

# The Influence of Various Fluoride Exposures on the Prevalence of Esthetic Problems Resulting from Dental Fluorosis

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## Abstract

**Objectives:** This study sought to determine the prevalence of esthetic problems due to dental fluorosis, and determine the relationship of different fluoride exposure histories to the occurrence of these problems. **Methods:** In 1993–94 2,715 children in grades 2 and 3 and 3,297 adolescents in grades 8 and 9 were examined by four dentists. Questionnaires detailing exposures to various fluoride technologies were collected from 3,022 of these study participants. Esthetic ratings of the participants' maxillary anterior teeth were made by the examiners, the participants themselves, and their parents using questionnaires designed for this purpose. **Results:** Data indicate that 46 percent of the participants had dental fluorosis. Only 40 percent had fluorosis on anterior maxillary teeth. The prevalence of esthetic problems ranged from about 1 percent to 4 percent, depending on how an esthetic problem was defined. Esthetic problems as defined by the participant were more prevalent for the "over 11" age group. Logistic regression results demonstrated significant associations between several of the classifications of esthetic problems and the use of fluoride supplements and dentifrices, and exposure to fluoridated water during the third year of life. **Conclusions:** Results suggest that the prevalence of esthetic problems is low in the communities surveyed, and that exposure to any number of fluoride technologies in the third year of life can increase a child's risk for this problem. [J Public Health Dent 1997;57(3):144-9]

**Key Words:** dental fluorosis, esthetic problems, fluoride, risk predictors.

The increased prevalence of dental fluorosis in North America is well documented (1-3). Until recently, however, little research had been done to evaluate public perceptions about the esthetics of dental fluorosis (4-8).

Clark (4) found that evaluations by children and their parents of the esthetics of teeth with different classifications of the Tooth Surface Index of Fluorosis (TSIF) suggested that the majority of children with scores of 1 had no esthetic concerns. Problems over esthetics increased as TSIF scores increased from 2 to 6. Riordan (7) assessed the opinions of university students, parents, public servants, and dentists concerning the facial esthetics of children with dental fluorosis. These evaluations of children with

Thylstrup Fejerskov Index (TFI) (9) scores ranging from 0 to 3 suggested that scores of 2 or greater were easily noticed, while scores of 3 aroused concern for most raters.

These studies suggest that professionals and lay persons can distinguish between fluorosed and non-fluorosed teeth, even at lower levels of severity. However, these studies fail to establish the extent or prevalence of the esthetic problem resulting from dental fluorosis in the community. Furthermore, no research has assessed the influence of different fluoride technologies on the risk of esthetic problems due to dental fluorosis. Current measurement systems for dental fluorosis fail to measure the degree of concern about the esthetics of visible

teeth; therefore, there is no way of knowing how dental fluorosis impacts on people's perceptions of facial esthetics (10). As Ripa suggests, the misconception that the increased prevalence of dental fluorosis increases the prevalence of esthetic or social problems for some people has seemingly persisted. Whether this issue might constitute a social or public health problem remains unanswered. Horowitz adds that, "although mild fluorosis is generally interpreted as having minimal cosmetic importance, it may be considered an esthetic problem to persons affected" (11). In reality, it is only the assumed increased prevalence of esthetic problems due to dental fluorosis that is of real concern. Because most cases of dental fluorosis in children are mild to very mild, there may not be a problem. This investigation quantifies the extent of this esthetic problem in a community, and determines risk predictors associated with this problem.

## Methods

This report analyzes baseline data from a longitudinal study that will monitor the prevalences of dental caries and fluorosis over time in communities that have defluoridated their water supplies. The study population consisted of all children and adolescents in grades 2, 3, 8, and 9 residing in Comox and Courtenay (twin cities), Campbell River, and Kamloops, British Columbia. Each of these communities, having been fluoridated for over 25 years, held referenda to determine if fluoridation would continue. Two of the three referenda failed. Kamloops voted to retain fluoridation and was included in this study as a positive control.

Following the review and approval of the protocol by the Institutional Review Committee at the University of British Columbia, a passive consent was used to solicit participation in the study. Lifelong residence histories and the use of various fluoride technologies from birth to the age of 6 were obtained from questionnaires sent home to parents. A nearly identical questionnaire was used in previous research, and its reliability demonstrated (4,12,13). The instrument consisted of a 35-item, self-administered, closed-end questionnaire that sought to determine each student's lifelong exposure to fluoridated water, and their use of infant formula, dietary fluoride supplements, and fluoride dentifrice during the first six years of life. Exposure was determined by requesting a yes/no response to the question concerning exposure for each year of life. The only modifications to the previously used instrument sought to determine the education status of the head of household, a parental esthetic evaluation of their child's teeth, and the opinions of the head of household regarding the safety and effectiveness of water fluoridation. This portion of the questionnaire was pilot tested using a convenience sample of parents prior to its use in the field.

**Clinical Evaluations.** The clinical examinations included use of the Thylstrup Fejerskov Index of Fluorosis (TFI); a modified DMFS index that scored both incipient (D<sub>1</sub>) and cavitated (D<sub>2</sub>) lesions on both pit and fissured and smooth tooth surfaces, where applicable (Canadian Dental Association, 1990); and esthetic evaluations of maxillary anterior teeth by the participants and examiners. Participants were examined for fluorosis in schools with and without the use of a standard dental light and the highest of the two TFI scores assigned. Teeth also were dried prior to the fluorosis examinations.

Esthetic ratings of the participants' teeth were made by the examiners (visible anterior teeth) prior to scoring for caries or fluorosis, and by participants and their parents or guardians using instrumentation developed by Riordan (7) and Clark (4). The three rater groups were asked to evaluate the esthetics of the participant's teeth by indicating an opinion about the statement, "The appearance of these

(my or my child's) teeth is pleasing and looks nice." Response choices included "agree strongly, agree, neutral, disagree, disagree strongly." Self-ratings by the participants were made prior to their clinical examination, and in isolation of the examination setting. Parents made their evaluation on the questionnaire that participants took home. Examiners had no prior knowledge of a participant's rating when they made their assessments. After the examiners finished their clinical examination, they were instructed to question participants to determine the explanation of or the source of a "neutral, disagree, or disagree strongly" response on their self-rating. Previous research indicated that response categories for these ratings were "too yellow, dental fluorosis, enamel hypoplasia, and a category where no observable condition was identified" (5). A second esthetic rating was made by each examiner using a previously tested 0–10 cm visual analog scale (VAS) (4). Any individual examiner's rating that was 1.5 standard deviations below their own mean rating for all children was classified as an esthetic problem.

An individual participant was classified as having an esthetic problem due to dental fluorosis in five different ways. Each different classification included at least a "neutral, disagree, or disagree strongly" participant response, and the presence of dental fluorosis as the observable explanation for the student's concern. One classification of an esthetic problem (Esthetic Problem #1) was defined by a "disagree or disagree strongly" examiner response to the reference statement. A second classification of an esthetic problem (Esthetic Problem #2) was defined by the aforementioned examiner response, or a "disagree or disagree strongly" participant response to the reference statement. A third classification (Esthetic Problem #3) was defined by a "neutral, disagree, or disagree strongly" participant and a "neutral, disagree, or disagree strongly" examiner response. The fourth classification (Esthetic Problem #4) was defined by a "disagree or disagree strongly" participant and a "neutral, disagree, or disagree strongly" parental response to the reference statement. A fifth classification of an esthetic problem (Esthetic Problem #5) was defined by a

"neutral, disagree, or disagree strongly" participant response and an examiner rating that was 1.5 standard deviations below their mean rating on the VAS. These five problem definitions were used as dependent variables in separate logistic regression models.

Four examiners participated in the survey. The principal investigator administered two separate, one-week training exercises at each of the two study sites (Kamloops and Comox/Courtenay/Campbell River) to standardize examiners in the use of the indices and esthetic assessments. During these exercises, half a day of training was devoted to the review and discussion of the examination criteria and procedures. Another half-day was used to demonstrate and review the actual clinical procedures with actual participants. Four other full days were spent performing examinations in schools. The first of these examination days included all duplicate examinations among the two examiners for that site and the principal investigator who has been standardized in the use of TFI and D<sub>1</sub>D<sub>2</sub>MFS. Three additional days were spent separately examining participants at the same school, and performing duplicate examinations when an interesting or challenging classification presented. Duplicate examinations in each study site during the main study generated reliability data on D<sub>1</sub>D<sub>2</sub>MFS and its components, the TFI, and the examiners' and participants' esthetic evaluations.

**Data Analysis.** Basic descriptive statistics such as the percent of children using specified preventive products and the percent of participants who presented with different classifications of esthetic problems were generated. Bivariate associations among the five classifications of esthetic problems, various dichotomous classifications of the exposure variables, and community of residence were tested for significance using the chi-square test statistic. On the basis of these analyses, logistic regression models were developed to determine the risk of experiencing an esthetic problem from dental fluorosis given a set of independent variables, including exposure to water fluoridation, fluoride supplement use, dentifrice use, exposure to infant formula, and the educational status of the head of household.

Various models were developed for the five esthetic problem definitions for both separate and combined age categories. Logistic regression analyses were performed using combined and separate age groupings recognizing that the identification of esthetic problems was more prevalent in the "over 11" age group. We assumed in this analysis that an individual's perception of his or her esthetics might change depending on age. For this analysis, only two age groupings were possible. Fluoride exposure variables were defined separately by total number of years, each year of exposure for years 1 through 6, and several combinations of years 1, 2, 3, and 4.

## Results

The reliability of the participants' esthetic ratings was good ( $\kappa=0.63$ ) for 134 participant duplicate ratings. Estimates of examiner reliability are presented in Table 1. One examiner in Kamloops had low numbers of intraexaminer duplicate examinations; her data are not included. Intraexaminer reliability in Kamloops was excellent, and in Comox/Courtenay/Campbell River it was generally excellent for both examiners, with the exception of one whose intraexaminer  $\kappa$  score was 0.36 for the esthetic rating. Interexaminer reliability was excellent in both study sites.

During the baseline survey in

1993-94, a total of 2,715 children in grades 2 and 3 and 3,297 adolescents in grades 8 and 9 were examined, while a total of 680 children and adolescents did not consent. Usable questionnaires were collected from 3,022 participants. Frequency distributions of participants by fluoride exposure variables reflect the varied and complex histories of exposure to the various types of fluorides available today (Table 2). The data suggest that approximately 50 percent of the participants with confirmed exposure histories had lifelong exposure to fluoridated water, about 25 percent had exposure to fluoride supplements for the first six years of life, and nearly all

**TABLE 1**  
Examiner Reliability

	n	Kappa Statistics	
		TFI	Esth
Intraexaminer			
Kamloops			
Examiner 1	14	0.49	1.00
Comox/Courtenay/Campbell River			
Examiner 1	28	0.65	0.36
Examiner 2	26	0.74	1.00
Interexaminer*			
Kamloops	22	0.74	1.00
Comox/Courtenay/Campbell River	58	0.64	0.71

\*Between examiner pairs in each study site, i.e., two in Kamloops and two in Courtenay/Comox/Campbell River.

**TABLE 2**  
Frequency Distribution of Fluoride Exposure Histories for all Participants by Study Site

	Study Site		
	Kamloops	Comox/Courtenay	Campbell River
Number of participants confirmed histories	1,662	747	613
Residency status in fluoridated community			
Lifelong exposure	1,081	363	332
No exposure under 6 years	212	146	89
All years under 6	318	202	179
Fluoride supplements under 6 years of age			
No exposure	448	252	154
4 or more years	668	295	285
6 years of exposure	456	183	179
Fluoride dentifrice exposure under 6 years of age			
Less than 1 year	37	36	22
4 or 5 years	1,408	582	476

**TABLE 3**  
Percent Distribution of Participants According to Most Severe TFI Score

Teeth	TFI Score							
	0	1	2	3	4	5	6	7
All								
Total #	3,271	1,323	1,046	299	43	26	3	1
Percent	54	22	17	5	<1	<1	<1	<1
Maxillary anterior								
Total #	3,644	1,240	836	226	35	18	0	0
Percent	61	21	14	4	<1	<1	0	0

**TABLE 4**  
**Percent Distribution of Esthetic Ratings by Rater Group**

Rater Group	Individual Ratings*				
	1	2	3	4	5
Examiner	8	85	5	2	0
Participants					
All	2	70	16	12	0
11 and under	3	81	8	8	0
Over 11	2	60	23	15	1
Parents/guardians	19	55	16	8	1

\*Rating descriptors: 1=strongly agree, 2=agree, 3=neutral, 4=disagree, 5=strongly disagree with the statement "The appearance of these (my or my child's) teeth is pleasing and looks nice."

**TABLE 5**  
**Prevalence of Esthetic Problems by Problem Definition and Age Group**

Problem Definition	Prevalence of Esthetic Problems		
	11 & Younger	Over 11	Combined
#1 (disagree & strongly disagree; examiner response only)	0.8	2.6	1.7
#2 (disagree & strongly disagree; participant or examiner response)	2.0	3.9	2.9
#3 (neutral, disagree, & strongly disagree; participant and examiner responses)	0.8	1.5	1.1
#4 (disagree & strongly disagree; participant and neutral, disagree, and strongly disagree; parental response)	0.4	-.9	0.6
#5 (neutral, disagree, and strongly disagree participant and a negative examiner rating*)	0.5	1.2	0.8

\*Negative rating determined by score that was 1.5 standard deviations below mean score on a visual analog scale.

children had exposure to fluoride dentifrices starting in their second year of life.

Data further indicate that 46 percent of the participants had dental fluorosis on at least one tooth, with 22 percent, 17 percent, 5 percent, and 1.2 percent demonstrating the most severe TFI scores of "1", "2", "3," and "4 or more," respectively. Dental fluorosis was slightly less prevalent and severe on the maxillary six anterior teeth (Table 3).

Results from Table 4 reflect the distribution of esthetic ratings by the different rater groups. Examiners rated teeth as more esthetically acceptable than the participants or their parents. These disparities to some extent represent the justification for defining some of the esthetic problems using the ratings of more than one group. The prevalence for esthetic problems shown in Table 5 ranged from about 0.5 percent to 4 percent, depending on how an esthetic problem was defined and the age group of the participant. These results indicate that esthetic problems as defined by the participant were more prevalent for the "over 11" age group. Differences in the prevalence estimates between Tables 4 and 5 demonstrate the conservative nature of the prevalence estimates used to define an esthetic problem for this study.

Results of the logistic regression models analyzing the relationship between the presence of esthetic problems and the independent variables for combined and separate age groups

**TABLE 6**  
**Results of Logistic Regression Analyses with Esthetic Problems as the Dependent Variable**

Independent Variable	Dependent Variable	Age Group	P-value	Odds Ratio*	95% Confidence Interval
Residence F-H <sub>2</sub> O	Problem #3	Combined	.05	3.8	1.02, 14.63
Third year of life	Problem #5	Combined	.04	7.4	1.15, 47.29
	Problem #2	11 and younger	.01	13.1	1.70, 97.32
F dentrice used	Problem #4	Combined	.04	7.2	1.09, 47.47
Third year of life	Problem #1	11 and younger	.04	7.4	1.07, 50.81
	Problem #4	11 and younger	.03	7.7	1.21, 49.33
Supplement use	Problem #4	Combined	.04	2.2	1.04, 4.46
Third year of life	Problem #2	Over 11	.01	2.7	1.31, 5.45
	Problem #3	Over 11	.01	4.0	1.69, 9.48
	Problem #4	Over 11	.04	3.6	1.33, 9.91

\*Age groups are 11 and younger, over 11, and combined.

are presented in Table 6. Statistically significant predictors of one or more of the different esthetic definitions were: residence in a fluoridated community during the third year of life, fluoride supplement use during the third year of life, and fluoride dentifrice use in the third year of life.

## Discussion

Much has been written about dental fluorosis and the debate about how to optimize the benefits and minimize the risks from fluoride ingestion (1,3,4,13-16). The real issue may have been confused and perhaps misrepresented by this scientific discussion, if not overtly, at least by omission. There is a presumption that the increase in dental fluorosis is bad. No study documents whether the public's perception agrees with this assessment. The scientific literature on the risk of dental fluorosis has used dichotomous variables such as the presence or absence of fluorosis or its various categories of severity as dependent variables in regression analyses (17). The implicit assumption underlying this approach is that dental fluorosis is a problem.

The analysis in this study operated under the assumption that dental fluorosis *per se* is not a problem. Some suggest that mild dental fluorosis usually presents itself in a mouth that can be called "beautiful." One might even go as far as to suggest that the optimal prevalence of mild dental fluorosis in a community is at or near 100 percent. This suggestion might at first seem completely counter to current thinking on the topic; however, if at this prevalence no children have an esthetic problem due to dental fluorosis, then one could assume that the population under study had received an appropriate dose of fluoride. The absence of esthetic problems due to dental fluorosis along with the lower caries prevalence would create the ideal outcome. If this premise is accepted, then the preferred dependent variable in logistic regression analyses should not be dental fluorosis, but the occurrence of esthetic problems due to dental fluorosis. Thus, the analysis for this study sought to identify first the extent of the problem, and second, risk predictors for any identified esthetic problem.

Several different definitions of an esthetic problem were offered to lend some degree of confidence to the esti-

mates of prevalence. Results suggest that the prevalence of esthetic problems due to fluoride ingestion ranges somewhere between 0.5 percent and 4 percent, depending on which definition is used and the age of the participant. Children under the age of 11 might not consider their esthetics to the same extent as most other age groups. Nevertheless, an attempt was made to demonstrate a range of estimates that might represent the different perceptions of esthetics from the dental profession's and the public's perspectives. The higher estimate for an esthetic problem of 4 percent represents about one out of every 11 subjects that presented with dental fluorosis, given that the prevalence in this study population was 46 percent. It is difficult to believe that the public would consider this estimate as an acceptable level of risk from the use of fluorides. Even with a more conservative estimate of 1 percent, it is difficult to label the prevalence of esthetic problems as insignificant.

The five esthetic problem definitions estimate a range of prevalences that perhaps represent the perception of facial esthetics that exists within the community among different lay, age, and professional subgroups. Clearly, many subgroupings are not represented in this study—for example, different ethnic, social, and age groups. These estimates represent either different combinations of responses from the various rater groups or different degrees of severity from the scale. This process of estimating prevalence instead of using the results of rater groups alone is intended to validate the opinions concerning esthetic problems due to dental fluorosis.

To some extent the participants'—and to an unknown extent the parents'—responses may represent opinions about esthetics that are unrelated to dental fluorosis. The apparent contradictory responses of some participants about the appearance of teeth suggested that the process was necessary. Some of the definitions might be considered somewhat liberal, e.g., classifying an esthetic problem from just the examiner's perspective or from either a participant's or an examiner's perspective—i.e., Problem Definitions #1 and #2. The remaining three definitions—i.e., #3, #4, and #5—all attempt to validate the overall classification of an esthetic problem by requir-

ing that two independent ratings meet certain negative criteria. The prevalences for these three ratings were lower than the other two, probably representing a conservative or low-end estimate of prevalence. The definitions of esthetic problems classified students using different combinations of responses, i.e., "neutral, disagree, or disagree strongly" and just "disagree, or disagree strongly." The former, more liberal classification, including the "neutral" response, is included to estimate again the presence of a less severe, but still relevant, esthetic problem. Approximately 70 percent of all of the participants' ratings and 93 percent of all examiners' ratings were either "strongly agree or agree," suggesting an overall positive predisposition to the esthetic appearance of participants' teeth.

The logistic regression analyses using esthetic problems as the dependent variable support the findings of Evans and Stamm (18), who suggest that children are at the greatest risk to dental fluorosis on maxillary central incisors between 22 months and 26 months of age. In our study, the only significant relationships between the various esthetic problem definitions and fluoride exposure variables were in the third year of life. No other years, combinations of years, or the educational status of the heads of households produced any statistically significant findings.

Regression results for the "over 11" group suggest that adolescents are at risk of esthetic problems only when exposed to fluoride supplements during the third year of life. The "11 and younger" age group was at risk when exposed during the third year of life to either fluoride dentifrices or fluoridated water. No apparent explanation for these disparate results could be found. The last official change in the fluoride supplement dosage schedule in Canada was in 1979 (19). Because 13- or 14-year-old adolescents in this study (grades 8 and 9—representing a large proportion of the adolescent group) were born in 1980 or 1981, and were four years of age in 1984 and 1985, it is unlikely that a different supplement dosage was used by parents of students in the different age groups. Also, despite the fact that fluoridation monitoring data are incomplete for study communities since 1979, the available data suggest that there were

no significant differences in fluoride levels were not present in the communities over time. The fluoride levels averaged 0.92 ppm (SD=0.21), 0.88 ppm (SD=0.28), and 0.95 ppm (SD=0.27) in Comox/Courtenay, Campbell River, and Kamloops, respectively, between 1985 and 1992 (20). Therefore, no apparent differences between potential fluoride exposures for the two age groups were identified that could explain the disparate findings.

These results are meant to estimate the prevalence of esthetic problems due to dental fluorosis and identify risk predictors for these esthetic problems in British Columbia, Canada. The results may or may not be similar in other regions of North America. Also, little is known about how the public views the esthetics of fluorosed teeth. What we do know suggests that there is some degree of consistency in the opinions of children, adolescents, examiners, and parents. All of these groups in this study easily identified teeth with esthetic problems. A follow-up survey is planned for these communities, and the same groups will be examined in the future. It will be possible to assess whether these problems have been treated professionally, or if they diminish in importance as the children and adolescents age.

The results and some of the limitations of this study suggest that we need to study further the relationships between specific fluoride exposures and esthetic problems due to dental

fluorosis. Additional research also is needed to clarify the actual impact of esthetic problems.

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