The Prevalence and Severity of Enamel Fluorosis in North American Children

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Abstract

The question considered in this review is the extent to which changes in the prevalence or severity of enamel fluorosis have occurred over the last half-century. Emphasis is given to a review of those studies in which subjects are drinking water that is fluoride deficient and those in which subjects are drinking optimally fluoridated water, either adjusted or natural. Trends in fluorosis were examined using two definitions of fluorosis (definite and any signs) and three types of comparisons—comparisons of pooled estimates from all available studies that include data from different communities and time periods, comparisons of estimates from the same communities at different times, and comparisons of estimates from selected studies in the early years of fluorosis research with results of the US National Fluorosis Survey done by the National Institute of Dental Research. A clear increase in fluorosis among populations drinking community water that contains less than 0.3 ppm fluoride was found. Results of the comparisons using studies with Dean's Index pooled at different time points, comparisons in the same communities over time, and comparisons of prevalence found in selected communities before fluoride was widely available with the National Fluorosis Survey all support this conclusion. An increase in the prevalence of fluorosis in those drinking optimally fluoridated water likely has occurred as well; however, evidence for such a trend is not as clear as for fluoride deficient communities because of mixed results depending on the type of comparison. The majority of fluorosis cases continue to be mild and seem of little esthetic consequence for most of the public or dental profession. But a few cases of more severe fluorosis can be found now in some communities. Because the prevalence of fluorosis is now higher than 50 years ago, we can conclude that fluoride availability to the developing enamel during critical periods when enamel is at risk of fluorosis has increased in North American children. [J Public Health Dent 1999;59(4):239-46]

Key Words: fluorosis, epidemiology, prevalence, severity, secular trends, North American, children.

Research on the prevalence and severity of enamel fluorosis can be divided readily into four distinct eras (1-3). The focus of the first era was generated by the public health expediency of finding the cause of mottled enamel, and once found, determining an acceptable level of fluoride in drinking water supplies. By 1938, most research shifted from this fluoride-fluorosis relationship to the fluoride-caries relationship because the etiology of enamel fluorosis, the concentrations of fluorides in drinking water that produced fluorosis, and its method of prevention were known. The first part of this era was devoted to examining the fluoride-caries relationship in naturally fluoridated communities, the second, beginning in the mid-1940s to community trials in which water fluoride levels were adjusted. Work in refining standards for fluoride levels in drinking water also were accomplished during this period. The third era, beginning in the mid-1970s, centered around the question of safe drinking water standards, primarily for water with above optimal levels of fluoride. The beginning of the fourth era is delineated in a publication by Leverett (4), who suggested that the fluoride burden might be reaching a critical level in the population, resulting in large benefits, but also in an increasing prevalence of fluorosis. This publication, which was nonspecific in terms of the magnitude of the trend or the subgroups of the population affected, began a series of analytic investigations into sources of fluoride that might be contributing to increased levels of fluorosis.

Since Leverett's article appeared in *Science* (4), a number of publications, some of which are comprehensive reviews, have examined the prevalence and severity of enamel fluorosis (4-10). Authors of these publications are in agreement that the prevalence of fluorosis has increased over the last 50 years, with the evidence for this population trend being described by one author as "compelling" by 1993 (11). There is further agreement that these estimates provide a biologic indicator of increasing fluoride exposure during critical times of tooth development; that fluorosis prevalence remains greater in fluoridated than nonfluoridated areas; and that the majority of cases are mild, being of little cosmetic concern to the public or health professionals. However, less agreement exists on the magnitude of the changes, the specific subgroups affected, or at what point the increase began. For example, consensus has not been reached on whether any changes in the prevalence of fluorosis have occurred among individuals living in fluoridated communities.

The purpose of this paper is to summarize current knowledge about the prevalence and severity of fluorosis in North American children, primarily US children. The question to be considered is the extent to which changes in the prevalence or severity of enamel

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fluorosis might have occurred over time. This question is relevant to this workshop and important because enamel fluorosis provides a method to monitor fluoride exposures in populations. Emphasis is given to a review of those studies in which subjects are drinking water that is fluoride deficient and those in which subjects are drinking optimally fluoridated water, either adjusted or natural. It is against these predictable background levels of fluoride that other sources of fluoride, such as supplements, should be evaluated.

Methods

Much of the uncertainty over the prevalence and severity of fluorosis derives from the sparseness of epidemiologic data on this condition, which produces large gaps in data points over time. Further problems are caused by a lack of comparability that derives in large measure from the differences in focus of research questions of interest in each of the fluorosis eras referenced before. Indices selected for use differ depending on the questions under investigation, data are presented differently, and fluorosis cases are not defined consistently. Nevertheless, the prevalence and severity of fluorosis can be estimated with sufficient precision at several points over the last 50 years to reach conclusions about general trends in this condition.

Review Process. An attempt was made to locate and review all published studies of the prevalence and severity of enamel fluorosis in North American children. Most of the initial research on fluoride and its risks and benefits was done by the Public Health Service during the first half of the 20th Century and is published in a single compilation of papers (12). This 636-page publication was searched manually to locate relevant publications on enamel fluorosis. Publications since 1966 were located using MEDLINE searching under the keyword "fluorosis" with the subheading of "epidemiology." The only existing national survey of enamel fluorosis was available for the Untied States as a published abstract (13) and unpublished accompanying tables and figures (referred to as the "National Fluorosis Survey"). Studies included in this review are limited to United States and Canadian population-based studies of school-aged children. The period covered is from 1934 to 1991, and includes children 6–17 years of age.

All publications included for review were abstracted using a standard form. The raw data resulting from the review of each publication were presented in a table with columns for study and year, geographic location, actual fluoride concentration in drinking water and concentration adjusted for the recommended optimum level for the temperature of the particular geographic area where the study was conducted, age, sample size, a percent distribution of subjects by fluorosis index scores, and the percent affected according to definite signs and any signs of fluorosis.

Definitions of Fluorosis Used for Prevalence Estimates. Most experienced investigators believe that enamel fluorosis can be diagnosed with a high degree of accuracy when differential diagnostic criteria are applied carefully. However, the potential for scoring a large number of teeth and surfaces with several degrees of severity leads to variation in the definition of a case, particularly for those indices that do not provide recommendations in this regard. Difficulties in following changes in the prevalence of the condition over time result.

Two case definitions are used in this paper for examining prevalence estimates. The first, referred to as "definite signs" of fluorosis, is the one recommended by Dean (14). He assigned each examined person to one of six categories based on the worst score for two or more teeth. Those subjects assigned to the "questionable" category were not considered in prevalence estimates, but were given a weight and used in the calculation of the CFI, creating some confusion in interpreting estimates for this category. It is unclear if Dean's use of this term represented his uncertainty over the effects of fluoride on enamel at low levels of exposure, diagnostic difficulties that he might have experienced, or his belief that this degree of fluorosis was not of enough esthetic concern to merit full consideration in the index. Likely, however, the label reflects difficulties he had in distinguishing mild fluoride opacities from nonfluoride ones, and thus his desire to reduce the number of false positives. Initially, upper incisors with thin, irregular, white opaque streaks on the incisal third of the tooth and premolars with white opacities 2 or 3 mm in extent on the cusp tips were considered affected at a level between "normal" and "very mild" (15). Unwilling to make a diagnosis at the individual level, questionable cases were considered a positive sign of fluorosis when found in a community with definite cases. After gaining additional experience with the index, some clinical conditions used to describe the questionable category, particularly the snowcapping of posterior teeth, were accepted as definitive indications of fluorosis and added as a criterion for "very mild" (14). My designation of this case definition as "definite" reflects Dean's conservative approach to defining a case, through both controlling for examiner reliability and eliminating single tooth maximum scores.

Dean's Index has been used infrequently during the last decade, primarily because the research questions have emphasized the identification of risk factors for fluorosis—making the use of a more sensitive index desirable. As a result, the TSIF (16) has come under more common use in North America. This index does not have the questionable category used in Dean's Index, and thus is based on the premise that any sign of fluorosis, regardless of the extent, is positive for a case.

To compare fluorosis prevalence found in these most recent studies with previous estimates, the questionable category in Dean's Index is considered a positive indication of fluorosis for the second case definition used in this paper, and is referred to throughout as "any signs" of fluorosis. These prevalence estimates are roughly comparable to results obtained with the TSIF, any differences being the result of the larger number of surfaces scored in the TSIF, which increases the probability of identifying affected areas, and the use of only one affected tooth surface rather than two or more teeth affected at the same level of severity. Findings in the single study in which comparisons between estimates derived from the use of both indices in the same subjects suggest that prevalence estimates based on the maximum TSIF score will be approximately 15 percent higher than those based on Dean's method (16).

It would appear that defining a case on the basis of having a tooth scored as questionable or higher is justified

from a biological perspective, even though examiner reliability may become a more prominent factor in the variation of estimates. Meyers (17) has suggested that there is a dose-response relationship between the prevalence of the questionable category of fluorosis and fluoride, indicating the lack of a threshold level for dental fluorosis. While questions related to the prevalence and severity of fluorosis in those drinking water containing fluoride above optimal levels are important, they are considered outside the scope of this review.

Presentation of Data. Trends in enamel fluorosis were examined using three types of comparisons: (1) comparisons of pooled estimates from all available studies that include data from different communities and time periods, (2) comparisons of estimates from the same communities at different times, and (3) comparisons of estimates from selected studies in the early years of fluorosis research with results of the National Fluorosis Survey done by the National Institute of Dental Research. For the first presentation, prevalence estimates, or percent affected, from studies using Dean's Index were averaged for each of the two definitions of a fluorosis case by community drinking water fluoride status and time period. Estimates from the different studies were averaged for roughly four year groupings—the 1930s–1940s, 1950s, 1960s, and 1980s. These aggregations generally correspond to the variation in research questions predominating at each particular time period. A subset of the first presentation compares results of available TSIF surveys done in the late 1980s or early 1990s in fluoridated communities with earlier estimates of fluorosis from the initial fluoridation trials with Dean's Index, using any signs of fluorosis as the case definition.

Results

Twenty publications reporting the prevalence and severity of fluorosis using Dean's Index and meeting the inclusion criteria were found (14,18-36). These studies provide fluorosis estimates for more than 150 communities and 33,000 subjects for the period 1934 through 1988. Nine studies were identified using the TSIF in the examination of over 6,000 subjects in 20 communities (16,33,37-43). The most common age group selected for study was 12–14-year-old children, but some samples included children as young as 6 years of age.

National Fluorosis Survey. The 1986–87 national survey of US schoolchildren conducted by the NIDR included assessments of dental fluorosis (13). These results are important for establishing a national baseline for future comparisons, as well as current reference for regional, state, or local surveys. Based on these findings, approximately 78 percent of the total US population 7 years of age and older does not have any definite signs of fluorosis, with the majority (76.2%) of the 22 percent affected considered to be very mild cases. The prevalence of fluorosis is higher in those children who continuously drink fluoridated water from birth than in those who do not. Approximately 16 percent of children in fluoride deficient communities have fluorosis, compared to 29 percent in fluoridated communities.

Overall estimates for the total US child population show some regional variation, with the Southwest demonstrating the highest prevalence at 39 percent, and the West Coast the lowest at 13.5 percent. They also show some variation by age, with children born before about 1972 having a lower prevalence than those born after this date. This observation using these national data have led some investigators to suggest that younger children in this survey might have received more fluoride and thus had a higher prevalence of fluorosis than the older ones; however, such an interpretation can be misleading because it is based on cross-sectional survey results (11).

Trends in Prevalence—Compari-

TABLE 1
Mean Percent Prevalence and Range of Enamel Fluorosis by Fluoride Status of Drinking Water and Study Period

Water F Status	Period	Refs.	Number of Communities	Mean % Prevalence*		% Range	
				Definite Signs	Any Signs	Definite Signs	Any Signs
<0.3 x optimal	1938–44	14,21,22	11	0.7	7.5	0.0–1.6	1.0–15.7
	1953–55	24,25	2	0.0	0.3	0.0–0.0	0.0–0.6
	1967	30	13	0.2	3.3	0.0–0.4	2.7–3.9
	1982–88	33-35	9	4.9	12.8	2.9–7.4	7.0–18.6
Optimal	1955–61	25,27-29	5	6.5	16.6	3.3–8.9	9.3–24.5
Adjusted	1986–88	35,36	2	7.7	19.7	7.7–7.7	17.5–21.8
Optimal	1935–39	14,19	4	17.7	46.7	10.6–33.0	31.9–60.8
Natural	1952–56	23-25	4	16.5	46.4	13.0–19.0	22.7–62.0
(within ±0.1	1967	30	13	28.2	73.0	20.8–32.9	60.0–81.9
ppm optimal)	1980–82	31,32	2	26.9	52.2	14.5–39.3	44.0–60.4
Optimal	1934–40	14,19,20	9	15.4	39.6	1.7–33.0	4.3–63.2
Natural	1952–56	23,24,26	4	16.5	46.4	13.0–19.0	22.7–62.0
(0.7–1.2 ppm	1967	30	23	25.9	69.1	14.4–32.9	55.3–81.9
optimal)	1980–82	35,36	2	26.9	52.2	14.5–39.3	44.0–60.4

*Definite signs of fluorosis=Dean's Index classifications of very mild or worse. Any signs of fluorosis=Dean's Index classifications of quetionable or worse. Includes data for continuous residents only.

sons of Pooled Estimates. The prevalence of definite signs and any signs of fluorosis derived from available North American studies of children according to time period and fluoride status of drinking water is summarized in Table 1. Only those studies that used Dean's Index for fluorosis measurements, were school-based, and were limited to continuous residents are included; results of the National Fluorosis Survey are omitted.

The prevalence of definite fluorosis in fluoride deficient communities shows a small increase over the period studied. The mean percent of subjects having definite signs of fluorosis increased from less than 1 percent in the 11 communities surveyed in 1938–44 to about 5 percent in the nine communities surveyed in 1982–88. The mean percent of children having any signs according to Dean's Index showed only a modest upward trend over the period.

The trend in fluorosis prevalence in communities naturally fluoridated to optimal levels is less clear than in fluoride deficient communities, primarily because of the wide variation in prevalence seen from community to community in each time period. For example, in studies during the 1930s, from 2 to 33 percent of children who were continuous residents of communities where the drinking water contained 0.7–1.2 ppm fluoride were found with definite signs of fluorosis; in 1980–82 15–39 percent were similarly affected, resulting in considerable overlap in maximum and minimum estimates. The maximum estimate in 1934–40 was only 6 percent less than in 1980–82. However, the minimum, mean, and maximum percent prevalence estimates all increased between 1934–40 and 1982. Based on the overall trend, a slight increase in the prevalence of fluorosis in naturally fluoridated communities appears to have occurred. This interpretation is not affected by using a narrow range for the natural fluoride content of water supplies (within ±0.1 ppm F) for the definition of "optimal."

For communities with fluoride levels in drinking water adjusted to optimal levels, there is likewise no clearly identifiable trend in the prevalence of fluorosis. Examination of change is complicated by a number of factors. First, only a small number of studies using Dean's Index are available for comparison at any one time—five from the results of the initial fluoridation trials in the United States, and a single follow-up to the Kingston-Newburgh trial. Second, the fluorosis results obtained from the early fluoridation trials seemed lower than expected based on Dean's work. This conclusion is evident by comparing the mean percent affected in the optimal fluoride adjusted group of studies with that of the naturally fluoridated areas. This observation led some investigators to speculate that the low prevalence was the result of examiners overlooking some fluorosis because of their preoccupation with caries examinations, which were done by the same examiners at the same sitting (29). These lower-than-expected estimates generally were confirmed, however, by at least two independent assessments (29,44). In perhaps the better known of the two studies, Russell (29) found an overall prevalence of 8.9 percent in a subsample of 12–14-year-old children in Grand Rapids. Overall, these comparisons of a very limited amount of data for communities where fluoride has been adjusted to optimal levels provide no evidence of any increase in enamel fluorosis.

Four additional studies are available if the definition used for fluorosis is "any signs" based on examinations using the TSIF Index (38,41-43). These studies permit a comparison of 1987–91 surveys in fluoridated communities with the earlier initial fluoridation trials in Newburgh, Evanston and Grand Rapids (Figure 1). This comparison would suggest that there has been an increase in fluorosis in those communities in which fluoride

FIGURE 1
Fluorosis Prevalence in Selected Fluoridated Populations

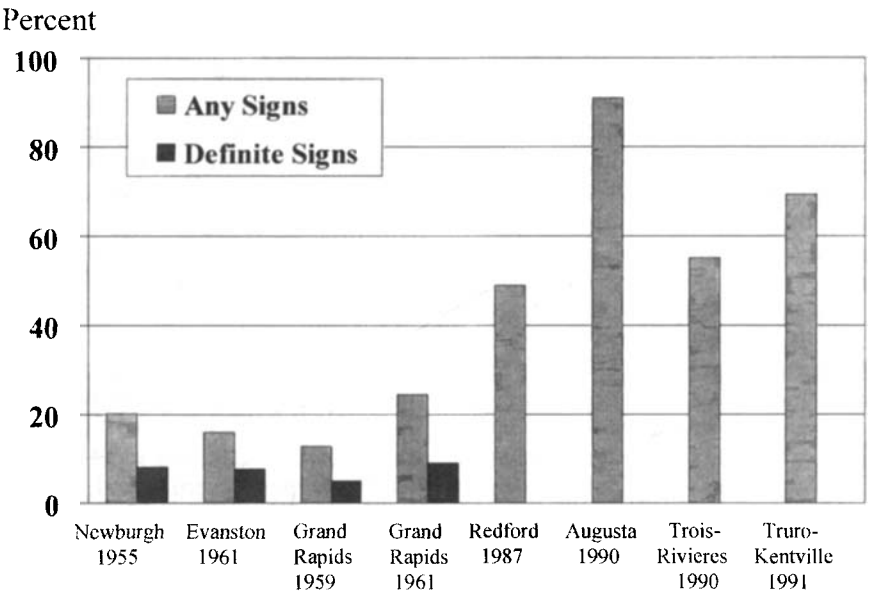


TABLE 2
Prevalence of Fluorosis in Selected Cities by Year of Survey*

Community	Year	*N*	% Prevalence†	CFI
Kewanee, IL	1939	123	12.2	0.31
	1980	336	14.5	0.39
Newburgh, NY	1955	261	8.1	0.15
	1986	459	7.7	0.19
Kingston, NY	1955	612	0.0	0.00
	1986	425	7.2	0.18

*Refs. 32, 35.
†Dean's Index classifications of very mild or worse.

in drinking water has been adjusted to optimal levels. The mean percent of subjects with any signs increased from 16.6 percent to 45.2 percent, close to a threefold increase during the approximately 30-year period. This comparison, once again, is compromised, by the wide variation in prevalence, particularly during recent surveys. The highest estimate for percent affected is from Augusta, GA, where 91 percent of continuous resident 12–14-year-old children were found to have fluorosis (42). These findings may be unusually high because of the wide variation in fluoride levels in the city water supply, as well as potential sample bias introduced by the low response rate.

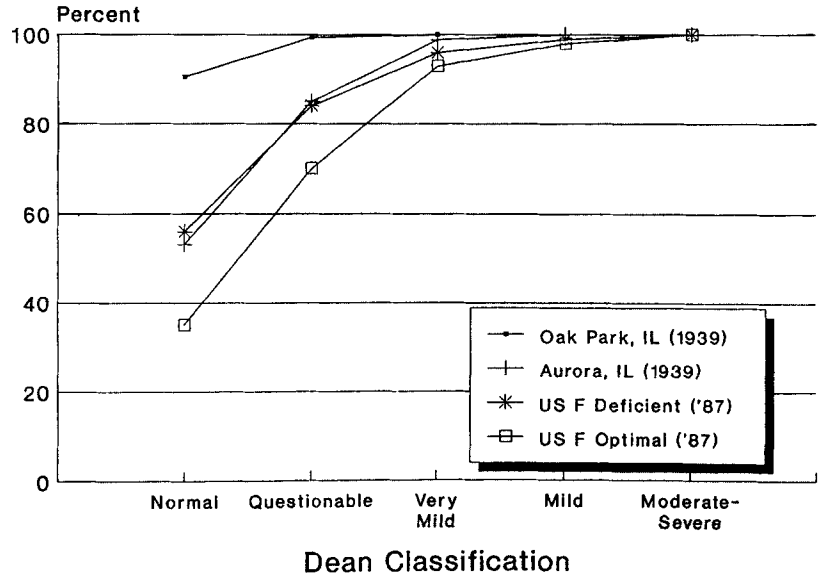
Trends in Prevalence—Comparisons of the Same Communities at Different Times. A follow-up fluorosis survey to Dean's "21-Cities" study has been conducted in naturally fluoridated Kewanee, IL, by Driscoll et al. (32); and to Ast's community fluoridation trial in Newburgh and the comparison community of Kingston, NY, by Kumar et al. (35). In the two fluoridated communities, the prevalence and CFI remained unchanged over the years studied (Table 2). In nonfluoridated Kingston, however, increases were observed in both the prevalence (0.0% to 7.2%) and the severity of fluorosis (0.0 to 0.18).

Another study comparing data collected by the same examiners from the same four communities in 1980, 1985, and 1990 and using the TSIF has been conducted by researchers at the National Institute for Dental Research (37,45). Data for one of the four Illinois communities, Kewanee, which is naturally fluoridated at about 1 times the optimal level are presented in Table 3. The percentage of 8–10-year-old and 13–15-year-old children affected with some fluorosis increased between 1980 and 1985. This apparent increase in fluorosis did not continue for the next five years. The number of surfaces affected with fluorosis in both age groups in 1990 was found to be lower than those of similar age examined in 1985, providing an indication of a cohort effect. Those children born in 1970–72 and examined as 8–10-year-olds in 1980 and 13–15-year-olds in 1985 seem to have had a higher level of fluorosis than those cohorts born before or after these years.

TABLE 3
Percent Distribution of Tooth Surfaces According to TSIF Scores, Kewanee, IL, 1980, 1985, and 1990 (Ref. 45)

		TSIF Score		
Age (Years)	Year	0	1–3	4–7
8–10	1980	81.2	18.7	0.1
	1985	72.0	28.0	0.1
	1990	81.4	18.6	0.0
13–15	1980	88.6	11.4	0.0
	1985	70.7	29.3	0.1
	1990	84.7	15.2	0.1

FIGURE 2
Cumulative Percent Distribution of Subjects According to Dean's Index, Selected Populations, 1939 and 1987



Trends in Prevalence: Comparisons of Selected Communities with National Fluorosis Survey. Further insights into changes over time can be gained by comparing results of selected community surveys done before fluoride availability increased with results of the National Fluorosis Survey. Cumulative percent distribution of subjects according to Dean's classification for two communities studied by Dean in his "21-Cities" study in the late 1930s (14), and results of the National Fluorosis Survey (13), stratified by fluoride deficient and optimally fluoridated water supplies, are presented in Figure 2. The two cities included in the earlier studies are Oak Park, IL, with no detectable levels of fluoride in the drinking water, and Aurora, IL, with 1.2 ppm natural fluoride. The Oak Park and Aurora surveys included 329 and 633 continuous resident 12–14-year-old children, respectively. These two cities were chosen for comparison because of their large sample sizes and because they became the standard of comparison in several subsequent studies. The percentage distributions of subjects in both fluoridated and nonfluoridated communities have shifted over time. In Oak Park, 99.4 percent of subjects did not have any definite signs of fluorosis. In 1986–87, the comparable estimate for children residing in communities with fluoride deficient water supplies was 84 percent, very similar to that for Aurora in 1939. The distribution of fluorosis in those subjects

with continuous residence in fluoridated communities and examined in 1986–87 differed from the other three distributions, with only 35 percent having no signs of fluorosis, 70 percent with none or questionable, and the remaining 30 percent having definite signs.

Trends in Severity of Enamel Fluorosis. Fluorosis scales normally are divided into severity categories based on what is considered to be of public health significance. Those teeth or surfaces with only slight changes in appearance according to Dean's Index have long been considered to be of little cosmetic importance (46). Clark et al. (47) confirmed this long-held belief in his findings that parents of children with TSIF scores of 3 or less express little concern over the color of teeth. On the other hand, those teeth or surfaces with staining as a result of fluorosis, hypomineralization resulting in a chalky appearance, or loss of enamel structure, are considered by professionals and the public to be undesirable.

The number of communities in which fluorosis assessments identified the presence of moderate-to-severe fluorosis in early and recent time periods is presented in Table 4. In the initial studies of the relationship between fluoride and fluorosis, fluorosis was not found at the moderate-to-severe level in either nonfluroidated or naturally fluoridated communities. Results from a total of 39 communities are available, without a single case of moderate-to-severe fluorosis being identified in continuous residents. Likewise, the early experimental trials with water fluoridation did not produce any moderate-to-severe fluorosis. Results from the few communities surveyed in the 1980s using Dean's Index suggest that cases are beginning to appear, although in small numbers. Of the six communities surveyed, four showed evidence of moderate-to-severe fluorosis. In these four surveys positive for moderate-to-severe fluorosis, the prevalence of fluorosis at this level was approximately 1 percent, with the actual number of cases ranging from a single person to a maximum of eight.

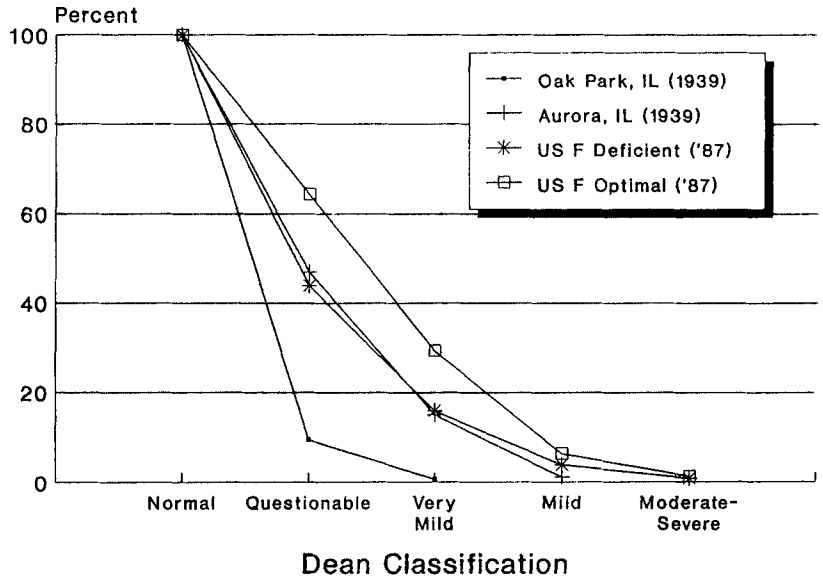
In Figure 3 a reverse cumulative percent distribution of subjects according to Dean's classification system is presented for the four study groups presented before in Figure 2—Oak Park and Aurora, IL, in 1939, and US fluoride deficient and optimally fluoridated in 1986–87. It is evident that the distribution of children across Dean's classification system has shifted over the four to five decades. In Oak Park, no child had fluorosis greater than very mild, while in Aurora, no child had fluorosis greater than mild, which affected only 1.1 percent. Current estimates for US schoolchildren show a distribution for fluoride deficient groups similar to Aurora, with a small but important difference. Slightly more were found to have mild fluorosis (3% vs 1.1%), and 0.8 percent had moderate-to-severe fluorosis, a percent that translates into approximately 50,000 children nationwide. The distribution for schoolchildren drinking fluoridated water is shifted throughout, with 5 percent having mild and 1.3 percent moderate-to-severe fluorosis.

TABLE 4
Number of Surveys Reporting the Occurrence of One or More Cases of Moderate-to-severe Fluorosis

Water Fluoride Status	Period	# of Communities	# with a Fluorosis Case*
<0.3 x optimal	1938–67	26	0
	1982–86	2	1
Optimal natural	1934–40	9	0
	1980–82	2	2
Optimal adjusted	1955–61	4	0
	1986–88	2	1

*Dean's Index classifications of moderate or severe.

FIGURE 3
Reverse Cumulative Percent Distribution of Subjects According to Dean's Index, Selected Populations, 1939 and 1987



Discussion

This review indicates that the prevalence of fluorosis is now higher than 50 years ago before fluorides were used to prevent dental caries. A clear increase has occurred in fluorosis among populations drinking community water that contains less than 0.3 ppm fluoride. Results of the comparisons using studies with Dean's Index pooled at different time points, comparisons in the same communities over time, and comparisons of prevalence found in selected communities before fluoride was widely available

with the National Fluorosis Survey all support this conclusion.

Most likely an increase in the prevalence of fluorosis in those drinking optimally fluoridated water has occurred, as well; however, evidence for such a trend is not as clear as for fluoride-deficient communities. Comparisons of pooled studies found no change during the periods studied, but the number of recent studies is very small. Comparisons of survey results from the same communities at different times provided mixed results. Two studies found no change (32,35), with the third showing a cohort effect (45). The latter study found an increase in fluorosis prevalence in a cohort of children born five years after the baseline comparison group. However, fluorosis prevalence in children born 10 years after the baseline comparison had returned to levels similar to those at baseline. The most compelling evidence for an increase in optimally fluoridated communities comes from the comparison of results of the National Fluorosis Survey with a few selected communities surveyed by Dean. Any conclusion that fluorosis prevalence has increased in fluoridated communities must be confirmed, however, by subsequent studies and maybe affected to a large extent by factors that are unique to each community.

The majority of fluorosis cases continue to be mild and of little esthetic consequence for most of the public or dental profession. But a few cases of more severe fluorosis can be found now in many communities. At a national level, the prevalence of moderate-to-severe fluorosis amounts to only 1.3 percent of the total US child population, some of which is due to communities having natural fluoride at levels above the recommended optimal amount. While the prevalence of fluorosis at this level of severity affects a small percentage of the US population, its occurrence in both optimally fluoridated and fluoride-deficient communities should not be overlooked, and can be taken as a warning sign that overall exposures to fluoride may be exceeding a desirable level.

The association between the occurrence of fluorosis and exposure to fluorides is a predictable biological one. Unlike dental caries, where the association between the condition and fluoride exposures is affected by a large number of factors, the prevalence of fluorosis is a direct result of the amount of fluoride consumed during a relative short period of one's life. In what is the largest study of fluorides and fluorosis, one that involved examinations in 100 communities in six states, Richards et al. (30) concluded that as the percentage of children showing clinical evidence of mild fluorosis approaches about 4 to 6 percent, some objectionable fluorosis will occur, and as the percentage increases beyond those levels, proportionately more children will have objectionable fluorosis. Estimates by Richards et al. were similar to those obtained by Dean in his original work in the 1940s. It appears that the prevalence of mild fluorosis in the US population is approaching a sufficient level that some moderate-to-severe cases can be expected. Based on the epidemiologic evidence concerning changes in the prevalence and severity of fluorosis—particularly the shift of the distribution of fluorosis severity scores upward, so that some more severe cases are beginning to appear—we can conclude that fluoride availability to the developing enamel during critical periods when enamel is at risk for fluorosis has increased in North American children.

Further work needs to be invested in determining factors that might contribute to individual and community variations in the prevalence and severity of enamel fluorosis. The occurrence of more severe cases in both fluoridated and nonfluoridated communities, along with the complete absence of such cases in fluoridated communities when water and diet was the major source of fluoride, suggests that individual behavior is a contributing factor for many of these cases. Resources also need to be devoted to the continuous monitoring of its prevalence and severity in local communities and at the national level.

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