



Endemic Fluorosis and Its Relation to Dental Caries (1938) [with Commentary]

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Endemic Fluorosis and its Relation to Dental Caries (1938)

(H. Trendley Dean)

COMMENTARY

Edward N. Brandt JR, MD, PhD



H. Trendley Dean

There is little question that the reduction of dental caries through fluoridation of the water supply, toothpastes, and similar substances has been a major public health accomplishment.

Dr. H. Trendley Dean wrote an excellent review of literature existing at that time on the relationship between fluoride, "mottled enamel," and dental caries. The first observations were reported in 1916 and concerned the Pikes Peak watershed in Colorado. There were further reports in the 1920s from both Japan and England. Each of these reports indicated an inverse relationship between enamel "mottling" and caries; however, precise measurements of the fluoride in water were not always provided and if they were, tended to be at a single point in time.

The major focus of this report is a study begun by the U.S. Public Health Service in 1933 to determine the "minimal threshold of toxicity of chronic endemic dental fluorosis." Dean reported clearly on the study design and execution as well as the results. In six cities, monthly water samples were analyzed for fluoride, leading to computation of a mean fluoride content. Study children had to have been born in the community, always resided there, and used the community water supply for drinking and bathing. Although small numbers of children were studied in each community, it was clear that the evidence from this study "...furnishes support to the hypothesis that a limited immunity from dental caries is operative among school children residing in endemic mottled enamel areas."

There are a number of important lessons to be learned from Dean's report. First is the importance of observation (as described in the earlier reports) and follow-up with careful epidemiological observations. Second is the necessity to look for confirmatory observations from other situations. Third, careful epidemiological studies (such as the 1933-1934 Public Health Service studies) to define the specifics of attacking a particular disease problem are essential. Finally, carefully and clearly written reports are essential to achieve widespread application of the findings.

This article clearly demonstrates all of the above and is a landmark paper for an important public health problem. Indeed, fluoridation is so widely accepted by the public today that most are not even aware of the early studies that demonstrated its effectiveness. Unfortunately, there are still people who do not accept solid data and resist preventive measures. That will always be true in our society, but should not interfere with our efforts to prevent disease and premature death.

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ENDEMIC FLUOROSIS AND ITS RELATION TO DENTAL CARIES¹

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By H. Trendley Dean, Dental Surgeon, United States Public Health Service

Introduction

The first thorough study of mottled enamel, that of Black (1) and McKay (2) at Colorado Springs and including the Pike's Peak watershed, reported as early as 1916 that, in regard to caries, the teeth of these Colorado children compare favorably with those of other communities where endemic mottled enamel is unknown. Black also wrote of the difficulty of successfully filling carious mottled enamel teeth and stated that, though the percentage of carious teeth is less than in non-endemic areas, probably a greater proportion of filled teeth are eventually lost because of the difficulty of retaining fillings in the hypoplastic tooth structure.

Workers in other countries have also commented on the qualitative aspects of this phenomenon. Mottled enamel is endemic in the southwestern part of the Japanese Archipelago. Masaki (3) reported 18 endemic areas in the Prefectures of Hyogo, Fukuoka, Ehime, Hiroshima, and Aichi, 12 of the 18 being located in Hyogo and Fukuoka. In an English abstract of his original report, this investigator states that "It is also remarkable that the percentage of dental caries is comparatively small among those who suffer this abnormality." The number of observations upon which this generalization was based is not stated in the abstract.

Ainsworth has commented on the lessened prevalence of dental caries among children in the endemic areas of Maldon and Heybridge, Essex County, England. In connection with the studies of the Committee for the Investigation of Dental Diseases, of the Medical Research Council, this investigator (4) examined approximately 4,000 children in the public elementary schools in various parts of England and Wales. He states (5) that the condition of the teeth in the Council schools at Maldon and Heybridge² was generally good, being well above the average for Council schools. He specifically notes that "there was relatively little caries: 7.9 percent of the permanent teeth were carious, as compared with an average in all districts examined of 13.1 percent; and 12.9 percent of deciduous teeth were carious against 43.3 percent in all districts." The percentages just quoted are reported as corrected for age distribution (4) in the different schools.

Erausquin (6) who has studied mottled enamel extensively in the Argentine Republic records that there appears to be an inverse variation between dental caries and "dientes veteados," the name by which endemic dental fluorosis is known in the Argentine. He stated, however, that the findings were not conclusive on the basis of the limited number of areas studied.

Probably the first attempt to study specifically the relationship of mottled enamel to dental caries was made by McKay (7) who, in 1929, attacked the hypothesis that dental decay might be superinduced by "defective" enamel structure, by citing as evidence the observation that mottled enamel teeth, which probably constitute "the most poorly constructed enamel of which there is any record in the literature of dentistry," do not appear to show any greater liability to dental caries than do normally calcified teeth.

His report refers to studies made at Bauxite (Ark.), Minonk (Ill.), Towner (Colo.), Bruneau (Idaho), and the Pima Indian School at Sacaton (Ariz.). Certain tabulated data from the last three named places are included in McKay's report. Table 1 has been compiled from certain of these data.

Table 1. - Variation in prevalence of dental caries in normal and mottled enamel teeth of three endemic areas according to Mckay

Locality	Number of children examined	Total number of permanent teeth examined	Number of teeth examined and percentage with dental caries				
			All teeth		Molar teeth		
			Number examined	Percent carious	Number examined	Percent carious	
Towner, Colo. (Pop. 154 in 1930).	¹ 55	1, 264	Normal teeth.....	879	11	254	46
			Mottled enamel teeth.....	385	9	101	42
Bruneau, Idaho (Pop. 481 in 1930).	¹ 54	1, 142	Normal teeth.....	356	16	126	64
			Mottled enamel teeth.....	797	8	213	33
Pima Indian School, Sacton, Ariz. (Pop. un-stated).	¹ 78	2, 178	Normal teeth.....	283	22	99	81
			Mottled enamel teeth.....	1, 895	14	529	58

¹ Age, sex, color, continuity of residence, and constancy of exposure to the mottled enamel-producing waters not recorded in the report.

In 1933-34 a study was begun by the United States Public Health Service to determine the minimal threshold of toxicity of chronic endemic dental fluorosis. In this study (8) (9) (10) consecutive monthly water samples were received from each of the cities surveyed, which permitted the computation of an arithmetic mean annual fluoride (F) content of the communal water supply. The clinical examinations in these cities were limited to those children who were born in the community, had always resided there, and had continuously used the common water supply for both drinking and cooking.

In certain of these cities, in addition to recording the degree of severity of mottled enamel, each child was examined for other defects of the enamel, such as present caries, past caries (fillings or extractions), pits and fissures, hypoplasias, etc. The examinations were made in a good light with the child seated facing a window. Mouth mirrors free from blemishes and new explorers were used. For each child examined in connection with the caries aspects of the study, the facts with respect to residence and continual use of the common water supply were verified by an interview with the child's parent or guardian.

The amount of caries recorded may appear somewhat higher than usual; for, in addition to definite cavitation, defects in the enamel on caries-susceptible surfaces showing either a discoloration or opacity around the edges and in which an explorer would cling, were counted as caries. All examinations were made, however, by one individual, the writer.

An analysis of these data indicates that a higher percentage of caries-free children is found in cities whose water supplies contain relatively toxic amounts of fluorides than in those communities with water supplies not so affected. Since in certain cities only the nine year old children were examined, comparisons will be limited to children of this age. It was decided also to omit cities where less than 25 children were examined at this age. Table 2 presents the pertinent data.

Table 2. - Percentages of caries-free children, 9 years of age in 6 selected cities classified according to their continuous use of water of different fluoride (F) concentration

Locality	Actual community mottled enamel index	Domestic water supply ¹		Number of children examined
		Fluoride (F) content	Total hardness	
Pueblo, Colo.....	Negative.....	<i>p. p. m.</i> 0.6	<i>p. p. m.</i> 303	49
Junction City, Kans.....	Negative.....	0.7	277	30
East Moline, Ill.....	Border-line.....	² 1.5	242	35
Monmouth, Ill.....	Slight.....	1.7	288	29
Galesburg, Ill.....	Slight.....	1.8	237	39
Colorado Springs, Colo.....	Slight.....	2.5	20	54

¹ For detailed mineral analyses of these waters, see ref. (8) (10)

² Subject to possible correction to 1.3 p.p.m.

The data shown in table 2 indicate a greater freedom from dental caries in the 122 children exposed to domestic waters of higher fluoride (F) concentration, both with respect to permanent and deciduous teeth. It is a well known fact that deciduous teeth are seldom affected with mottled enamel; in this particular group, only 3 children, all of Colorado Springs, showed even the mildest forms of mottled enamel in their deciduous teeth, general in the second deciduous molars. Of the 122 children in the group, 60 were caries-free with respect to the permanent teeth. Of these 60, 33, or 55 percent, were affected with mottled enamel. In the whole group (122), the incidence of mottled enamel was 53 percent. These observations suggest that the limited-immunity-producing factor present in the water is operative whether or not the tooth is affected by mottled enamel. Whether this mechanism functions locally, systematically, or both ways, is not known.

Relation of Endemic Fluorosis to Dental Caries in Large Population Groups

Source of data - The disclosure of an inverse relation between the prevalence of dental caries and the fluoride concentration of the domestic water supply, as shown in table 2, raises the question of the kind of relationship between these two variables in other and larger population groups. The requisite data on dental caries are provided by the dental survey of school children 6-14 years of age, made in 26 States in 1933-34 (11) under the direction of United States Public Health Service. This survey included a total of 34,283 examinations of white children in South Dakota, 15,465 in Colorado, and 48,628 in Wisconsin, made by dentists reported as using a mouth mirror and explorer in making examinations. Furthermore, these examinations were made on a standard examination form and largely for the purpose of recording the amount of dental caries in the school population; the marked differences, therefore, in the amount of caries noted in groups using domestic waters of different mineral composition takes on an added significance.

Data on mottled enamel, on the other hand, are furnished by a recent (1938) survey of South Dakota made by the writer. During this survey (April-May 1938), approximately 3,300 school children in 51 communities were examined for mottled enamel, and endemic mottled enamel was demonstrated in 35 communities, each having a common water supply. A comparable degree of mottled enamel was widely prevalent in the surrounding rural districts in certain of the counties, ascribable to the general custom of farmers of obtaining their domestic water supply from artesian wells in the Dakota sandstone. Moreover, the examination of school children with discontinuities in their residence pointed to 21 other places in the State, not as yet surveyed, but where, on the basis of clinical signs present in the children, mottled enamel is endemic.

Method of analysis - All South Dakota counties listed in Bulletin No. 226 (11) in which 35 percent or more of the estimated population of ages 6-14 years had been examined, were selected for study. On the basis of the mottled enamel data, these counties were divided into three groups: (a) Counties where mottled enamel is prevalent, (b) counties where mottled enamel distribution is uneven, and (c) counties which, so far as we know, are entirely free from mottled enamel. Both the 1933-34 dental needs survey and the 1938 mottled enamel studies were made in these South Dakota counties lying east of the Missouri River.

In computing an index which might point out differences in dental caries in the several counties, it was decided to express the amount of caries (severity) in terms of the number of carious permanent teeth per 100 children. In order to study that age group with the maximum number of permanent teeth in mouth, the 12-14 year group was selected for study. All children referred to in the tables to follow are white. The amount of caries was determined by combining the data associated with the following items: "Caries, permanent teeth," "Extraction indicated, permanent teeth," "Filled permanent teeth," and "Extracted permanent teeth." For each of these items, the bulletin gives the number of carious permanent teeth per 100 children. Adjustment was made for sex, and the amount of caries for each county was expressed in terms of the number of carious permanent teeth per 100 children. In Public Health Bulletin No. 226, examinations from communities with a population under 5,000 were combined with examinations from the rural areas and designated "balance of county."

The South Dakota counties selected from the bulletin were classified solely on the basis of the prevalence of or freedom from endemic mottled enamel as shown by the mottled enamel study. The cities of Aberdeen, Huron, and Sioux Falls were classified on the basis of whether or not the common water supply was producing mottled enamel. The results of these computations are contained in table 3. Similar computations were also made for four Colorado cities and eight Wisconsin cities; the results are shown in table 4.

Discussion

This paper, after reviewing the findings of the earlier workers in the field, submits evidence that furnishes support to the hypothesis that a limited immunity from dental caries is operative among school children residing in endemic mottled enamel areas. This evidence may be summarized as follows:

Prevalence—Observations made on a selected sample of 9-year old children continuously exposed to waters of different fluoride concentrations, with the history of exposure personally verified in each instance by an interview with the child's parent, indicate that a high percentage of children are caries-free in those places where the common water supply contains appreciable amounts of fluorides. For instance, of the 114 children who had continuously used domestic water comparatively low in fluorides (0.6 to 1.5 p. p. m.), only 5, or 4 percent, were caries-free. On the other hand, of the 122 children of comparable age who had continuously used domestic waters containing 1.7 to 2.5 p. p. m. of fluorides, 27, or 22 percent, were caries-free. In other words, within the range of these observations, limited to a total

of 236 nine-year old children, the percentage of caries-free children in areas with domestic waters containing appreciable amounts of fluorides was over 5 times the corresponding percentage in areas with domestic water containing lower fluoride concentrations.

Severity, or amount of caries—To provide additional evidence of the relation of dental caries to endemic fluorosis, a computation of the dental caries attack rate on the permanent teeth of 12-14-year old children was made with the use of data collected in 1933-34 (Public Health Bulletin No. 226) and correlated with the data subsequently obtained on the geographical distribution of mottled enamel in South Dakota. Briefly, this study shows that, in the group of counties³ where mottled enamel is generally prevalent, an examination of 1,902

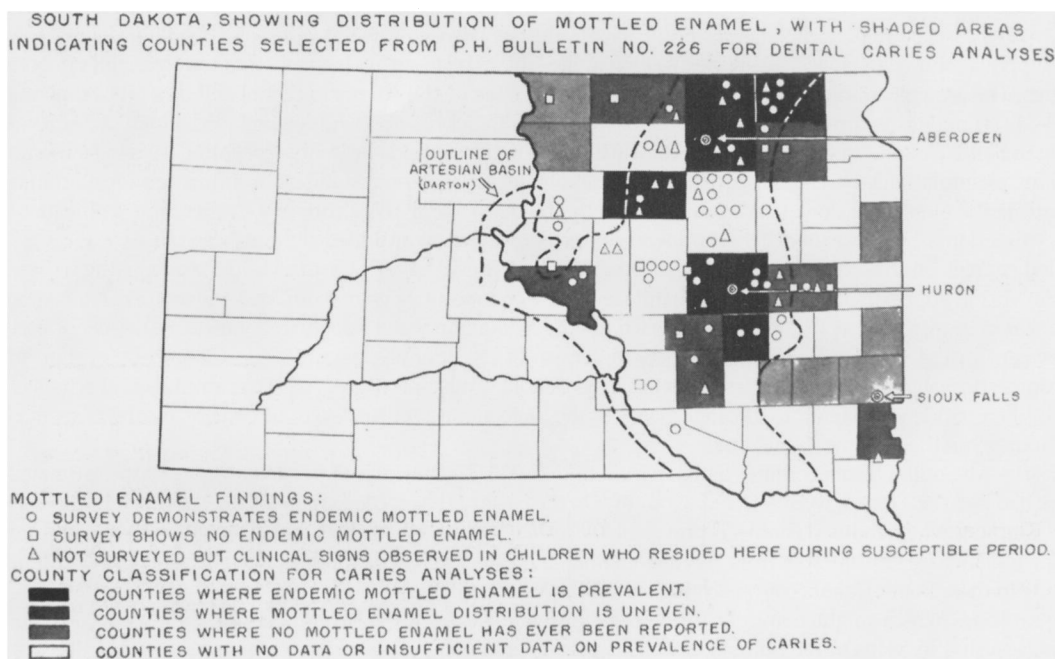


Table 3. - Dental Caries attack rates in permanent teeth of 12-14 year old white children in selected South Dakota counties and cities classified according to the prevalence of mottled enamel.

County	Number of children examined (12-14 years)	Number of carious permanent teeth per 100 children	Remarks
(a) COUNTIES WHERE MOTTLED ENAMEL GENERALLY IS PREVALENT			
Beadle (less Huron).....	332	256	Mottled enamel general throughout county. Areas include Hitchcock, Wolsey, Virgil, Yale, Cavour, and rural districts.
Brown (city, Aberdeen).....	653	203	On basis of clinical examinations, old city deep well water contained fluorides in excess of minimal threshold.
Faulk.....	266	149	Mottled enamel general throughout county. Areas include Faulkton, Orient, Cresbard, Chelsea, and rural districts.
Marshall.....	391	251	Mottled enamel severe in western half of county, including Kidder, Britton, Langford, Newark, Amherst, and rural districts. No information on eastern half of county.
Sanborn.....	260	103	Mottled enamel prevalent in county including Artesian and numerous rural districts.
Total.....	1,902	201	
(b) COUNTIES WHERE MOTTLED ENAMEL DISTRIBUTION IS UNEVEN			
Jerauld.....	295	294	Alpena and Wessington Springs are negative; some mottled enamel in and around Lane.
Aurora.....	340	227	Mottled enamel around Stickney and rural districts in northern part of county.
Kingsbury.....	398	330	Distribution varied, Iroquois, Bancroft, Esmond, and Lake Preston are endemic. DeSmet and Arlington, two largest communities in county are negative.
Day.....	666	309	Some mottled enamel in extreme western part of county around Pierpont. Bristol and Andover are negative by survey. No indications of mottled enamel in any other section of county.
Hughes.....	184	206	Blunt negative for mottled enamel; cases being developed in rural district around Harrold.
McPherson.....	346	394	Some mottled enamel in extreme eastern part of county around Leola. Eureka surveyed and negative. County generally free of mottled enamel.
Lincoln.....	536	284	Some mottled enamel observed from Beresford; no other record of mottled enamel in county.
Total.....	2,765	314	
(c) COUNTIES WHERE NO MOTTLED ENAMEL HAS EVER BEEN REPORTED			
Beadle (city, Huron)....	436	398	Negative for mottled enamel; obtains city water from James River with deep well as a reserve.
Campbell.....	264	368	No record of mottled enamel in this county. Herreid negative by survey.
Denel.....	212	218	No reports of mottled enamel in this county.
Hanson.....	271	382	Do.
McCook.....	344	407	Do.
Minnehaha:			
City, Sioux Falls....	608	451	No reports of mottled enamel in this city; State chemist reports 0.4 p. p. m. F in treated city water.
Balance of county..	584	476	No reports of mottled enamel in this county.
Moody.....	433	498	Do.
Walworth.....	329	355	Do.
Total.....	3,481	415	

white children, 12-14 years of age, disclosed 201 carious permanent teeth per 100 children. In the intermediate group of seven counties where the mottled enamel distribution was uneven, and at times sporadic, the examination of 2,765 children showed 314 permanent teeth affected per 100 children; and in the third group of counties and the cities of Huron and Sioux Falls, where no endemic mottled enamel areas are known to exist, an examination of 3,481 children showed a dental caries attack rate of 415 permanent teeth per 100 children. These data indicate that the dental caries attack rate in this particular population is inversely proportional to the prevalence of mottled enamel.

Table 4. - Dental Caries attack rates in permanent teeth of 12-14 year old white children of ALL Colorado and Wisconsin cities listed in public Health Bulletin no. 226

City	Number of children examined (12-14 years)	Number of carious permanent teeth per 100 children	Fluoride (F) content of common water supply (p. p. m.)	Reference
Colorado				
Colorado Springs.....	208	162	2.5	(8)
Pueblo.....	411	194	0.6	(8)
Denver.....	637	342	0.5	(12)
Fort Collins.....	207	296	None	(12)
Wisconsin				
Green Bay.....	687	275	2.3	-----
Sheboygan.....	244	710	0.5	(13)
Manitowoc.....	661	682	0.35	(13)
Two Rivers.....	382	646	0.3	(13)
Milwaukee.....	2,645	917	0.3	(13)
West Allis.....	160	831	0.3	(13)
Baraboo.....	119	733	0.2	(13)
La Crosse.....	47	731	0.12	(13)

¹ "Extraction indicated" for boys "Unknown", 4.2 rate for girls used in this adjustment. - Author.

² Determination made by Senior Chemist E. Elvolve, Division of Chemistry, National Institute of Health. Approximately the same amount has been reported by DeWitt and Nichols (J. Am. Water Works Assoc., 29:980-984 (July 1937). Note- For the mineral constituents, other than fluorine, of these Wisconsin waters, see Public Water Supplies of Wisconsin. Wisconsin State Board of Health, July 1935.

Similar comparisons made among four cities of Colorado show that in the non-endemic communities, Pueblo, Fort Collins, and Denver, the dental caries attack rate is 194, 296, and 343, respectively; on the other hand, in the endemic area, Colorado Springs, only 163 permanent teeth per 100 children were affected. Applying the same methods of study to eight Wisconsin cities, it was found that in the seven where no endemic mottled enamel is known to exist and where the fluoride (F) content of the communal water supplies ranges from 0.1 to 0.5 p. p. m., the severity of dental caries showed rates from 646 to 917 carious permanent teeth per 100 children. But in the city of Green Bay, where the city water contains 2.3 p. p. m. of fluoride (F), only 275 carious permanent teeth per 100 children were recorded.

It is fully realized, of course, that the causes of dental caries are, as Rosenau states, "complex and perhaps multiple." Mill's recent analysis of Public Health Bulletin No. 226, ⁴ moreover, indicates that the dental caries attack rates (amount of dental caries) vary markedly in different geographical regions.

An inspection of the data included in this paper brings out the fact that, regardless of the dental caries attack rate of the region, the use of a domestic water which in itself is capable of producing mottled enamel is concomitant with a lower amount of dental caries.

Relation to dental caries research—The relationship of chronic endemic dental fluorosis (mottled enamel), a water-borne disease, to dental caries raises several questions, for example:

1. What role, if any, does the physical structure of a tooth play in either susceptibility to or immunity from dental caries?
2. Is the higher fluoride content of the enamel of a mottled-enamel tooth the immunity-producing factor?
3. Is the limited immunity due, directly or indirectly, to the well-known inhibitory action of fluorine on enzymatic processes?
4. While on the basis of our present knowledge it appears justifiable to associate the observed results with the presence of fluorides in the domestic water, the possibility should not be overlooked that other elements of comparatively rare occurrence in water or ordinary constituents of drinking water present in unusually large concentration may directly or through a synergistic action with the fluoride,

produce the observed effects. For this reason, it appears essential to obtain as complete chemical analyses as possible of the domestic water of communities which are under investigation for dental caries.

Summary

1. Examinations of 236 nine-year old children with verified continuity of exposure showed that a higher percentage of children is caries-free in those communities where the domestic water supplies contain higher concentrations of fluorides (F) in comparison with communities using waters of lower fluoride concentrations. This limited immunity to dental caries seemed operative with respect to the deciduous teeth as well as the permanent teeth.

2. An analysis of dental caries attack rates in a relatively large number of children in the three States thus far studied (South Dakota, Colorado, and Wisconsin) indicates that the severity of dental caries is, in general, lower in mottled enamel areas as compared with normal areas in the same State.

3. Inasmuch as it appears that the mineral composition of the drinking water may have an important bearing on the incidence of dental caries in a community, the possibility of partially controlling dental caries through the domestic water supply warrants thorough epidemiological-chemical study.

Acknowledgement

The outline of the artesian basin in eastern South Dakota shown in figure 1 was taken from plate LXIX, by N. H. Darton, in part 2 of the Seventeenth Annual Report of the United States Geological Survey, 1895-96.

The writer desires to express his indebtedness to Senior Statistician Wm. M. Gafafer and Senior Chemist E. Elvove, National Institute of Health, for many helpful suggestions and criticisms in the preparation of this paper, to the Wisconsin State Board of Health for supplying information on the fluoride content of the water supplies of the seven Wisconsin cities with high dental caries attack rates, and to Principal Statistician Selwyn D. Collins, National Institute of Health, for a review of the paper.

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¹ From the Division of Infectious Diseases, National Institute of Health

² A total of 214 children was examined in the 2 schools

³ The city of Aberdeen is included in the group of counties as this city was using 3 deep well water supply at the time of the dental caries survey. This water supply produced a mild degree of mottled enamel in about 30 percent of the children continuously using the water.

⁴ *J. Dent. RM.*, 16; (Oct.) 1937.