



## Project Summary

# Analysis of Costs for the Treatment of Dental Fluorosis

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This research project was initiated to provide basic data to be used in a cost/benefit analysis for communities whose fluoride levels exceed the drinking water maximum. Much has been written regarding the technology and associated costs for removing fluoride from community water supplies. However, little information is available concerning the economic benefits or disbenefits associated with various levels of fluoride in drinking water. This study focuses on the costs of remediation for high levels of fluorosis in community water supplies.

The initial data set used in this study was from a project conducted by the University of Texas at San Antonio for the Environmental Protection Agency's Health Effects Research Laboratory. This earlier project, entitled "A Clinical Study of the Dental Effects in a Critical Zone," was used to select representative cases of fluorosis from a selected set of Texas communities with water fluoride levels from optimum to 4.0 milligrams per liter (mg/L). The clinical findings of each case were presented to a panel of clinical practitioners for diagnosis of the extent of cosmetic deformity and dental dysfunctional effects present in the dentition as a result of excessive fluoride. Cost estimates were made for the remedial care proposed for each subject by each panel member. Using these data an evaluation was made of the beneficial effects of optimum water fluoride levels (savings resulting from caries reduction) against the adverse costs of excessive fluoride. Optimum fluoride level is defined by reference to the National Interim Primary Drinking Water Regulations where optimum levels are defined ac-

ording to temperature. In general, the optimum level is approximately 1 mg/L.

*This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

### Introduction

The Food and Nutrition Board of the National Research Council has stated that fluoride is a normal constituent of diet, and is an essential nutrient. In addition, fluoride in drinking water will prevent dental caries. When the concentration is optimum no ill effects will result and the caries will be 60% to 65% below the rates in communities with little or no fluoride. Optimum is defined by reference to the National Interim Primary Drinking Water Regulations where "optimum" levels are defined according to temperature. In general, the optimum level is approximately 1 mg/L. Excessive fluoride in drinking water supplies produces objectionable dental fluorosis which increases with increasing fluoride concentration above the recommended upper control limits. Other expected effects from excessively high intake levels are: (a) bone changes from water containing 8-20 mg fluoride per L consumed over a long period of time; (b) crippling fluorosis when 20 or more mg of fluoride from all sources is consumed per day for 20 or more years; (c) death when 2,250-4,500 mg of fluoride is consumed in a single dose. The optimum fluoride level for a given community depends on climatic conditions because the amount of water (and con-

sequently the amount of fluorides ingested by children is primarily influenced by air temperature. This relationship was first studied and reported by Gallagen and Associates in the 1950's, but has been further investigated and supported by Richards et al. in 1967. The control limits for fluoride supplementation are simply the optimum concentrations for a given temperature zone as determined by the Public Health Service, DHEW, plus or minus 0.1 mg/L. Many communities with water supplies containing less fluoride than the concentration given as the upper limit for the appropriate air temperature range have provided fluoride supplementation.

### **The First Study**

In order to more fully understand the issues related to fluoride ingestion, a research project was initiated by the University of Texas at San Antonio. This research project was intended to identify significant dental changes (mottled enamel) that occur in a human population continually ingesting water from a supply which contains naturally occurring fluoride and to identify the level at which these changes occur. A second objective was to conduct a random survey to elicit community attitudes relative to what is objectionable in terms of mottling and discoloration of teeth. In this study, information regarding mottling and discoloration of teeth was correlated with fluoride levels in the public water supply of 16 communities.

Subjects were recruited through the public school system in each community. Students from grades 2-6 and 9-12, whose families used water delivered by the community water system, served as a source of volunteers. An oral examination was performed to determine the degree of enamel mottling and dental caries. The urine specimens taken from a random sample of subjects were analyzed for fluoride. Information regarding personal and health background was obtained, using specially designed questionnaires. An opinion survey of high school subjects, mothers of subjects, and random sampling of adults in the community was conducted regarding perception of enamel mottling. The opinion survey found that the appearance of anterior teeth with very mild and mild mottling was generally acceptable by community standards. However, the majority of mothers of high school students with moderate visible

mottling are dissatisfied with the appearance of such teeth. In households studied where water fluoride was more than twice the optimum level, 25% of the adults were willing to pay \$2.50 extra per month for their city water to prevent enamel mottling, while another 25% of these adults were unwilling to do so. The other half of the adults surveyed in the cities were "neutral" to "willing" to pay for defluoridation. One-third of the respondents in the "mother survey" were very "willing" to pay, while only one-sixteenth of them were unwilling.

Enamel mottling was strongly associated with the fluoride level of the community water supply. The dental caries rate was found to vary inversely with the fluoride level of the community water supply. There was a steady decline in the DMFS (decayed, missing and filled surfaces) score in both age groups (7-12 and 14-18), with increasing levels of fluoride. However, the 7-12 group experienced a greater reduction in average score from 0.38 to 0.15 as the water fluoride level increased from 0.5 times optimal to 0.5-2.9 times optimal.

There appears to be a direct and nearly proportional relationship between the communities' water fluoride level and average fluoride intake. A strong dose response relationship was observed between the median fluoride level of the city schools and the average urinary fluoride concentrations of the students. It was observed in the data that as the level of fluoride increases well beyond the optimum range there appeared to be a U-shaped curve associated with the DMFS score. Apparently as the fluoride level increased above the optimum, the negative benefits associated with fluorides increased. The proper remedial action for fluorosis is to perform a series of dental procedures. In order to gather information on these negative benefits a second study was conducted by the University of Texas at San Antonio in which a dental panel was convened and cost information was collected in order to assess the remediation costs associated with the correction of fluorosis. These data are unique and the second study, which is the subject of this report, is described below.

### **The Second Study**

There are no documented reports of controlled studies to indicate the extent of dollar expenditures for the cost of

dental care to repair either cosmetic and/or functional dental defects due to fluorosis. A lack of data in this facet of fluoride research led to an assumption by the dental profession that the effects of tooth mottling are limited to the cosmetic discoloration of teeth. In order to test this premise, a study to assess the extent of the effects of mottling and the potential costs for repair of these defects was conducted. The specific objectives of this study were to:

1. Evaluate the extent of cosmetic and dysfunctional effects attributed to fluoride.
2. Determine the costs for restoring the cosmetic appearance and dysfunction to a level acceptable in the community.

### **Selection of Panel**

Dental practitioners were interviewed as potential members of a panel to evaluate the economic impact of dental fluorosis. Each practitioner selected for the panel was practicing in or located adjacent to a community where water fluoride levels have resulted in mottled enamel defects requiring some type of remedial treatment. A further requirement was that each panelist have experience in providing remedial care for subjects with mild, moderate, and severe mottling.

After being selected for the panel, each clinician traveled to the University of Texas Dental School at San Antonio where an orientation session was conducted by the research staff prior to case evaluation.

### **Selection of Cases**

The records of all subjects examined in the communities with water fluoride levels from optimum to 4.0 mg/L were screened to identify representative cases for study and evaluation. Representative cases were selected from all the Dean's categories (a numerical rating of 1 to 6 that defines severity of mottling) with the exception of normal, questionable, and very mild. The documentation on each subject selected for study consisted of a complete visual and tactile examination of all surfaces of all teeth for dental decay and mottling. These data were reproduced on a graphic chart of the dentition. Additionally for each case selected, five color transparencies with views of the dentition from right, left, upper occlusal, and inner occlusion were provided to the

panelists. A total of 55 representative cases were selected for presentation to the panel.

## Results

There was a large variability in the numbers and types of procedures (a procedure is a type of treatment, e.g., amalgam filling, gold crown, etc.) that each consultant suggested for the same case. This finding was not surprising as the consultants were recruited from widely separated geographic regions in the United States. This diversity probably reflects the diverse economic conditions under which they practice and their prior training.

The types of treatment recommended for each subject were classified as either optimum care or minimum care. Minimum care generally consisted of correcting the cosmetic discoloration using materials and procedures which are not considered permanent, meaning that they will probably need to be replaced one or more times throughout the individual's lifetime. Correction of the dysfunctional problem is generally accomplished using methods and materials that are less durable and less expensive than those recommended for optimum care.

Optimum care implies use of the most durable and aesthetic materials and procedures currently available. This level of service would be considered permanent and should last the lifetime of the individual providing they maintained good oral hygiene and received periodic professional care.

It should be noted that bleaching comprised a significant number of the procedures proposed by all of the consultants. The long-term aesthetic results are apparently satisfactory to the point where additional treatment is seldom required. This type of procedure represents the least costly form of care for the cosmetic problem of mottling. Other types of procedures, e.g., mastic or laminate, are more costly, yet are not considered a permanent type of restoration. Use of the bleach procedure, where indicated, greatly reduces the overall cost of treatment, particularly of the moderate and severe cases. In most instances, if treatment is indicated for mild cases, bleaching would probably solve the aesthetic problem with the least possible cost and discomfort to the subject.

It has been assumed that the primary cost in dealing with the problem of mot-

tling was the cost for correcting the cosmetic discoloration present on the tooth. The pool of subjects being studied were initially divided into three subgroups according to their mottling score (Dean's Score of 4, 5, or 6).

Each consultant was requested to develop a treatment plan for each case under a minimum care treatment plan and an optimum care treatment plan. In addition, they were requested to classify and separate the treatment as cosmetic or functional. A further division was made for sequencing of treatment. Treatment was divided into "current care" and "later care" (deferred). Current care is treatment that should be performed now or in the very near future. Later care is treatment that would probably be necessary later in their life so as to maintain normal functioning occlusion. This projection is based on the consultant's prior experience with similar cases in their own private practice.

Treatment costs were divided into cosmetic and functional types. Cosmetic treatment consists of those procedures required for correction of tooth discoloration. Functional types of treatment are required where there has been excessive wear, breaking, or fracturing of teeth so that mastication is impaired.

Cosmetic and functional treatments were also divided into current and later categories. Current treatment is treatment that should be rendered now, whereas later treatment includes procedures necessary at a future date to correct the cosmetic and/or functional problems.

A comparison of the mean costs for cosmetic and functional treatment shows that cosmetic costs exceed functional costs in the mild and moderate cases, however, the reverse is true in the severe cases (Dean's Score of 6). A comparison of the costs for cosmetic and functional treatment indicates that the estimate for functional treatment exceeds the cosmetic costs in the severe mottling cases. A mean cost for all consultants shows that the estimated costs for restoring function exceeds the cosmetic costs in all categories except the minimum later costs. This represents a new finding and raises an issue that has been overlooked or ignored by previous investigators and the profession, i.e., that repair of the cosmetic discoloration was the only cost involved, or that repair of dysfunction was never considered to be a problem.

The costs for repairing dysfunction are a result of the excessive wear, chipping, and fracturing of teeth which appears to occur in subjects who have moderate and/or severe mottling. Since the majority of the subjects in our study were teenagers, the projected costs (later costs) are estimates based on the future care that will be needed to maintain or reestablish their normal functional occlusion.

The problems encountered may in fact increase in severity during later life. No data exists at this point in time to permit an accurate assessment of the problem. Only anecdotal information and preliminary findings in our investigations suggest possible outcomes for subjects with moderate to severe fluorosis. These findings consist of excessive cusp wear, breaking, and chipping of the teeth.

An additional analysis was made using the Visible Mottling Score (a mottling score based on the six upper anterior teeth and the six lower anterior teeth). Dean's Classification of mottling was also used to compute the score. The group was then divided into three subgroups according to their mottling score (Dean's Score of 3, 4, or 5). The size of the subgroups in the first analysis, using the entire mouth, as compared to the subgroups in the second analysis is substantial. Using the visible mottling score results in more subjects being classified as mild and fewer subjects classified as moderate and severe.

There is wide variability in costs between the consultants in many of the categories. Since they represent different geographic regions of the country as well as different economic levels (in terms of patients treated), this difference is to be expected. The mean costs per subgroup, i.e., Dean's Score of 4, 5, or 6, increase as the severity of mottling increases. Later costs appear minimal for the group classified as Dean's Score of 4, whereas those classified as Dean's Score of 5 or 6 had substantial cost for the treatment plan.

Since the severity and prevalence of tooth mottling is related to the water fluoride levels, it is important to examine the various facets of the problem and determine a dose-response relationship. Using Dean's Score allows for the classification of subjects into mild, moderate, and severe categories and to examine the projected costs for each case.

The type of procedures used for the minimum care treatment generally have a useful life of 5 to 7 years. Thus to assess the lifetime cost requires replacement of these fillings on an average of once each 7 years. The treatment of a subject is usually completed by age 20. Using an arbitrary age 62 as the average life span of subjects would require replacement of all fillings six times between the ages of 20 and 62, providing the subject did not lose any of their teeth.

The procedures used for the optimum type of treatment are considered permanent restorations. Thus a yearly maintenance program should provide adequate care for preserving the dentition in a good state of health. Treatment under this plan should be completed by age 20. Using the age 62 as the average life span of subjects requires a maintenance period of 42 yrs. The estimated yearly maintenance cost is \$50. Thus, the estimated total cost for optimum care is the initial current and later costs plus the number of years times \$50. (Initial cost plus years [42] plus yearly cost [\$50.00]).

Regression analysis was used to establish a formula to relate the average cost per dentist (minimum and optimum) to mottling severity and age of the subject. Costs were standardized by use of a cost index to facilitate ease of comparison. The best equations given the data and the variables for minimum and optimum have been calculated. In order to measure significance, "t" values have been given in parenthesis below each variable (the higher the "t" value the more significant the variable):

*Equation 1*

$$MC = 181.43 + 0.27A^2 + 20.509D^2$$

$$(-2.92) \quad (5.30) \quad (4.35)$$

$$(R^2 = 0.44; F^2 = 20.81)$$

Where

MC = Minimum costs/case  
A = Age  
D = Dean's Index

and for optimum standard costs:

*Equation 2*

$$S = -1581.12 - 2.333(A)^2 + 147.74(D)^2$$

$$(3.58) \quad (6.38) \quad (4.60)$$

$$(R^2 = 0.51; F^2 = 26.07)$$

Where

S = Optimum costs/case.

The focus of the analysis was to assess the dental treatment costs of lifetime residents of a community who were exposed to water fluorides throughout their lives. Any assessment of the impact of defluoridation must include its effect on the caries activity in the community. The average DMFS scores determined by Segreto and Collins in the first study were used to develop the treatment cost based on the water fluoride level. The dollar cost was computed using the DMFS for each water fluoride level multiplied times 28 (teeth) times \$15 (per surface). The resulting figure would be the per capita costs of treatment for dental caries.

**Major Conclusions From the Study Were as Follows**

1. The mean minimum treatment costs for correcting cosmetic discoloration exceeded the costs of restoring dental function (using Dean's Classification). However, the costs for restoring function in the severe category exceeded the costs for correcting cosmetic discoloration. These findings were also true when the cases were evaluated using the Visible Mottling Index.

2. The mean optimum treatment costs for correcting cosmetic discoloration exceeded the costs for restoring dental function for mild and moderate mottling (using Dean's Score and the Visible Mottling Index), however, the costs for restoring function exceeded the costs for correcting cosmetic discoloration in the severe category (using both Dean's Score and the Visible Mottling Index).

3. Where indicated, bleaching is an effective treatment for the cosmetic discoloration of teeth resulting from dental fluorosis.

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*The complete report, entitled "Analysis of Costs for the Treatment of Dental Fluorosis," (Order No. PB 87-170 817/AS; Cost: \$13.95, subject to change) will be available only from:*

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