Dental fluorosis in children residing in communities with different water fluoride levels: 33-month follow-up

Richard D. Jackson, DMD Sue A. Kelly Barry Katz, PhD Edward Brizendine, MS George K. Stookey, PhD

Dr. Jackson is a research associate; Dr. Kelly is assistant director of Clinical Research; Dr. Katz is a professor; Dr. Brizendine is a clinical statistician; and Dr. Stookey is a professor and they are all at the Oral Health Research Institute, Indiana University School of Dentistry.

Abstract

Purpose: The purpose of these examinations was to monitor changes, in the prevalence of dental fluorosis.

Methods: In February 1992 and December 1994, children who were residents of one of three communities with varying levels of fluoride in their communal water supply were examined for dental fluorosis. Since some children were available at both examination periods, it was also possible to determine changes in the incidence of dental fluorosis.

Results: The prevalence of fluorosis increased by approximately 14%, 20%, and 6% in the negligibly, optimally, and 4X optimally fluoridated communities, respectively. In the negligibly and optimally fluoridated communities, the incidence of dental fluorosis increased by 12% and 7%, respectively. In the 4X optimally-fluoridated community, all the children examined had evidence of fluorosis at both examinations.

Conclusion: Fluoride continues to be the primary therapeutic agent for the prevention of dental caries in adults and children. With the downward adjustment in the fluoride supplement schedule, continued monitoring of the prevalence of dental fluorosis in young children is needed to determine if any additional steps are even necessary to restrict fluoride intake during the years that enamel formation is occurring. (Pediatr Dent 21:249-255, 1999)

In the 1930s, it was found that the ingestion of excessive quantities of fluoride during the period of pre-eruptive tooth formation resulted in chronic endemic fluorosis. It was also demonstrated that when the concentration of fluoride in the water supply was 1.0 ppm, fluorosis affected less than 10% of the children examined.[1,2] While these observations were valid at the time, for all practical purposes, fluoride contained in the water supply was the only source of fluoride available.

In recent years, there has been growing evidence that the prevalence of dental fluorosis is increasing in both optimally and negligibly fluoridated communities.[3-13] In reviewing studies performed in the 1980s, Pendrys and Stamm[14] found that the reported prevalence of dental fluorosis in fluoridated communities ranged from 13%-51% ($\bar{X}$=23%). In negligibly fluoridated communities, the range was approximately 3%-25% ($\bar{X}$=10%). A 1994 review of the literature by Clark,[13] found that the prevalence of dental fluorosis ranged between 35%-60% in optimally fluorosis dated communities and 20%-45% in negligibly fluoridated communities. All of the data indicate that the current prevalence of dental fluorosis is substantially greater than that observed by Dean in the 1930s. The purpose of this study was to investigate the prevalence and incidence of dental fluorosis in children who were long-time residents of three Indiana communities, and to compare these data to data collected previously in the same three communities. The initial examinations were conducted during February 1992 and repeated in December1994.

Methods

Prior to initiation of each investigation, the protocols and supporting documents were approved by the Institutional Review Board serving the Indiana University Medical Center. The procedures, possible discomforts or risks, as well as possible benefits were explained fully to the human subjects involved and their informed consent was obtained prior to the investigation.

The study sites were: Connersville (≅0.2 ppm F), Brownsburg (≅1.0 ppm F), and Lowell (≅4.0 ppm F), Indiana. These naturally fluoridated communities were purposely selected to reflect a range of water fluoride levels. In addition, each community had a documented water fluoride history for the preceding 50 years.[15-20] All communities were served by one or more deep wells and since they were in the same climatic zone, the level of optimal water fluoride (1.0 ppm F) was identical for all three communities. The demographic characteristics of the three communities were similar and they were considered to be of sufficient size to permit recruitment of the required number of patients.

At both time periods, the study included children between 7 and 14 years of age who met our criteria of lifetime residency. Lifetime residency was defined as being born to parents residing in the community and not being absent from the community for more than two weeks in any one year. In addition, acceptable subjects were required to:

1. be willing to read and sign a letter of consent and obtain parental consent,
2. have no factors in their medical history which would con traindicate a dental examination,
3. be available during the examination periods ,
4. be of the proper age at the time of the examination,

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Table 1. Criteria of the Tooth Surface Index of Fluorosis

Numerical score	Descriptive criteria
0	Enamel shows no evidence of fluorosis.
1	Enamel shows definite evidence of fluorosis, namely areas with parchment-white color that total less than 1/3 of the visible enamel surface. This category includes fluorosis confined only to the incisal edges of anterior teeth or cusp tips of posterior teeth.
2	Parchment-white fluorosis totals at least 1/3 but less than 2/3 of the visible surface.
3	Parchment-white fluorosis totals at least 2/3 of the visible surface.
4	Enamel shows staining in conjunction with any of the preceding levels of fluorosis. Staining is defined as an area of definite discoloration that may range from light to very dark brown.
5	Discrete pitting of the enamel exists, unaccompanied by evidence of staining of intact enamel. A pit is defined as a definite physical defect in the enamel surface with a rough floor that is surrounded by a wall of intact enamel. The pitted area is usually stained or differs in color from the surrounding enamel.
6	Both discrete pitting and staining of the intact enamel exists.
7	Confluent pitting of the enamel surface exists. Large areas of the enamel may be missing and the anatomy of the tooth may be altered. Dark brown stain is usually present.

5. provide residency questionnaire information indicating that their primary source of water during their lifetime had a comparable level of fluoride (+/- 0.1 ppm fluoride) as their community water supply.

The last criteria allowed the recruitment of children who had either used well water with a comparable fluoride level or had moved from a community where they had used a communal water supply which was comparable in fluoride content to that of their current community.

Thus, a lifetime resident was defined as a subjects whose primary water supply contained a verifiable fluoride level which was comparable to their current community of residence. Results of the assays had to be equivalent to that of the communal water supply. All children who stated that they currently used well water as their primary water source were instructed to provide water samples from these wells for direct fluoride assay. The Fluoridation Census (1993)[21] was used to verify the water fluoride content for those children who had moved from another community. The use of bottled water or spring water as the primary water source while residing in any community was used an as exclusion criteria.

Panelists brushed their teeth with dentifrice and water prior to each examination. All examinations at both time periods were performed by a single examiner during school hours using portable dental chairs and lights, plane surface mirrors, and No. 23 explorers. Compressed air was not used prior to the examinations.

The Tooth Surface Index of Fluorosis (TSIF) [22] was used to determine the prevalence of dental fluorosis. The criteria for the index are summarized in Table 1. The TSIF was developed in response to perceived shortcomings of Dean's index when used in areas where the concentration of fluoride was exceptionally high. It was felt that the use of Dean's index could result in a majority of the scored teeth to be placed into only one of two categories—"moderate" and "severe." [22] The TSIF is not an ordinal scale and thus scores are not averaged, but rather arrayed in a frequency distribution.

In this investigation, only the permanent teeth were examined. A surface had to be fully erupted in order to be scored and, if restored, sufficient tooth structure (> than 75%) had to remain. Anterior teeth received two scores (buccal and lingual) and posterior teeth received three scores (buccal, lingual, and occlusal). To distinguish between mild fluorosis and nonfluoride opacities, the criteria developed by Russell [23] were used. Table 2 summarizes the clinical parameters which were used to differentiate mild dental fluorosis from other enamel opacities.

In order to introduce a degree of blindness to the examinations, children who used well water which contained higher or lower levels of water-borne fluoride during the period of tooth development were also included in the examination roster: however, these data were not included in the data analyses. A number of wells surrounding the 4.0 ppm F community were found to have a low level of fluoride (ª 0.3 ppm F), while numerous wells surrounding the negligibly fluoridated community contained approximately 0.8-1.0 ppm F. Children using wells in the optimally fluoridated community were examined if their wells contained ≥2.0 ppm F or ≥0.3 ppm F. Water samples collected from wells were directly analyzed for fluoride using a fluoride-ion specific electrode (Orion # 96-09-00).

Prior to the initial examinations, the fluorosis examiner was trained in the use of the TSIF by an experienced examiner. The training consisted of a two-day session during which the examiners discussed the index, reviewed color slides illustrating the seven categories and performed examinations on 17 children who resided in the 4.0 ppm F community. The examinations were performed on children who had used city water (4.0 ppm F) their entire life as well as children who had used private wells which contained a low level of fluoride (<0.3 ppm F) during the period of tooth development. The examiner was not aware of the residency status of the participants. Intra-examiner variability was calculated and has been reported previously.[12] Prior to the examinations conducted in

Table 2. Differentiation of Mild Fluorosis from Nonfluoride Enamel Opacities		
Characteristic	Mild fluorosis	Nonfluoride enamel opacity
Area	Usually seen on incisal edge or cusp tip	Usually centered in smooth surface; may affect entire crown
Shape	Lines follow incremental lines; irregular form on cusp tips	Round or oval
Demarcation	Fades into surrounding enamel	Clearly demarcated borders
Color	Often "paper-white"	Ranges from creamy-yellow to reddish-orange
Teeth affected	Usually seen on homologous teeth	Usually one to three teeth; may occur singly
Gross hypoplasia	None; pitting does not occur	Absent to severe
Detection	Often invisible under strong light	Seen m ost easily under strong light

1994, the examiner underwent a one-day refresher course with the same experienced examiner. The refresher course was conducted in the 4.0 ppm F community and included a review of the criteria and performance of examinations in a similar manner to those conducted in 1992.

Results

In 1992, 344 children were examined, and 357 children were examined in 1994 (Table 3). The mean age of the participants was 9.9 in 1992 and 10.0 in 1994. At the initial examination, females comprised 54% of the panel and in 1994, females combined 49% of the panel. Nonwhites comprised approximately 2% of the panelists examined at both time periods. This percentage reflected the demographic composition of the communities.

Table 4 summarizes the percentage distribution of dental fluorosis seen at each time period. Any examined permanent tooth surface having a TSIF score ≥ 1 was defined as being fluorosed. Scores of 5, 6, and 7 have been combined for convenience and percentages have been rounded to the nearest whole number. As expected, in both years, the prevalence of fluorosis was directly related to the water fluoride level of the community. In 1992, approximately 45% of the children had evidence of fluorosis in the optimally fluoridated community as compared to 64% in 1994. In the negligibly fluoridated community, 18% had evidence of fluorosis in 1992 compared to 33% in 1994. At both time periods, the majority of children with dental fluorosis had TSIF scores of either 1 or 2 in these two communities. No scores greater than 3 were recorded in either the negligibly or optimally fluoridated community. In the 4.0 ppm F community, the prevalence of dental fluorosis was high (> 90%) at both time periods, although less severe scores were seen in the children examined in 1994 (Table 5).

In the 0.2 ppm F community, children 7-10 years of age experienced a slight increase in the percentage prevalence of dental fluorosis during the 33-month examination interval. However, in the 1.0 ppm F community there was a 33% increase in the number children 7-10 years old having a TSIF score >0. Most of this increase was confined to changes in TSIF scores from 0 to 1. Among children 11-14 years of age, those residing in the negligibly fluoridated community had the greatest increase in the prevalence of fluorosis (21%). Again, most of this increase was confined to changes in TSIF scores from 0 to 1. In the 4.0 ppm F community, the prevalence of dental fluorosis increased between the two examination periods in both age groups. The severity of fluorosis appeared to decrease between the two examinations periods with smaller percentages of children having scores of 5, 6, or 7.

Table 3. Demographic Characteristics by Time Period

	1992 Time period 1				1994 Time period 2			
F Level (ppm)	N	Mean age (Years)	Sex M	Sex F	N	Mean age (Years)	Sex M	Sex F
0.2	126	9.7	47	79	129	9.8	58	71
1.0	117	10.1	53	64	123	10.0	61	62
4.0	101	9.7	52	49	105	10.3	63	42
Total	344	9.9	152	192	357	10.0	182	175

Table 4. Percent Distribution of Children by TSIF Score and Fluoride Level

F Level (ppm)	N	Time period*	TSIF score 0	1	2	3	4	5-7
0.2	126	1	82	15	3	0	0	0
	129	2	67	26	5	1	0	0
1.0	117	1	55	34	9	1	1	0
	123	2	35	48	11	6	0	0
4.0	101	1	8	23	17	26	7	20
	105	2	1	32	17	30	11	9

* Time period: 1=1992; 2=1994

Table 6 summarizes the percentage prevalence of dental fluorosis of the children who were examined at both examination periods. In the 0.2 ppm F community, 30% of the children had evidence of dental fluorosis at the initial examination. At the subsequent examination, 42% had evidence of dental fluorosis. In the 1.0 ppm F community, the percentages were 51% in 1992 and 58% in 1994. Further analyses of the data indicated that the increase in dental fluorosis noted at the second examination was due to the eruption of additional permanent teeth with fluorosis in children who had shown no evidence of fluorosis in 1992.

Data regarding the use of fluoride supplements was collected at each time period. In 1992, 96% of the children returned information concerning the use of fluoride supplements in infancy (Table 7). In the 0. 2 ppm F community, 58% reported use of supplements compared to 20% in the 1.0 ppm F community. Of those reporting that they had used supplements, 24% in the 0.2 ppm F community had fluorosis (TSIF score ≥1) compared to approximately 10% of the children in the same community who had not used supplements. In the 1.0 ppm F community, 59% of the children reporting the use of supplements had evidence of fluorosis compared to 43% of those who reported not having used supplements. In 1994, similar data were also collected with 97% of the children returning information concerning the use of supplements during infancy. In the negligibly and optimally fluoridated communities, use of fluoride supplements during infancy was reported by 47% and 14% of the children, respectively. For those reporting the use of supplements, fluorosis was evident in 54% of negligibly fluoridated communities and 53% in optimally fluoridated communities.

Discussion

Data from this study corroborate a number of other recent investigations indicating that the prevalence of dental fluorosis is increasing in both negligibly and optimally fluoridated communities in the US.[13] While the prevalence of dental fluorosis did rise during the intervening 33-month period, this must be tempered with the observation that the majority of the increase was in categories 1 and 2.

Dental fluorosis of low severity has not been found to pose any esthetic concerns to children or their parents. Clark et al[24]

Table 5. Percent Distribution of Children by TSIF Score

F Level (ppm)	N	Time period*	TSIF score 0	1	2	3	4	5-7
				7-10 Years of age				
0.2	77	1	82	16	3	0	0	0
	81	2	72	22	4	3	0	0
1.0	69	1	62	29	7	0	2	0
	77	2	29	49	17	5	0	0
4.0	69	1	7	29	15	29	3	18
	57	2	2	35	16	28	11	9
				11-14 Years of age				
0.2	49	1	82	14	4	0	0	0
	48	2	60	31	8	0	0	0
1.0	48	1	44	42	13	2	0	0
	45	2	47	47	0	7	0	0
4.0	32	1	9	9	22	19	16	25
	48	2	0	29	19	31	13	8

* Time period: 1=1992; 2=1994.

Table 6. Percentage Prevalence of Fluorosis for Children Examined at Both Time Periods

Water F Level (ppm)	N	TSIF score >1 1992 %	1994 %
0.2	43	30	42
1.0	45	51	58
4.0	46	100	100

found that of 1057 questionnaires which were compared to clinical scores, only those scores of 4 to 6 were of esthetic concern to the child and their parents. Much lower levels of child or parental concern were associated with scores of 1, 2, or 3.

At present, we have no definitive data to aid us in determining the exact causative factors which resulted in the increased prevalence of dental fluorosis seen in this investigation. The increased prevalence may be the result of small contributions from a number of sources, such as dentifrice, supplements, and the diet rather than from a single source. As the fluoride content of all three communities remained stable prior to and during the investigation, it is assumed that the increase seen at the 1994 examination period was a result of increased fluoride ingestion from sources other than water.

The age when toothbrushing is initiated, the amount, and to a lesser degree, the frequency of use of fluoridated dentifrice have been identified as factors in the development of dental fluorosis, especially in optimally fluoridated communities.[11, 25, 26] It has been estimated that 78% of the mild-to-moderate fluorosis seen on the maxillary central incisors can be attributed to toothbrushing when more than a "pea-sized" amount of a fluoridated dentifrice is used more frequently than once per day during the first eight years of life.[27] It could be argued that the percentage of children using a fluoridated dentifrice has been constant for a number of years with up to 60% using a fluoridated dentifrice by two years of age and over 95% by three years of age.[28] However, what has changed is the commercial introduction of fluoridated dentifrices targeted specifically for use by children. Use of such products have been found to increase the amount of dentifrice used by young children and therefore increasing the amount that can be ingested.[29]

The inappropriate use of fluoride supplements[11,25,30,31] and even their highly compliant use[32] have also been implicated as a potential cause of the increase in dental fluorosis. Previously, investigations concerning the use of supplements as a potential cause of the increase in dental fluorosis had been restricted to optimally fluoridated communities. It is interesting to note that in the negligibly fluoridated community, 47% of the children who reported using fluoride supplements had evidence of dental fluorosis as compared to 23% of the children who did not report the use of supplements. However, these data are based on parental recall and may be subject to error. The implication that the use of fluoride supplements during infancy and early childhood may also be a causative factor for the development of dental fluorosis in negligibly fluoridated communities warrants further investigation.

Recognizing the potential impact of supplements on the development of dental fluorosis, the American Dental Association and the American Academy of Pediatric Dentistry have already recommended a downward adjustment in the fluoride supplement schedule.[33] At the present time, it is too early to determine if this will be sufficient to reduce the prevalence of dental fluorose. Thus there is a need for continued monitoring of the prevalence of dental fluorosis to determine the effect of the revised supplement schedule on the development of dental fluorosis and to determine if further steps are even necessary.

Foods and beverages which are processed in fluoridated communities are frequently consumed in nonfluoridated communities. It has been reported that this may result in a significantly greater intake of fluoride in nonfluoridated communities.[34] While most foods contribute little to fluoride intake, soft drinks have been extensively analyzed for fluoride because of their increasing consumption by children. Clovis and Hargreave[35] concluded that the consumption of carbonated beverages in negligibly fluoridated communities, which were processed in optimally fluoridated communities provided a significant portion of the fluoride intake by children in negligibly-fluoridated communities.

Several points should be considered when the data presented in this paper are reviewed. While the data indicate that dental fluorosis is increasing among school children in the US, the data are based on the examination of a panel of volunteers rather than of a random sample of children in each community. Since the children were all volunteers, the parents of these children

Table 7. Effect of Supplement Use on Fluorosis

F Level (ppm)	Examination	N	Supplement use No NF/NE* (%)	Yes NF/NE (%)
0.2	1	121	5/51 (10)	17/70 (24)
	2	124	15/66 (23)	27/58 (47)
1.0	1	111	38/89 (43)	13/22 (59)
	2	122	70/105 (67)	9/17 (53)
4.0	1	101	86/92 (94)	7/9 (78)
	2	102	95/96 (99)	6/6 (100)

*NF=Number of children with dental fluorosis.
NE=Number of children examined.

may have been more conscious of their child's dental health than the general population and, consequently, their children may have brushed their teeth at an earlier age, with a greater frequency, and with more dentifrice. Similarly, the parents may have taken their child to the dentist at an earlier age than the general population and may have been more diligent in their child's use of any prescribed fluoride supplements.

A recent paper by Heller et al. [36] reviewed data from the 1986-1987 National Survey of Oral Health of US School children conducted by the National Institute of Dental Research. Their analyses of the data indicated that there was little difference in caries levels in children who had ingested water containing 0.7-1.2 ppm F and considerably more fluorosis (8%) when compared to children ingesting water containing 0.3-0.7 ppm F. They suggest the data indicate that reconsideration of the policies regarding optimal water fluoridation may be appropriate for the US. In fact, the mean dfs and DMFS of children residing in communities with 0.3-0.7 ppm F was higher as compared to children residing in communities with 0.7-1.2 ppm F. Dental fluorosis, while more prevalent in children who drank water containing higher fluoride levels, was categorized as a 1 or a 2 which were considered by Dean to be "very mild' and "mild". Since fluoridated water provides an anticaries benefit to adults as well as children, other steps to target fluoride intake during the period when teeth are most susceptible for the development of dental fluorosis would appear to be more appropriate than decreasing water fluoride levels.

If further steps are needed, the development of a dentifrice with a lower concentration of fluoride for use by young children would seem to be a reasonable response to reducing fluoride ingestion in this age group. Such dentifrices are already available in other countries. In addition, increasing parental awareness concerning the use of only small amounts of dentifrice by young children should also be advocated.

In 1994, dental fluorosis examinations were conducted on school children between the ages of 7-14 years from three Indiana communities with varying amounts of fluoride in their water supplies. Similar examinations had been performed approximately 33 months previously in the same communities with a similar panel of children. Using the TSIF, the percentage prevalence of dental fluorosis increased in all three communities from that found at the initial examination period. The greatest change in prevalence was seen in children 7-10 years of age who resided in the optimally fluoridated community. While there was an increased prevalence of fluorosis, there was no accompanying increase in severity.

Conclusion

1. Fluoride continues to be the primary therapeutic agent for the prevention of dental caries in adults and children.
2. With the downward adjustment in the fluoride supplement schedule, continued monitoring of the prevalence of dental fluorosis in young children is needed to determine if any additional steps are even necessary to restrict fluoride intake during the years that enamel formation is occurring.

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ABSTRACT OF THE SCIENTIFIC LITERATURE

ARCH DIMENSIONS AND SPEECH IN CLEFT LIP/PALATE CHILDREN

This investigation studied the relationship between several arch dimensions and the occurrence of misarticulation in several dental consonants in 263, six-year-old Finnish speaking, non-syndromic children with isolated cleft palate, cleft lip/alveolus, unilateral and bilateral cleft lip and palate. Using the techniques of Moorrees, dental plaster casts were measured; the speech was analyzed by calibrated speech pathologists. In general, Finnish non-cleft children are expected to be able to correctly produce the "r", "s," and "l" sounds by five years of age. The occurrence of misarticulations of "r", "s" and "l" increased and dental arch dimensions decreased, with cleft severity. Misarticulations were associated with narrower and shorter maxillary arches and shallower palates, but not with mandibular arch dimensions. A narrow maxillary arch, especially anteriorly, was the most common finding among subjects with "r", "s," and "l" misarticulations. The smaller size of the maxillary arch seems to be associated with the occurrence of dental consonant misarticulation. Cleft type was not related with statistical significance to misarticulations. Boys showed more frequent misarticulations of at least one of the sounds (52%) than girls (30%).

Comments: Speech mechanisms appear highly adaptable and widely ranging compensatory behavior can result in adequate articulation even in the presence of severe abnormalities of the orofacial structures. Dental arch size and shape should therefore be considered only as a possible contributory hazard to clear speech production. LBM

Address correspondece to: Dr. J. Laitenen, Matkamiehentie 10 A 13, FIN-00320 Helsinki, Finland.

The association between dental arch dimensions and occurrence of Finnish dental consonant misarticulations in cleft lip/palate children. Laitien J, Ranta R, Pulkkinen J, Haapanen M-L Acta Odont Scand 56:308-12, 1998.

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ABSTRACT OF THE SCIENTIFIC LITERATURE

PREOPERATIVE FASTING PRACTICES IN PEDIATRICS

An ASA task force proposed preoperative fasting parameters which were sent back for further review, as they failed to represent the wide variations in fasting recommendations. The current investigation was therefore undertaken to determine preoperative fasting practices in major pediatric medical centers.

Fasting guidelines from 51 programs were solicited and analyzed. In 50% of centers, clear fluids were allowed up to two hours prior to GA, 61% allowed breast milk up to four hours preop, and 50% of centers allowed formula up to six hours preop. No consensus for solids in children less than three years was found, however 50% of centers restricted solids after midnight in children over three yrs.

In conclusion, the authors discuss the difficulty in developing practice guidelines for fasting in pediatric anesthesia. NPO after midnight, while easiest, is not safe practice in children. The incidence of severe hypotension during induction, secondary to hypovolemia in fasting children is reduced with more liberal preop fluid intake. The authors recommend the "2-4-6-8 rule", which is what the majority of institutions appear to be following. This restricts -clear fluids to 2 hrs, breast milk to 4 hrs, formula to 6 hrs, solids to 8 hrs. FKH

Address correspondence to: Dr Ferrari, Dept. of Anesthesia, Children's Hospital, 300 Longwood Avenue, Boston, MA, 02115 E-mail: Ferrari@a1.tch.harvard.edu

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