443) were participants in the Iowa Fluoride Study, a birth cohort study of fluoride exposures and intake, fluorosis, and caries. Early-erupting permanent teeth were assessed for fluorosis using the FRI at approximately age 9. Fluorosis prevalence rates were calculated separately for specific teeth and different combinations of teeth, with varied FRI zones included and using different thresholds. Mean numbers of teeth with fluorosis were calculated.* ***Results:*** *Tooth-specific fluorosis prevalence varied, with maxillary central incisor fluorosis most prevalent and mandibular incisors least affected. Considering three zones of each tooth (cervical zones excluded), 40.6% overall had at least one tooth with mild or more involved fluorosis, 30.2% were questionable fluorosis, and 29.1% had no fluorosis. When only FRI zone I areas were considered, the corresponding percentages were 33.2%, 29.3%, and 37.5%, respectively. When different combinations of teeth were used to define fluorosis cases, the prevalences estimated using three zones were generally 1 to 9 percentage points higher than those estimated from FRI zone I only. Most fluorosis was mild, with only 7 individuals (1.6%) having FRI severe fluorosis.* ***Conclusions:*** *The FRI has advantages for use in analytical epidemiologic studies of dental fluorosis. However, the population prevalence estimates vary, depending on the index and case definition used. Therefore, it is recommended that consideration be given to concurrent use of another index (i.e., TSIF, TF, Dean's) if prevalence estimates are an important study outcome.*

Key Words: dental fluorosis, Fluorosis Risk Index, fluorosis prevalence

Introduction

The prevalence of dental fluorosis has increased during the past few decades in many developed countries in both fluoridated and non-fluoridated areas due to the availability of fluoride in many forms (1-2). Several indices have been developed for use in epidemiological studies of fluorosis. The most widely used indices include Dean's Fluorosis Index (3-4), the Thylstrup-Fejerskov (TF) index (5), and the Tooth Surface Index of Fluorosis (TSIF) (6). These indices assume that the etiology of the defect is excessive fluoride ingestion, and diagnostic criteria are based on the clinical appearance and the extent of the surface affected by the lesion. More recently, the Fluorosis Risk Index (FRI) (7) was developed to improve researchers' ability to relate the risk of fluorosis to the developmental stage of the permanent dentition at the time of exposure to fluoride. The FRI assesses fluorosis on four enamel zones on each tooth, with the zones classified according to the age at which enamel formation is initiated. Specifically, 10 early developing zones are defined as FRI-I zones (occlusal cusp areas of first molars and incisal edges of 6 of the 8 incisors), while there are 24 FRI-II zones (that develop and erupt later). The other zones are not used to define FRI-I or II. Thus, it has great potential for use in analytical epidemiological studies to permit a more accurate identification of associations between age-specific ingestion of fluoride and the development of permanent tooth enamel fluorosis, and has been used in several studies (8-13).

Because it is designed for analytical research, the FRI has not been used in descriptive prevalence studies of fluorosis. However, the prevalence in a study is also important to determine. Since it is often not practical to use both the FRI for analytical purposes and another index for prevalence in the same study, the purpose of this paper is to report results and address implications concerning fluorosis prevalence on early-erupting permanent teeth using the FRI, in a birth cohort from the Iowa Fluoride Study. The prevalence of fluorosis was determined in several ways using the FRI.

Methods

Children included in the present study were part of the Iowa Fluoride Study, a prospective study investigating Iowa children's fluoride exposures, biological and behavioral factors, and children's dental health (14-16). A total of 628 children (319 females and 309 males) were examined for fluorosis on the early-erupting permanent teeth, mostly at about

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8-10 years of age (mean age 9.3, SD 0.7, range 7.7-12.0). This cohort is 98% Caucasian, from families of relatively high socioeconomic status (71% having family income of $30,000 or more and 46% of mothers having completed 4 years of college), 44% were first children, 32% had breast-fed for at least 6 months, only 4% had low birth weight (< 2,500g) and 3% had developmental disorders such as congenital heart diseases.

Children were examined for dental fluorosis on early-erupting permanent teeth by two trained and calibrated dentist examiners using the Fluorosis Risk Index (FRI) (7). Twelve early-erupting permanent teeth were examined for each subject (4 mandibular incisors, 4 maxillary incisors, and 4 first molars). A mouth mirror and exam light were used, and teeth were dried slightly with gauze. Fluorosis was differentiated from non-fluorosis opacities based on Russell's criteria (17, 18) and from "white spot" carious lesions based on color, texture, demarcation and relationship to the gingival margin. Using the Fluorosis Risk Index, three zones (incisal edge, incisal third, and middle third) of facial surfaces were assessed separately for these early-erupting permanent teeth, with FRI scoring criteria differentiating no fluorosis (FRI score 0), questionable fluorosis (50% or less of zone with white striations, FRI score 1), definitive fluorosis (greater that 50% of zone with white striations, FRI score 2), and severe fluorosis (zone displays pitting, staining, and/or deformity, FRI score 3) (7). Cervical zones were excluded from these analyses because many of these zones could not be scored due to incomplete eruption. Person level inter-examiner reliability was 77% agreement (Kappa=0.53, 95% CI 0.12-0.93) for permanent incisors, 88% (Kappa=0.60, 95% CI 0.09-1.00) for permanent first molars, and 77% (Kappa=0.53, 95% 0.12-0.93) for all 12 teeth combined. Zone level agreement was 88% (Kappa=0.46, 95% CI 0.29-0.62) for permanent incisors, 94% (Kappa=0.72, 95% CI 0.53-0.90) for permanent first molars, and 90% (Kappa=0.54, 95% CI 0.42-0.67) for all 12 teeth.

Any tooth with any zone scored 9 (unable to score) on any of the 3 non-cervical zones of the 12 early-erupting permanent teeth was excluded and, therefore, 443 subjects with 3 zones of all 12 teeth scored were included in the analyses. Fluorosis prevalence rates were calculated separately for specific teeth and different combinations of teeth using both FRI zones I only (incisal edges/occlusal tables only on 10 teeth, excluding two maxillary lateral incisors) (7) and three zones combined (incisal edge, incisal third, and middle third on any of the 12 teeth). In addition, a third case definition category included teeth with at least 2 of 3 zones on a tooth scored as questionable being included as cases.

Results

Considering three zones (cervical zones were excluded), 40.6% of subjects overall had at least one tooth with fluorosis, 30.2% had only questionable fluorosis, and 29.1% had no fluorosis. Most fluorosis was mild (FRI score 2), with only 7 individuals (1.6%) having severe fluorosis (FRI score 3). Table 1 presents fluorosis prevalence for individual teeth. Tooth-specific fluorosis prevalence varied, ranging from 2.5% to 27.5%, with maxillary central incisor fluorosis most prevalent (26.6-27.5%) and mandibular incisors least affected (2.5-4.1%). Considering FRI zone I only (incisal edges of 6 incisors and occlusal tables of first molars), 33.2% of subjects had definitive fluorosis (3 subjects had severe fluorosis), 29.3% questionable fluorosis, and 37.5% no fluorosis. Maxillary central incisors were most commonly affected (about 23%), followed by first molars (9.3-16.7%), and mandibular incisors were only affected in 1.4-4.1% of subjects.

Fluorosis prevalence rates, using three different criteria to define fluorosis cases, are summarized further in Table 2. Considering FRI zone I only, the mean number of teeth affected for the entire sample was 1.06 (SD 1.95). Among those with FRI zone I fluorosis, the mean number of teeth affected was 3.18 (SD 2.16), with 59.2% having 1-2 teeth affected, 14.3% having 3-4 teeth affected, and 26.5% having 5-10 affected.

Again when three zones were considered, 34.5% had at least two teeth with fluorosis, 23.5% had fluorosis on both maxillary central incisors, and

TABLE 1
Percentage of subjects with fluorosis by tooth*

		Three zones: occlusal table/incisal edge, incisal third and middle third			FRI zone I only: incisal edge/occlusal table		
Tooth	N	Fluorosis cases†	Questionable‡	Non-fluorosis cases¶	Fluorosis cases†	Questionable‡	Non-fluorosis cases¶
3	443	17.2	22.8	60.0	16.7	22.3	60.9
7	443	21.2	26.0	52.8			
8	443	27.5	23.0	49.4	23.7	20.1	56.2
9	443	26.6	25.7	47.6	22.6	21.9	55.5
10	443	16.9	27.3	55.8			
14	443	14.0	19.9	66.1	13.8	19.9	66.4
19	443	11.1	17.8	71.1	9.3	16.5	74.3
23	443	4.1	9.7	86.2	4.1	8.6	87.4
24	443	2.9	8.1	88.9	1.8	5.9	92.3
25	443	2.5	8.4	89.2	1.4	6.1	92.6
26	443	3.2	9.0	87.8	3.2	7.9	88.9
30	443	11.3	17.6	71.1	9.3	16.0	74.7

* Any tooth with any zone of score 9 (unable to score) on any of the three non-cervical zones of the 12 early-erupting permanent teeth was excluded from the table.
† A tooth with fluorosis was defined as having a zone with FRI score of 2 or 3.
‡ Questionable fluorosis was defined as having a zone with FRI score of 1, but no other zone with a score of 2 or 3.
¶ A tooth without fluorosis was defined as having all zones with FRI score of 0 (or 7).

TABLE 2
Percentage of subjects with fluorosis using different criteria

Teeth Considered* (number of teeth)	Number of teeth required to show fluorosis	Sample size	Percentage of subjects with fluorosis: FRI zone I†	Three zones†	Two or more zones with questionable fluorosis on a tooth also considered as fluorosis
Incisors and 1st molars (12)	1	443	33.2	40.6	55.8
	2		27.5	34.5	46.3
Incisors (8)	1	443	27.1	36.6	49.7
	2		20.1	29.8	40.4
Maxillary central incisors (2)	2	443	19.6	23.5	34.5
First Molars (4)	2	443	14.9	15.6	22.1
Maxillary central incisors and 1st molars (6)	2	443	27.5	30.9	42.0

* Three zones of each incisor and 1st molar (12 teeth) must be scored to be included in the table.
† Fluorosis is defined as FRI score of 2 or 3.

15.6% had fluorosis on at least two first molars. The mean number of teeth affected for the entire sample was 1.58 (SD 2.61). Among those with fluorosis, the mean number of teeth affected was 3.90 (SD 2.78), with 44.4% of them having 1-2 teeth affected, 26.7% having 3-4 teeth affected, 25.6% having 5-10 teeth affected, and 3.3% having more than 10 teeth affected. To assess underestimation of fluorosis prevalence due to excluding the cervical zones, the authors looked at the subset of subjects with twelve fully erupted teeth (n=159). Only one of these subjects had fluorosis on a cervical zone but no definitive fluorosis on any of the other three zones, so these prevalence estimates are probably only about 1% lower than what would have been assessed with fully erupted teeth.

With three zones assessed and fluorosis defined on a tooth as having any FRI score 2 or 3 or having at least two of three scored zones with FRI score 1 (questionable fluorosis), 46.3% of subjects had at least two teeth with fluorosis, 34.5% had fluorosis on both maxillary central incisors, and 22.1% had at least two first molars with fluorosis. These fluorosis prevalences are reported in the last column in Table 2.

Discussion

Historically, dental fluorosis has been assessed using several indices based on the clinical appearance of the enamel and the extent of the surface affected. Choice of an index is dependent on the purpose of the study. For example, Dean's index (3-4) provides valuable historical perspective on the prevalence of fluorosis over time. Fluorosis in the moderate and severe range is best discriminated using the TSIF or TF indices since they provide additional categories of fluorosis in the moderate to severe range (5-6). Compared with the tooth-level Dean's index and surface-level TSIF, the FRI assesses fluorosis on four enamel zones on each tooth, with the zones classified into FRI zone I and II according to the age at which enamel formation is initiated. Therefore, it has advantages for use in the analytical epidemiologic studies of age-related risk factors for dental fluorosis (7).

Apparently due to widespread use of fluoride, the prevalence and severity of dental fluorosis in the US have increased since the 1930s-1940s, with the largest increase in the non-fluoridated communities. Depending on fluoride levels in drinking water, fluorosis prevalence rates among children in the US have generally been reported to be about 3-18% for suboptimal communities, 21-56% for optimal communities, and 37-93% for natural occurring above-optimal communities (1, 19-25). For example, data from the 1986-87 National Survey of US School Children showed that, among 12- to 14-year-old children living in households served by public water systems during the children's first eight years of life, the prevalence of fluorosis (ranging from very mild to severe) was 37.8% among children with natural fluoride of 0.7 to 4.0 ppm (compared with 25-40% in the 1930s), 25.8% in the optimal fluoride group of 0.7 to 1.2 ppm (12-15% in the 1930s) and 15.5% in the suboptimal group of less than 0.7 ppm (6.5% in the 1930s) (25).

The majority of children in this research study drank water with the optimal fluoride level (0.7-1.2 ppm) and overall 34.5% had definitive fluorosis (FRI score 2 or 3) on at least two teeth. This result is generally consistent with most contemporary prevalence studies of fluorosis in North America. When considering FRI zone I only, fluorosis prevalence rates were generally lower than when all three zones were used, whether for specific teeth or for different combinations of teeth. For example, 40.6% had at least one tooth with fluorosis for three zones assessed vs. 33.2% for FRI zone I, and 23.5% had both maxillary central incisors with fluorosis on at least one of three zones vs. 19.6% for FRI zone I only, respectively. Therefore, using FRI zone I only would generally underestimate fluorosis prevalence in populations in epidemiologic studies. This is understandable because the FRI zone I only includes a very small part of the available tooth area (incisal edges for 6 of the 8 incisors and occlusal tables for first molars). Since the enamel on FRI zone I areas develops early, subjects with no FRI-I fluorosis may still be at risk of developing fluorosis on the other zones of the same teeth. Other possible concerns with use of FRI zone I parts of the teeth are that the incisal edges of the incisors are particularly susceptible to wear (possibly reduc-

ing the apparent dental fluorosis) and molar zone I fluorosis could be obscured by occlusal restorations or sealants.

The FRI was originally designed for case-control, analytical studies of age-related fluoride exposure risk factors for fluorosis and the purpose of the scoring criteria is to maximize the contrast of the identified case and control groups. If the examiner has any doubt as to whether a surface zone is positive or negative, the zone is scored as questionable. This includes those with 1-50% of a zone affected by fluorosis, but not reaching the >50% threshold. Therefore, the FRI tends to produce a substantial number of questionable fluorosis zones. As shown in the study, approximately 30% of subjects were categorized as having only questionable fluorosis. How the questionable cases are treated in analytical epidemiologic studies could have considerable impact on the results and subsequent conclusion. For example, as shown in the last column in Table 2, when a tooth with at least two of three zones with questionable fluorosis (FRI score 1) was also considered as having fluorosis, the prevalences were about 7%-15% higher than those when only definitive/severe fluorosis was considered as fluorosis (FRI score 2 or 3).

Subjects who have teeth (or zones) with incomplete eruption certainly have an impact on the estimate of fluorosis prevalence, since these teeth (or zones) are simply not available to be examined, and it is not known how many of them would have fluorosis. In the study, when limited to the subset of 159 subjects whose early-erupting permanent teeth were all fully erupted (12 teeth), 45.4% had at least one tooth with fluorosis compared with 40.9% when all subjects with varying numbers of zones scored were combined. Mainly due to incomplete eruption, the cervical zones were excluded from the analyses in this study. This is obviously a study limitation.

An interesting finding from the study relates to bilateral symmetry in fluorosis occurrence when comparing prevalence among tooth pairs (Table 1). In general, there was bilateral symmetry. However, there were some differences in prevalence between maxillary right vs. left first molars and lateral incisors. While the difference in prevalence between right and left maxillary first molars could be attributable to slight differences in vision or lighting when examining right vs. left side, this does not appear to be a plausible explanation for differences in prevalence between right and left lateral incisors. Thus, it appears that while there is general bilateral symmetry in fluorosis occurrence within an individual, this symmetry is subject to some degree of variation.

The cohort in this study is a well-defined group of children, with data and prevalence rates unique to this Iowa cohort. The high percentage with questionable fluorosis may not be the same for other populations. Also, exams were not conducted with a second fluorosis index in this cohort, so it is not known how the prevalence would differ from these results and what percentage of the FRI's questionable fluorosis would be classified as fluorosis using a second index. Compared with some other indices, such as the TF index, for which teeth are dried thoroughly before scoring for fluorosis, a procedure that usually accentuates any existing fluorosis, the FRI scoring system only uses gauze to slightly dry the teeth, and compressed air is not used. This practice could also have impact on fluorosis prevalence determined from the use of the FRI. The choice of index should be a thoughtful one based on the purposes of the study: descriptive, analytical, or both.

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