Prevalence of Dental Mottling in School-aged Lifetime Residents of 16 Texas Communities

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Abstract: The severity of dental mottling in 2,592 school-aged, lifetime residents of 16 Texas communities was investigated in 1980-81 to identify factors associated with mottling and to construct a prediction model for the prevalence of mottling. The communities were selected to obtain a wide range of levels of fluoride in the drinking water. The children within each of the communities were contacted through their schools and received a dental examination to assess the severity of mottling. Information on demographic, dental health practice, and other candidate predictor variables was obtained from a questionnaire completed by a parent. A number of water quality measurements were also recorded for each community. White and Spanish-surname children had about the same prevalence of mottling while Blacks had a higher prevalence, odds ratio ($\widehat{OR}$) = 2.3, 95% confidence interval = 1.4, 3.7. Children from homes which had air conditioning had a lower prevalence of mottling ($\widehat{OR}$ = .6, (0.4, 0.8)). The use of fluoride toothpaste or drops and the number of fluoride treatments were almost identical among those who did and did not develop moderate mottling. In addition to fluoride, total dissolved solids and zinc were water quality variables associated with mottling. (*Am J Public Health* 1985; 75:1408–1412).

Introduction

The recognition of the protection against dental caries provided by fluoride in drinking water is considered one of the major public health advances of this century.[1] It is also recognized, however, that dental mottling occurs at fluoride levels in excess of those that provide most of the protection against dental caries.[2,3]

The epidemiologic studies conducted by Dean in the 1930s demonstrate the relationship between the prevalence of mottling and the level of fluoride in drinking water.[4-9] The now-standard classification of the degree of mottling exhibited by an individual as normal, questionable, very mild, mild, moderate, or severe was proposed by Dean at that time.[4,9,10] His Community Fluorosis Index (CFI), which is a weighted sum of the frequency of each of the six categories of mottling,[10] was later proposed as a useful summary measure of the degree of mottling in a community and exhibits a simple piecewise linear relationship with the natural logarithm of the level of fluoride in the drinking water.[11]

Major drawbacks of the CFI include its inability to describe the distribution of the population across the six categories of mottling and its dependence on an imposed set of weights which indicate a greater precision in the diagnosis of severity of the mottling than actually exists. Moderate and severe mottling are generally considered cosmetically objectionable while questionable, very mild, and mild mottling results in what is considered by some only a minor cosmetic effect.[12,13] The brittleness of moderately and severely mottled teeth may be associated with elevated caries levels.[14-17] No such adverse dental health effect has been associated with questionable, very mild, and mild mottling. The magnitude of these qualitative differences is not adequately represented with the usual weights given to the levels of severity of mottling.

Because of these qualitative differences, only two categories of severity of mottling are considered in the present paper. Those with moderate and severe mottling are treated as one category; those characterized as normal, questionable, very mild, and mild are treated as the other category. This dichotomization is implicit in the work by Richards, *et al*,[18] in the establishment of "optimal" fluoride levels.

Higher air temperatures are associated with the consumption of greater amounts of water and, therefore, a greater intake of fluoride.[18,19] Richards, *et al*, have proposed the establishment of an "optimal" level of fluoride as a monotonically decreasing, piecewise linear function of mean maximum daily air temperature. The "optimal" fluoride level, according to Richards, *et al*, is just below that at which moderate mottling first appears. Galagan and Vermillion[19] developed a method for determining an "optimum" fluoride concentration in drinking water which accounts for the effect of air temperature on water consumption. The current Environmental Protection Agency (EPA) fluoride standard is set at twice the "optimal" level based on Galagan and Vermillion's method which is said to have factor-of-optimal equal to 2. (See Clark and Corbin[20] for a discussion of the evolution of the EPA's fluoride standard.)

The prevalence of moderate and severe mottling in school-aged, lifetime residents of 16 Texas communities is the topic of this report. Predictors of such mottling other than fluoride and mean maximum air temperature are identified. Variables measured at the community level as well as the individual level are considered. Both types of variables are included in a logistic regression model which is developed to predict the prevalence of moderate and severe mottling.

Methods

A complete description of study design and subject selection has been published elsewhere and only an outline of the relevant features is presented here.[21] Sixteen Texas communities were selected to reflect a wide range of levels of fluoride in the drinking water. Emphasis was placed on selecting some communities near and beyond twice the optimal level of fluoride in the drinking water. All children who were lifetime residents of the communities and who were enrolled in grades 2–6 (ages 7–13) and grades 9–12 (ages 14–19) of the public schools were eligible to participate in the study. Cooperation was not always received from grade school and high school principals of a community so that both age groups are not available for some communities.

The mean concentration of fluoride in the drinking water

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TABLE 1—Texas Communities Included in the Study along with Several Community-level Predictor Variables, Prevalence of Mottling and the Community Fluorosis Index

Texas Community	Fluoride		Mean Maximum Daily Air Temperature (°Fahrenheit)	Number of Lifetime Residents Examined	% with Moderate Mottling**	Community Fluorosis Index
	ppm	Factor of* optimal				
New Braunfels	0.2	0.3	78.6	103	0.0 (0)	0.26
San Marcos	0.2	0.3	78.4	223	0.0 (0)	0.14
San Antonio	0.3	0.4	78.8	125	0.0 (0)	0.05
Kingville	0.7	1.0	83.0	359	0.3 (1)	0.53
Alvin	1.0	1.3	76.6	211	0.9 (2)	0.47
Angleton	1.0	1.3	76.6	187	1.1 (2)	0.59
Kerrville	1.1	1.4	77.1	128	0.0 (0)	0.33
Alpine	1.8	2.3	76.1	23	13.0 (3)	1.41
Littlefield	1.9	2.3	72.8	108	14.8 (16)	1.36
Fort Stockton	1.9	2.5	79.0	300	3.7 (11)	1.06
Hillsboro	2.1	2.7	76.8	197	4.6 (9)	1.37
Monahan	2.1	2.7	77.6	169	13.6 (23)	1.35
Perryton	2.3	2.7	69.7	91	6.6 (6)	1.33
Gatesville	2.3	3.1	78.0	111	4.5 (5)	1.20
Abernathy	2.4	2.9	73.2	67	32.8 (22)	2.02
Taylor***	3.3	4.3	78.4	190	30.0 (57)	1.89

*Calculated according to Galagan and Vermillion.[12]
**Per cent (Number).
***Because only one child who resided in Taylor, had severe mottling, this comparison is actually between children with moderate mottling and children with mottling less severe than moderate.

and the mean maximum daily air temperature for the selected communities are listed in Table 1. The values for these variables for each community are an average of measurements taken between 1960 and 1978. The number of measurements contributing to these averages varied by community and ranged from six to 15. Table 1 also presents the fluoride level measured as a factor of optimal; the percentage of children with moderate mottling; and the Community Fluorosis Index for each community.

Other community-level predictors were: total dissolved solids (TDS), calcium, potassium, zinc, strontium, lead, vanadium, chrome, titanium, mangesium, iron, nickel, copper, arsenic, rubidium, molybdenum, and barium. Measurements for these predictors were made at the schools at the time of the dental examinations except for TDS, which is an average of measurements taken since 1960. The desired range of fluoride values was achieved with a narrow range of average air temperatures. A wide range of values was achieved for each of the other candidate predictors although most communities were clustered at the lower levels of each of these variables. A number of these trace elements have been investigated as risk factors for mottling; zinc, strontium, and chromium have been found to be strongly associated in animal studies.[22–24] Strontium has been reported as a risk factor in one epidemiologic study.[25]

Packets containing information sheets, screening questionnaires, and consent forms were distributed to 27,566 children and 5,273 (19 per cent) were returned. Of these, 2,621 were lifetime residents. Because of the stated preference for lifetime residents, the response rate for eligible subjects may be substantially greater than the overall 19 per cent response rate. All respondents were invited to participate in the dental examination described below. Only 2,592 lifetime residents are considered in this report (Table 1).

Each child received a dental examination performed by one of the authors (VS), and their parents were asked to complete a second questionnaire. Examinations, conducted in a specially equipped vehicle, included an evaluation of each tooth for enamel mottling and complete visual tactile caries assessment of each tooth surface. Each child was graded as being in one of Dean's six categories of mottling.[4,10]

Demographic, dental health practices, and other information on each child was obtained from the second questionnaire (Table 2).

The univariate statistical analysis of individual-level variables was stratified on community. This is analogous to blocking in analysis of variance and controls for differences among communities while identifying predictors within communities.[26] The odds ratio for the association between moderate mottling and levels of the candidate risk factors was obtained using the Mantel-Haenszel method.[27] The variables which are continuous in nature (mother's age, mother's education, months breastfed, etc.) were also examined using linear regression.[26] The two methods of statistical analysis produced essentially the same results.

The univariate analysis performed on each variable used all individuals for whom that variable was not missing (Table 2) and, because of missing values, involved a different number of individuals for each variable. Once attention could be focused on a smaller number of predictor variables, further analysis was restricted to the subset of individuals for whom all variables are known.

The multivariate analysis was based on the logistic regression model[28] because of the sigmoid shaped dose-response relationship between the prevalence of moderate mottling and fluoride concentration in the drinking water exhibited in previous studies.[4–9,18] The model was first fit using the individual-level predictors, controlling for the 16 communities as in a stratified analysis. After the individual-level predictors had been identified, the stepwise variable selection routine was used to identify community-level predictors.[29] The usual statistical tests were adjusted to accommodate the correlation introduced by children residing in 16 communities.[30]

Results

The prevalence of moderate mottling is increased with fluoride level in the community drinking water (Table 1).

TABLE 2—Candidate Individual-level Predictor Variables for the Prevalence of Moderate Mottling among Children in 16 Texas Communities, 1980–81

Sex	
Male	1255 (48)*
Female	1337 (52)
Race	
White	1112 (43)
Spanish	1221 (47)
Black	250 (10)
School Grade	
2–6	2094 (81)
9–12	498 (19)
Home Air Conditioning**	
Age 0–2	Yes 1137 (46)
	No 1330 (54)
Age 2–6	Yes 1284 (52)
	No 1166 (48)
Breastfed, months	
0	2069 (80)
1—12	483 (19)
13+	25 (1)
Children in Family	
1–2	826 (33)
3–4	971 (39)
5+	700 (28)
Mother's Education (yrs)	
0–8	684 (27)
9–11	1225 (48)
12	409 (16)
13+	253 (10)
Mother's Age at Child's Birth (yrs)	
<=19	349 (15)
20–24	792 (33)
25–29	604 (25)
30–34	390 (16)
35<=	256 (11)
Fluoride Toothpaste	
Always	1490 (64)
Sometimes	802 (35)
Never	23 (1)
Number Fluoride Treatments	
None	1558 (61)
1–3	684 (27)
4+	301 (12)
Fluoride Drops	
No	2408 (94)
Yes	161 (6)

*Number of children (per cent). The number of children may not total to 2,592 because of missing values.

**Information on air conditioning was obtained for two age intervals since exposure at earlier ages, when permanent teeth are forming, may be a better predictor.

However, there were substantial differences in the prevalence of mottling among communities with the same fluoride level and substantial deviations from a monotonically increasing relationship for absolute fluoride as well as for fluoride measured as factor-of-optimal. Thus it appears that predictors other than fluoride and air temperature are needed to explain the variation in the prevalence of moderate mottling.

TABLE 3—Estimates for the Coefficients of the Logistic Regression Model for the Prevalence of Mottling among Children in 16 Texas communities, 1980–81

Variables*	Coefficient	Odds Ratio (95% Confidence Interval)
Intercept	−6.26	—
Home Air Conditioning age 2–6 years	−0.54	0.58 (0.40,0.85)
Race	0.84	2.32 (1.44,3.71)
Fluoride	1.59	4.90 (3.80,6.33)
Total Dissolved Solids	−1.41	0.24 (0.14,0.41)
Zinc	0.78	2.18 (1.26,3.78)

*Air Conditioning: 0 for No, 1 for Yes; Race: 0 for Others, 1 for Blacks; Fluoride: Factor-of-Optimal; Total Dissolved Solids: 0 for <800 ppm, 1 for >800 ppm; Zinc: 0 for <100 ppm, 1 for >100 ppm.

The Community Fluorosis Index (CFI), although not the focus of this article, is also presented in Table 1 to indicate that the level of mottling in these 16 communities is comparable to that found by others.[10,17,18] The limitations of the CFI in indicating the percentage of children in the different mottling categories are also apparent from the Table.

The individual-level variables are listed in Table 2. Most children were either White or had a Spanish surname and were in grades 2–6. About half the children lived in households with air conditioning; 20 per cent were breastfed for a month or more; and 28 per cent lived in households with five or more children. A large proportion (73 per cent) of the mothers had completed some high school. Almost all the children used fluoride toothpaste, a large proportion (39 per cent) had received at least one fluoride treatment, and relatively few had used fluoride drops.

In univariate analysis, children who were White or had a Spanish surname had about the same prevalence of mottling while Blacks had a higher prevalence. Children from homes which had air conditioning between ages 2–6 years had a lower prevalence of mottling. The use of fluoride toothpaste or drops and the number of fluoride treatments were almost identical among those who did and did not develop moderate mottling, and there wsa little or no association of moderate mottling with sex, grade, breastfeeding, mother's education, or mother's age at the time of the birth.

After including race and air conditioning as individual-level predictors and controlling for level of fluoride in the drinking water, TDS and zinc were the only community level predictors found to be associated with the prevalence of mottling. Various transformations of TDS and zinc were examined for this model. The simple dichotomization of these variables was found to provide as good a fit as more complex transformations. A natural break occurred among the TDS values at 800 ppm, and for zinc at 100 ppm.

The estimates for the coefficients for the logistic model are presented in Table 3. The odds ratios for the individual-level predictors are comparable to those observed in the univariate analysis, indicating the absence of confounding by the other variables.

The observed and predicted prevalences of moderate mottling for the reduced data set are presented in Table 4. The overall fit of the model is quite good, and many of the

TABLE 4—Observed and Predicted Prevalence of Moderate Mottling among Children in 16 Texas Communities, 1980–81

Texas Community	TDS*	Zinc*	Number at Risk	Prevalence of Moderate Mottling**	
				Observed	Predicted
New Braunfels	415	18.4	103	0.0 (0)	0.3 (0.3)
San Marcos	491	284.0	199	0.0 (0)	0.7 (1.3)
San Antonio	398	0.8	114	0.0 (0)	0.3 (0.4)
Kingsville	1260	3.6	324	0.3 (1)	0.2 (0.8)
Alvin	785	22.3	195	1.0 (2)	1.2 (2.2)
Angleton	751	14.1	181	1.1 (2)	1.3 (2.4)
Kerrville	590	2.1	119	0.0 (0)	1.7 (2.1)
Alpine	245	192.8	22	13.6 (3)	14.9 (3.3)
Littlefield	550	68.1	108	14.8 (16)	8.2 (8.9)
Fort Stockton	1870	50.2	282	3.9 (11)	2.5 (6.9)
Hillsboro	1340	58.2	191	4.2 (8)	4.5 (8.6)
Monahan	550	11.0	165	13.9 (23)	13.7 (22.5)
Perryton	550	16.0	86	7.0 (6)	11.8 (10.2)
Gatesville	1340	3.5	109	4.6 (5)	5.6 (6.1)
Abernathy	550	373.0	65	33.8 (22)	31.4 (20.4)
Taylor	960	3.3	179	31.3 (56)	32.7 (58.6)

*Total dissolved solids, parts per million.
**Per cent (number).

differences in prevalence among communities with the same fluoride levels have been addressed. Only for the community of Littlefield is there a relatively large discrepancy between predicted and observed prevalence (14.8 per cent observed vs 8.2 per cent predicted).

Discussion

The association of the prevalence of mottling with race has not been observed in other studies. In fact, Dean reported in the 1930s that race and color did not appear to affect the prevalence of mottling.[6,7] Most of Dean's studies were conducted in predominantly White populations so that the statistical power of detecting a difference due to race was probably very low.

The lower prevalence of mottling among children from households which had air conditioning is consistent with what is already known about the effect of air temperature on the prevalence of mottling. This association could also be attributed to socioeconomic status since families with air conditioning most likely had higher incomes. However, mother's education, another surrogate measure of socioeconomic status, was not associated with mottling.

Five towns had high values for TDS, providing substantial confirmation that high TDS is associated with lower prevalence of mottling. This association might be due to the amount of water consumed by the children, since high TDS would make the water less palatable. Another explanation is that TDS could interfere with the measurement of the level of fluoride in the drinking water which is available for incorporation in the tooth enamel. The reported fluoride levels include all fluoride in the water, even that fluoride which is bound. Higher levels of TDS might indicate that a higher proportion of the total fluoride is bound and thus not available for incorporation into the tooth enamel. Alternatively, TDS might interfere with the actual measurement of fluoride so that reduced values are obtained. Other explanations are possible and additional research on this association is warranted.

The association with zinc is less convincing since only three towns had high values of zinc. It should also be noted that zinc values are based on a single measurement taken at the time of the dental examinations and may be less reliable than the measurements of fluoride and TDS which were averages of measurements taken over many years. The existence of a real association is reinforced, however, by the identification of zinc exposure as a cause of mottling in animal studies.[23]

Only one child in this study had severe mottling, substantially less than that expected on the basis of previous work. Driscoll, *et al*,[17] found severe mottling in 23 per cent of the children in Illinois communities with 4.0 fluoride level as factor-of-optimal. However, only 7 per cent of those children had moderate mottling, resulting in a total of 30 per cent with the two most advanced levels of mottling. This total is comparable to the 34 per cent prevalence rate observed in the community of Taylor. Thus, if one focuses on the combined prevalences of moderate and severe mottling, then the findings reported here are comparable to those of other researchers.

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