Dental Fluorosis in Children Exposed to Multiple Sources of Fluoride: Implications for School Fluoridation Programs

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SCHOOL WATER FLUORIDATION has emerged in the past 20 years as an effective and practical method for delivering fluorides to students in rural areas. One of the several criteria used in determining if a school qualifies for a fluoridation program relates to the existing systemic fluoride exposure of children attending the school. To prevent possible dental fluorosis, no child in the school population may consume water at home or from any other source that contains significant amounts of fluoride (*1*). The fluoride content of home water supplies is determined before installation of the fluoridation system. Following initiation of the program, monitoring of school and home water supplies becomes critical. Numerous changes in fluoride exposure may occur within the student population, some of which may result in their consumption at home of drinking water with optimum levels of natural or adjusted fluoride in addition to the fluoride ingested while at school.

When these situations occur, the school fluoridator is removed, depriving perhaps the majority of children of benefits, so as not to expose a small percentage to what is believed to be an excessive level of fluoride. If, however, it was determined that a child receiving the combined amounts of fluoride beginning at school age or 5 years of age is not at risk to dental fluorosis, the fluoridator could remain.

A rural, elementary school in southeastern North Carolina uses well water with a natural fluoride concentration of 4.5 ppm, which is 5.6 times the recommended water fluoride level of 0.8 ppm for community fluoridation in that area. Private wells in the geographic area surrounding the school are known to have varying amounts of naturally occurring fluoride.

The natural occurrence of fluoride in this area of the State made possible a study to determine the effect of school water fluoridation combined with varying degrees of fluoride exposure in the home environment on the appearance of teeth. Excessive intake of fluoride during production and development of enamel can result in dental fluorosis. The condition is characterized by defective enamel structure, mainly opacities or pitting. The clinical appearance of fluorosis represents a broad spectrum, varying from a few small, white enamel opacities to almost complete failure of enamel formation. Enamel that is moderately or severely affected is susceptible to attrition, fracture, and staining. Only the moderate to severe degrees of fluorosis are esthetically objectionable.

The objective of this study was to determine if continuous, lifetime use of home drinking water naturally fluoridated to optimum levels combined with the use of school water having 4.5 ppm natural fluoride, beginning at school age, causes objectionable levels of dental fluorosis in school-age children.

Methods

The study population at the school included 307 students, ages 5 to 15, in grades kindergarten through 8. Samples of home water supplies were collected for 292 of these students. The fluoride concentrations of the water samples were determined by the electrode method (*2*). The results of the fluoride analyses indicated concentrations in private wells in the area ranging from 0.10 to 6.50 ppm, with an average of 2.26 ppm. Residence and water histories were obtained

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through self-reporting and verification by the school principal, who was a lifelong resident of the community.

Examinations for the presence or absence of dental fluorosis and its severity were performed by four examiners who calibrated their techniques according to definitions and examination criteria suggested by Dean (*3*). All examinations were performed in a designated room in the school; portable dental chairs and lights, a No. 23 explorer, and a plane surface mirror were used. Two scores were determined for each student, one representing fluorosis prevalence in early erupting permanent teeth and one in late erupting permanent teeth. Each score was based on the most severely affected tooth in each group of teeth. At least one tooth of the group had to be present for a score to be assigned. This method is a modification of the one suggested by Dean. For each individual examined, he assigned one score based on the two most severely affected teeth in the mouth.

Examinations were completed on 295 students; 12 were absent on the days of the survey. Of those examined, 74 were eliminated from the final analysis—59 because they were not continuous residents of the county, 12 because no water sample was returned, and 3 because they were undergoing orthodontic treatment and could not be examined, leaving 221 students, or 72 percent of the enrolled population.

To measure the effects of home and school fluoride exposure, only students with at least one erupted premolar or second molar were included in the analysis for this paper. Incisors and first molars are not at risk to fluorosis after school age since calcification of these teeth is usually completed by age 5 (*4*). The susceptibility of different tooth types within the same mouth was also considered in determining the final sample. Moller (*5*) has shown that different teeth within the same mouth exhibit various degrees of susceptibility to fluorosis. The premolars are most severely affected, followed by second molars, maxillary incisors, canines, first molars, and last, mandibular incisors. Including in the analysis only those students with erupted premolars or second molars provided a measure of the maximum effect of fluoride exposure. A final sample of 120 students resulted.

The sample was divided into four groups based on the fluoride content of home water supplies. The ranges and means of fluoride concentrations (in ppms) for each group were as follows: group 1, 0.00–0.24, with an average of 0.18; group 2, 0.25–1.99, with an average of 0.87; group 3, 2.00–3.99 with an average of 3.13; and group 4, 4.00–6.50, with an average of 4.82. The mean fluoride concentration for all 120 home well water samples was 2.34 ppm.

For each group, both a quantitative and qualitative Community Index of Dental Fluorosis (Fci) was calculated according to the methods suggested by Dean (*3,6*). To determine the quantitative index, a weight is assigned to each of six classifications of fluorosis given at the time of the examination, and the weighted scores for all individuals within each group are averaged (*3*). The Fci rating of disease severity is built on an ordinal scale and should not be treated with equal interval statistics. Mean scores are presented in this paper for comparative purposes. Statistical tests were not applied to these means. For the qualitative index, seven descriptive terms—negative, borderline, slight, medium, rather marked, marked, and very marked—are derived from the percentage distributions of the six classifications of fluorosis (*6*).

The possibility exists, even though a reasonable degree of reliability has been achieved through examiner study, discussions, and calibration sessions, that the data are not valid—valid meaning in the context of this paper the extent to which teeth were correctly scored according to the six classifications defined by Dean. Validity is critical to the conclusions of this study since the normative standard suggested by Dean was to be used for comparison.

To provide a permanent record of examiner judgments, color transparencies were made at the time of the examinations. A sample of students examined by each surveyor was selected to provide a spectrum of fluorosis severity. In all, 41 students, or a 13.9 percent sample of the examined population, were photographed. Sixty-three fluorosis scores were assigned to these 41 students: 40 to early erupting permanent teeth and 23 to late erupting permanent teeth. The transparencies were later reviewed and scored by an independent investigator. Since these scores were assigned when projections of the slides were being studied—allowing unlimited time for referring to written definitions and criteria and the opportunity to compare different cases and degrees of severity—they were accepted as the more accurate interpretation for determination of validity.

Table 1. Comparison of photographs and clinical examinations for the presence or absence of dental fluorosis for 63 teeth scores of 41 school children

Photograph	Clinical examination		Total
	Normal	Fluorosis	
Normal	11	1	12
Fluorosis	3	48	51
Total	14	49	63

Table 2. Frequency distribution of fluorosis classifications for school children with at least 1 late erupting tooth, grouped by fluoride content of their home water supplies

Fluoride range (ppm)	Average concentration (ppm)	Number of children	Fluorosis classification: Normal		Questionable		Very mild		Mild		Moderate		Severe	
			Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0.00–0.24	0.18	30	24	80	3	10	3	10	..	..	..	..	..	..
0.25–1.99	0.87	25	14	56	7	28	3	12	1	4	..	..	..	..
2.00–3.99	3.13	35	8	23	6	17	14	40	3	9	3	9	1	3
4.00–6.50	4.82	30	7	23	4	13	10	33	6	20	3	10	..	..
Total	2.34	120	53	44	20	17	30	25	10	8	6	5	1	1

Photographs are not an entirely satisfactory method to validate fluorosis prevalence since it is difficult to visualize all surfaces of a tooth in a two-dimensional photograph. However, with special attention to the quality and composition of the photographs, the limitations of this method can be overcome.

Results

A comparison of scores obtained by the two methods—photographs and clinical examinations—is presented in table 1. Two types of classification errors—sensitivity and specificity—were calculated. Sensitivity, or the proportion of students who truly manifested fluorosis (very mild or greater) and were classified as such, was 48/51 x 100, or 94 percent. Specificity, or the proportion of students without fluorosis who were classified as such, was 11/12 x 100, or 92 percent. It appears that a high degree of validity was obtained in the clinical examinations with respect to the presence or absence of dental fluorosis.

Absolute and percentage frequencies for the six fluorosis classifications by level of fluoride exposure for the four subgroups are presented in table 2. As the fluoride concentrations in the home water supplies increased, both the prevalence and severity of fluorosis increased. Of the students examined in the lowest fluoride group, in which the average fluoride concentration was 0.18 ppm, 80 percent had premolars or second molars that were normal according to the study criteria. Only a few students in each of the two lowest fluoride groups (10 and 16 percent) exhibited fluorosis, and this was of the mild types. The percentage of students in the normal category decreased to 23 percent in the two highest fluoride groups. More than 60 percent of the students in these two groups had fluorosis; the majority of the cases were very mild to mild, and 12 and 10 percent were moderate to severe. Of the total sample, 39 percent exhibited fluorosis—33 percent of the mild types and 6 percent moderate to severe.

The quantitative and descriptive fluorosis indices for each of the four fluoride exposure groups are presented in table 3. As measured by either index, the prevalence and severity of fluorosis demonstrated a positive correlation with levels of fluoride in home drinking water. For the two groups with average fluoride concentrations of 0.18 and 0.87 ppm in home water supplies, the Community Index of Dental Fluorosis scores were 0.15 and 0.34, respectively. Descriptively, the presence of fluorosis was negative in these two groups. On the other hand, the two highest fluoride groups with scores of 1.03 and 1.10 exhibited fluorosis which can be described as slight and medium. The index for the total sample was 0.68, or slight.

Discussion

The severity of fluorosis at the high fluoride exposure levels (groups 3 and 4) does not appear to be as great in this study as has generally been found in surveys of populations living in areas with comparable temperature and fluoride levels. The reliability of water histories could be a possible explanation. These are notoriously difficult to obtain and are complicated by

Table 3. Fluorosis index for children with at least 1 late erupting tooth, grouped by fluoride content of their home water supplies

Fluoride range (ppm)	Average concentration (ppm)	Number of children	Fluorosis index: Quantitative	Qualitative
0.00–0.24	0.18	30	0.15	Negative
0.25–1.99	0.87	25	0.34	Negative
2.00–3.99	3.13	35	1.03	Slight
4.00–6.50	4.82	30	1.10	Medium
Total	2.34	120	0.68	Slight

a number of factors. Also, changes in either water intake or the resistance of people to fluorosis, or both, over the more than 40 years since Dean's original work cannot be excluded from the consideration of low fluorosis prevalence in the high fluoride groups of this study. Englander (*7*) suggested that objectionable fluorosis may not now be as prevalent as it once was. He cited decreased consumption of water because of air conditioning, changes in food processing and in dietary and nutritional patterns, and increased mobility as possible contributing factors.

Dean suggested that when the Fci for a group is 0.6 or greater, fluorosis is severe enough to be considered a public health problem. Scores below 0.4 do not indicate an unesthetic or objectionable condition. In this survey, the two groups with continuous exposure from birth to average fluoride concentrations of 0.18 and 0.87 ppm in their home environment and 4.5 ppm at school beginning at ages 5 or 6 did not exhibit objectionable levels of dental fluorosis (Fci = 0.15 and 0.34, respectively). However, two groups of children drinking water from the same source at school, but having high average fluoride concentrations in their home water supplies did exhibit fluorosis severe enough to be classified as objectionable.

The findings of this survey suggest that exposure to optimum levels of community fluoridated water from birth and school fluoridated water from ages 5 to 6 will not result in objectionable fluorosis (excluding third molars). The basic theoretical question underlying this study relates to the possible unesthetic effects of combined community and school water fluoridation on certain teeth beginning at 5 or 6 years of age.

If the excessive fluoride exposure of these children (assumed to be approximately 2 mg per day for 180 days per year) is in fact enough to result in objectionable fluorosis, and fluorosis occurs because of some factor operating throughout amelogenesis, the late erupting teeth should be at risk to fluorosis. Calcification for the first premolar, cuspid, second premolar, and second molar is not completed until 5 to 6, 6 to 7, 6 to 7, and 7 to 8 years of age, respectively (*4*).

Fluorosis is commonly recognized as a disturbance in amelogenesis. However, the exact nature of the disturbance and at what stage in enamel formation damage occurs are not known. Recent experimental studies of fluoride uptake and distribution in enamel throughout its life cycle have implicated early enamel formation as the critical stage. Studies in continuously growing rat incisors (*8,9*), in bovine incisors (*10,11*), and in developing pig enamel (*12*) all suggest that the high protein, low mineral enamel matrix has a high concentration of labile fluoride.

It has been suggested that these high concentrations of fluoride may be responsible for hypoplasia or hypocalcification seen in fluorotic mature enamel, and that only the early stages of amelogenesis are fluoride sensitive (*12–14*). There is limited clinical evidence to support this hypothesis. Kempf and McKay (*15*) reported that in Bauxite, Ark. (13.7 ppm) children not drinking from the central water supply but attending school in the village from 6 years of age and on did not develop fluorosis. This level of fluoride exposure (assumed to be approximately 4 to 5 mg per day) was not fluorosis producing at this age. Two children with third molars present moved to Bauxite during ages 5 to 8 years, one at 6 and one at 7, and did not exhibit fluorosis of any teeth except the third molars.

Reports of three studies on the effects of fluoride supplementation beginning at birth are available. Studies by Aasenden and Peebles (*16*) and Margolis and associates (*17*) used the same fluoride regimen: 0.5 mg fluoride per day from shortly after birth to 3 years of age and 1 mg per day thereafter. In both studies, impressive reductions occurred in the incidence of caries; however, Aasenden and Peebles also reported a high prevalence of dental fluorosis. The third study, by Arnold and associates (*18*), used a regimen similar to the Aasenden and Peebles study after 3 years of age. From birth to age 2, no specific dosage was given (fluoride was added to drinking water); from 2 to 3 years of age, 1 mg of fluoride was given every other day. Few subjects were available for analysis, but dental fluorosis was observed in only 4 of 121 children. Three of the four cases of fluorosis were classified as questionable and one as very mild. In the Aasenden and Peebles study, 0.5 mg was toxic for those teeth highly susceptible to fluorosis and in the early stage of enamel development during the first 2 years of life. In the Arnold study, teeth possibly escaped objectionable levels of fluorosis because they had passed through the fluoride-sensitive period before 1.0 mg per day was administered.

The results of the study presented here agree with those of investigators who suggest that damage occurs during the early formative stages of enamel development, and that drinking home water fluoridated at the optimal concentration and school water fluoridated at the recommended level poses no threat of objectionable fluorosis. However, the findings of this study must be considered tentative, pending corroborative evidence, because of the small sample size and wide range of fluoride concentrations in each group.

The hypothesis that fluorosis results from high concentrations of fluoride only during the matrix stage of enamel development is of clinical significance. The fluoride dosage could be increased when all teeth have passed through the fluoride-sensitive or early maturative stages of development, possibly increasing the fluoride concentrations in the outer layers of enamel with an accompanying increase in caries resistance, without risk of fluorosis.

Several researchers have suggested that children, starting at age 6, might derive anticaries benefit from increased levels of fluoride with no danger of fluorosis (*14,19,20*). Englander (*7*) reported enhanced anticaries benefits from drinking water containing fluoride at 5 ppm. The intriguing possibility exists that school fluoridation might be a safe and useful supplement to community fluoridation as a means of further controlling dental caries.

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SYNOPSIS

ROZIER, R. GARY (School of Public Health, University of North Carolina at Chapel Hill) and DUDNEY, GEORGE G.: *Dental fluorosis in children exposed to multiple sources of fluoride: implications for school fluoridation programs. Public Health Reports, Vol. 96, November-December 1981, pp. 542–546.*

Naturally occurring fluorides of varying levels made possible a study to determine if continuous, lifetime use of home drinking water fluoridated to optimum levels combined with the use of school fluoridated water beginning at school age causes objectionable levels of dental fluorosis as defined by Dr. H. Trendley Dean in 1936.

Examinations were performed on 120 children who had fluoride concentrations in home well water ranging from 0.1 to 6.5 ppm and attended a school with a private water source containing 4.5 ppm natural fluoride (5.6 times the optimum for community fluoridation in the area). Fluorosis scores were calculated for each of four groups formed according to fluoride concentrations in home water supplies. The group with an average concentration of 0.87 ppm was found to have a Community Index of Dental Fluorosis well within Dean's normal limits. The results suggest that children consuming water at home containing the optimal fluoride concentration and drinking water at school containing the recommended fluoride level (4.5 times the optimum) are not at risk to dental fluorosis that impairs appearance. If this finding is corroborated by future clinical studies, the target population for school fluoridation can be expanded and the administration of these programs facilitated.