



Examination of esthetic improvement and surface alteration following microabrasion in fluorotic human incisors in vivo

Terri E. Train DDS, MS Alton G. McWhorter, DDS, MS N. Sue Seale, DDS, MSD
Carolyn F. G. Wilson, DDS, MSD Ingrid Y. Guo, MS, PhD

Abstract

Improvement of appearance and alteration in surface enamel was evaluated following microabrasion of teeth with differing degrees of fluorosis stain in vivo. Eighty-two fluorotic permanent maxillary central incisors from 41 patients were divided into categories of mild (32), moderate (30), and severe (20). Teeth received 30-sec applications of PREMA™ until no stain remained or for a maximum of 10 min of treatment. Ten teeth needed only 5 min of treatment. All others received the maximum. Standardized intraoral photographs and duplicate polysiloxane impressions were taken prior to treatment, after 5 and 10 min of treatment, and at least 4 days after treatment. Slides were randomized and viewed independently by two standardized observers and rated for area of white spot lesions (WS), stain amount (SA), and stain intensity (SI). The Wilcoxon's signed rank test indicated a significant difference in the area of WS ($P < 0.05$) and SA and SI ($P < 0.005$) from pretreatment to successive ratings. Kruskal-Wallis analysis revealed significant differences among the three severity groups for amount of WS, SA, and SI ($P < 0.005$). Mildly stained teeth had the best esthetic result, moderately stained teeth improved but continued to demonstrate WS and staining, and severely stained teeth showed some improvement, but more than 50% of the surface had WS and > 25% of the surface was stained. SEMs at 10X magnification were made of the models and randomly rated for type, depth, description, and area of surface defects by the two observers. Mild teeth showed no significant changes from pretreatment to 10 min of treatment. Moderate and severe teeth showed no significant change in type and depth of defects from pretreatment to 10 min of treatment but were significantly worse in description and area of defects. Despite esthetic improvement in all groups, moderate and severe teeth showed more defective surfaces following microabrasion. This technique can only be recommended as definitive treatment for teeth with mild fluorosis. (Pediatr Dent 18:353-62, 1996)

Dental fluorosis is a disorder that occurs during tooth development when excessive amounts of fluoride are chronically ingested.¹⁻⁴ Fluorosed enamel is characterized clinically by white opacities that vary from minor striations to extensive areas of lusterless enamel.^{1, 2, 4-7} Histologically, increased amounts of fluoride will cause hypomineralization, or porosity, in the enamel.³⁻⁵ The severity depends on the concentration of fluoride ingested, the duration of fluoride exposure, the stage of ameloblastic activity, and individual variations in susceptibility.^{2, 3}

In the milder forms of fluorosis, porosity and hypomineralized areas are found only in the outermost layers of enamel. With increasing severity, the porosity and depth of involvement are increased.¹⁻⁴ In severe cases, post-eruptive breakdown of the tooth surface can result in pitting, which can predispose the underlying porous enamel to rapid staining and discoloration.^{1, 4}

The increasing use of fluoride has led to a higher incidence of fluorosis, which has become the impetus to search for cosmetic solutions. The most popular technique currently in use to improve the cosmetic appearance of fluorosed teeth is microabrasion. It has evolved from a technique reported by McCloskey in 1984, previously described by Dr. Walter Kane in 1916, in which hydrochloric acid and heat were used to remove endemic fluorosis stains.⁸ Croll and Cavanaugh modified the McCloskey technique by mixing 18% HCl with pumice to form a paste, which was applied to the teeth with a wooden applicator.^{9, 10} The technique removes surface enamel, and Croll has coined the term "microabrasion". After several years of testing and observation, Premier Dental Products developed the commercially available PREMA™ Microabrasion Kit (Premier Dental Products Co, Norristown, PA), which uses a 10:1 gear reduction handpiece for paste application.

Previous research regarding the amount of enamel loss with the microabrasion technique reports amounts

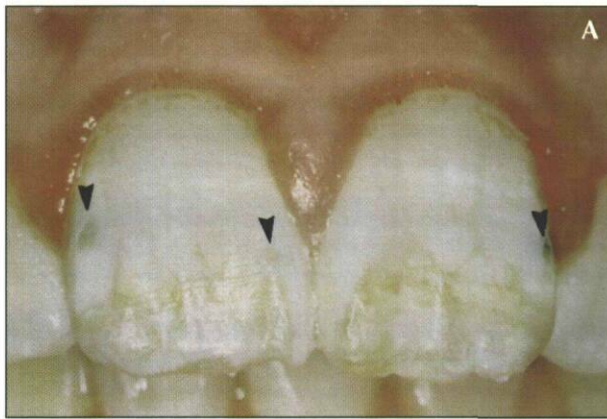


Fig 1. Moderately fluorosed maxillary permanent central incisors. A) Pretreatment photograph: Note pits on distal at arrows, total white spot involvement of surface and > 25% stain. B) Photograph after 10 min of treatment: Note smoother surface, improvement in white spot, and removal of stain.

TABLE 1. THE DEAN'S INDEX FOR CLASSIFICATION OF DENTAL FLUOROSIS

Classification (Score)	Criteria
Normal (0)	The enamel represents the usual translucent semivitriform type of structure. The surface is smooth, glossy, and usually a pale, creamy white color.
Questionable (0.5)	The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is used in those instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of "normal" is not justified.
Very mild (1)	Small, opaque, paper-white areas scattered irregularly over the tooth, but involving less than 25% of the tooth surface. Frequently included in this classification are teeth showing no more than about 1–2 mm of white opacity at the bicuspids or second molars.
Mild (2)	The white opaque areas in the enamel of the teeth are more extensive, but involve less than 50% of the tooth.
Moderate (3)	All enamel surfaces of the teeth are affected, and surfaces subject to attrition show wear. Brown stain is frequently a disfiguring feature.
Severe (4)	All enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is discrete or confluent pitting. Brown stains are widespread and teeth often present a corroded-like appearance.

For the purposes of this study, category (1) and (2) were combined.

ranging from 46–246 μ , but most researchers believe that this is a safe technique and that sufficient enamel remains.^{11–15} Research available concerning the effect of the microabrasion technique on surface enamel has been done on extracted, nonfluorosed teeth. Several investigators report that the technique results in a smoother surface.^{16,17} All of these investigators felt the technique to be safe and enamel loss not to be excessive.

To date, little research on microabrasion has evaluated enamel surface changes on fluorosed teeth in vivo. Sub-surface structural defects^{1, 7, 18} may predispose the tooth to more severe surface alterations than previously reported in normal teeth after microabrasion. In addition, limited studies compare the effectiveness of the treatment to various degrees of stain or identify predictors for numbers of treatments required to improve different degrees of stain. The three-fold purpose of this study was to: 1) examine the effectiveness of microabrasion for removing color and improving appearance in differing degrees of fluorosis stain, 2) assess the number of treatments needed to remove varying degrees of fluorosis stain, and 3) determine the effect of microabrasion on the surface enamel by SEM examination, using the microabrasion technique described by Croll in fluorosed teeth in vivo.

Materials and methods

Patients were solicited from private practices and dental school clinics in Dallas, Texas. A letter describing the project and a brochure describing the technique were provided at the screening appointment. Criteria for acceptability included the following:

1. Two permanent maxillary central incisors at least two-thirds erupted

2. Staining consistent with the appearance of mild, moderate, or severe dental fluorosis on both teeth
3. Presence of symmetrical distribution of fluorosis within the dentition and a fluoride history to verify systemic ingestion as the etiology of the enamel defects
4. No contraindications to treatment
5. Consent for treatment.

The technique used in this study involved the PREMA™ Microabrasion Kit. The paste is a mixture of approximately 15% HCl and pumice that is applied with a 10:1 gear reduction handpiece. The manufacturer's guidelines for the PREMA™ technique were not specific enough for a controlled study and were modified as follows:^{19,20}

1. A treatment was defined as five applications of the paste with each application lasting 30 sec (kit instructions suggested a range of 20 to 30 sec per application). Thus each treatment lasted 2 1/2 min.
2. Treatments were terminated when there were no visible stains or after a maximum of four treatments (i.e., after 10 min of total treatment time), whether stain was still visible or not.

3. All severities of fluorosis stains, as measured by the Dean's index, were treated in this project.²¹
4. Treatments were confined to fluorotic lesions.
5. After two and four treatments, impressions and photographs were taken.

At the first appointment, the teeth were cleaned with prophylaxis paste to enable the principal investigator (PI) to assess the teeth accurately. The teeth were dried with cotton rolls, and within 30 sec of drying, the degree of staining was assessed. The PI assigned the patient to a mild, moderate, or severe group (according to the severity of stain) as determined by the Dean's index for dental fluorosis (Table 1).²¹ Two vinyl polysiloxane impressions of the maxillary central incisors were taken and the patient was dismissed.

The Dean's index was modified slightly for use in this project by combining the categories of very mild and mild. Before the project, the PI was trained and standardized in the use of the index by classifying photographs of fluorotic teeth from a previous study. Disagreements with the previous classifications were reviewed and discussed until consistency was achieved.

At the second appointment, color photographs of the teeth were taken using a ring flash. A new camera was purchased and used for all photographs taken in

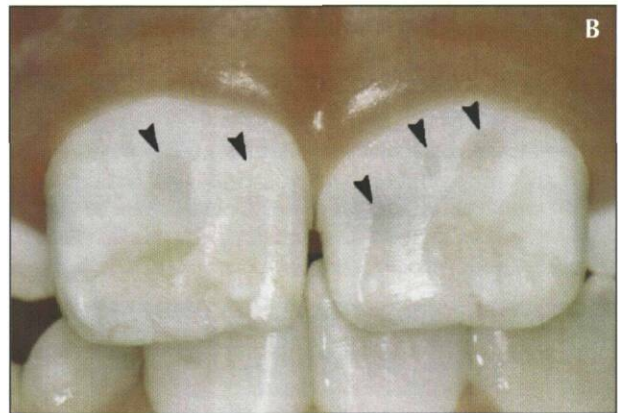


Fig 2. Moderately fluorosed maxillary permanent central incisors. A) Pretreatment photograph: Note white spot > 50% and no staining. B) Photograph after 10 min of treatment: Note areas of enamel loss.

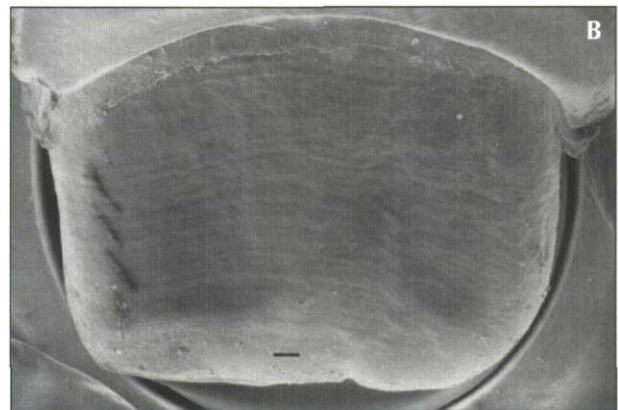
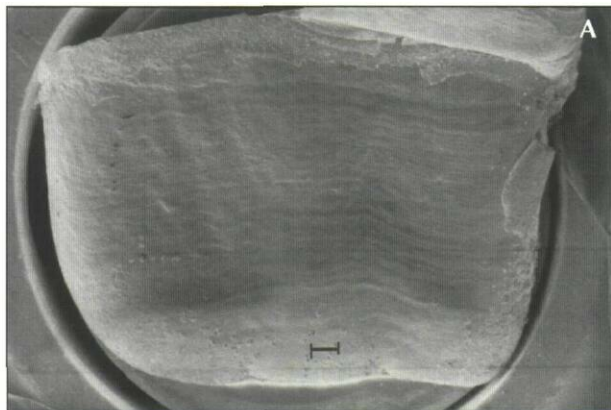


Fig 3. Pretreatment photomicrograph of moderately fluorosed maxillary permanent central incisors (bar = 0.5 mm). A) Right incisor: Note total involvement of facial surface with grooves. B) Left incisor: Note total involvement of facial surface with grooves.

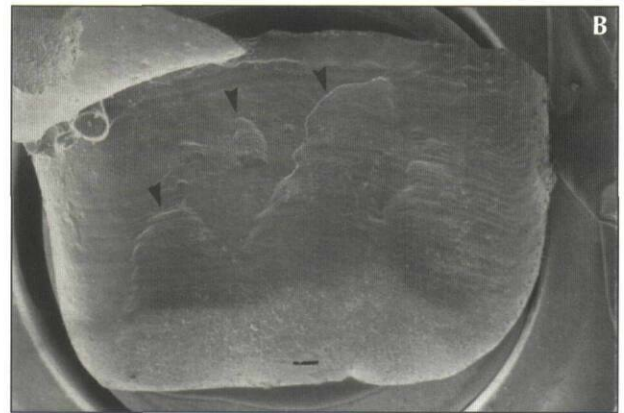
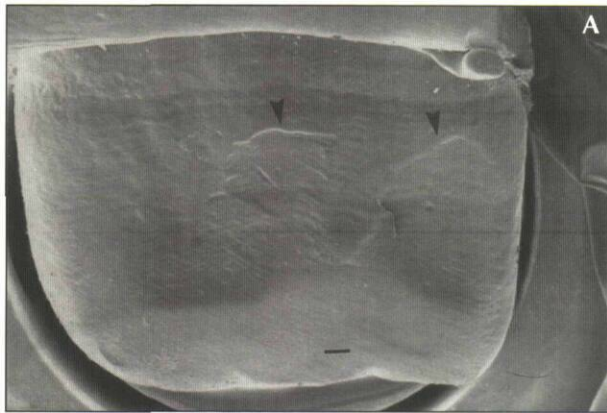


Fig 4. Photomicrograph of moderately fluorosed maxillary permanent central incisors following 10 min of treatment (bar = 0.5 mm). A) Right incisor: Note development of pits (arrows) in addition to the continued presence of the grooves. B) Left incisor: Note development of pits (arrows) in addition to the continued presence of the grooves.

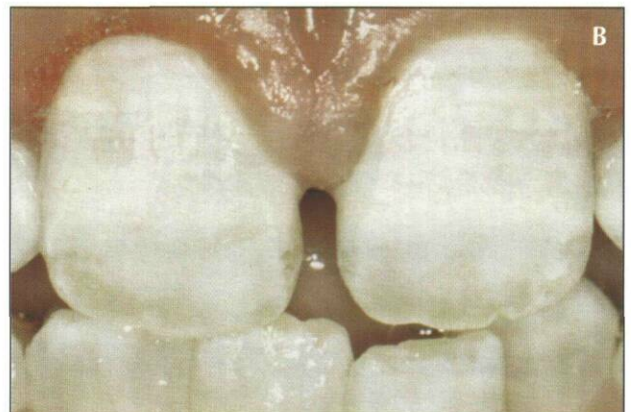
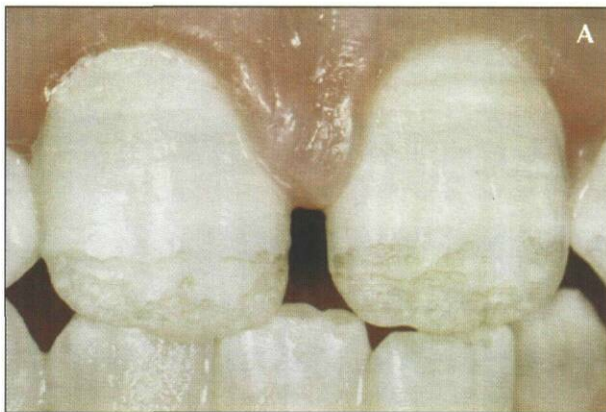


Fig 5. Severely fluorosed maxillary permanent central incisors. A) Pretreatment photograph: Note pits and grooves in incisal one-third and total white spot involvement of surface. B) Photograph following 10 min of treatment: Note smoothing of surface, stain removal, and increased translucency in the incisal one-quarter.

this study. The PI took all photographs at pre-established, standardized settings and focal length in the same dental unit. When the camera was not being used for this study, it was locked away. The two maxillary central incisors were isolated with a rubber dam sealed with copal varnish. Teeth were cleaned as in the initial appointment and treated with the PREMA™ paste for 30 sec using the prototype hand-held applicator and rotary mandrel. The teeth were rinsed with water for approximately 10 sec using an air-water syringe. Following each 30-sec application, the teeth were rinsed before the PI evaluated them for remaining fluorosis stains. The teeth were wet during the evaluation, as instructed by Croll.²² If staining was still present, the procedure was repeated; if no staining still remained, treatment was discontinued. Periodically, the teeth were evaluated visually for the thickness of the labial enamel and for surface defects, as stated in the manufacturer's instructions. Photographs and duplicate impressions were taken after the second treatment and again after the fourth. Following microabrasion, the teeth were treated with fluoridated prophylaxis paste and neutral sodium fluoride for 4 min. The majority of patients received all microabrasion treatments at one appointment.

Patients returned for a third evaluative appointment at least 4 days after the microabrasion treatment. The treated teeth were cleaned with a dry toothbrush to remove any plaque before photographs were taken.

Two pediatric dentists were trained and standardized in the use of the parameters developed for this study in the following manner. Criteria to be used for ranking were explained and discussed fully. Photographs of fluorosed teeth from patients in a previous fluorosis study were viewed and ranked independently. Disagreements were discussed and a consensus was reached. For our study, changes in cosmetic appearance of the teeth were judged by viewing color photographs taken pretreatment, after 5 min of treatment, after 10 min of treatment, and at a recall appointment at least 4 days following treatment. Representative photographs from each period were randomized and viewed blindly and independently by the raters at two different times according to the following three sets of criteria. Duplicates of some slides were inserted to test intrarater consistency.

Amount of white spot (WS) discoloration as a function of percent of surface of tooth involved:
0 = none

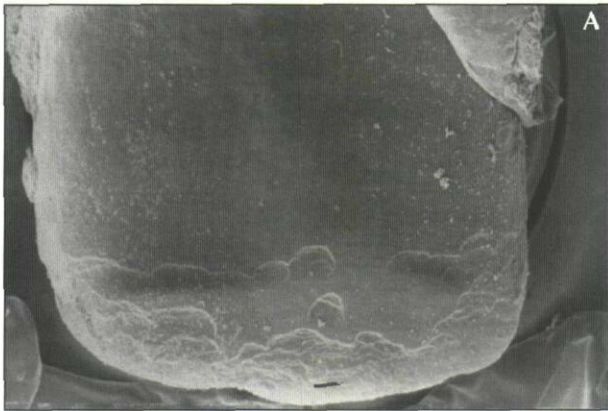


Fig 6. Pretreatment photomicrograph of severely fluorosed maxillary permanent central incisors (bar = 0.5 mm). A) Right incisor: Note the enamel breakdown in the incisal one-third. B) Left incisor: Note the enamel breakdown in the incisal one-third.

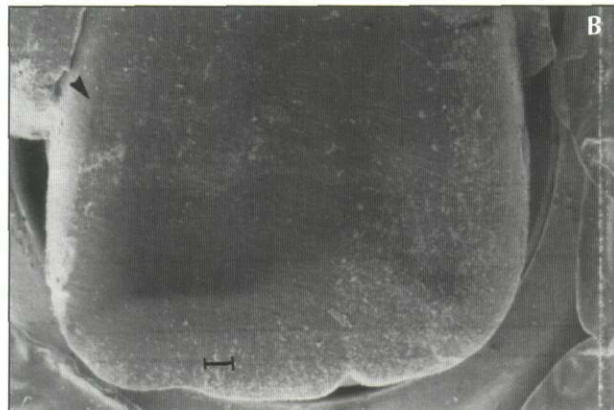
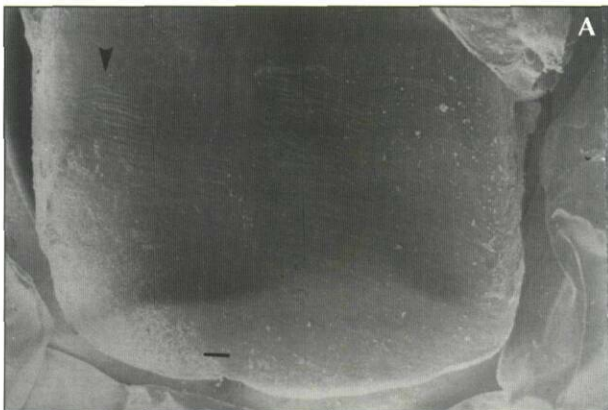


Fig 7. Photomicrograph of severely fluorosed maxillary permanent central incisors following 10 min of treatment (bar = 0.5 mm). A) Right incisor: Note the dramatic improvement in surface pitting, but increased grooving at arrows involving > 50% of surface. B) Left incisor: Note the dramatic improvement in surface pitting, but increased grooving at arrows involving > 50% of surface.

1 = questionable

2 = < 25%

3 = > 25% but < 50%

4 = 50% or more

5 = entire surface involved or pitting present.

Intensity of yellow, orange, or brown stain (SI):

0 = none

1 = light to medium

2 = dark

Amount of stain (SA) as a function of percent of surface of tooth involved:

0 = none

1 = < 25%

2 = > 25% but < 50%

3 = > 50%

Pretreatment rankings were compared with interim treatment (5 min), immediately after treatment (10 min), and recall rankings for each of the three sets of criteria using the Wilcoxon's signed rank test.

Surface alterations as a result of treatment were determined through examination by SEMs of impressions of the teeth taken at each treatment interval. The SEM evaluation was accomplished using three epoxy models from each patient: one made from an initial impres-



Fig 8. Photograph 6 months following treatment of moderately fluorosed maxillary permanent central incisors. Note stained areas, which correspond to areas of enamel loss following 10 min of treatment.

sion, one taken after 5 min of treatment, and one taken after 10 min of treatment. All 209 models were examined by SEM at 10X magnification to evaluate the changes in the surface enamel that were produced by the microabrasion treatment, and photomicrographs were taken of the enamel surface. Representative pho-

TABLE 2. MEANS AND STANDARD DEVIATIONS FOR WHITE SPOT (WS) BY FLUOROSIS RATING

Assessment Period	Mild	Moderate	Severe
Pretreatment	2.47 ± 1.164	3.63 ± 1.273	4.40 ± 1.231
5 min	2.66 ± 0.971*	4.03 ± 0.928*	4.65 ± 0.875*
10 min	2.22 ± 0.732‡	3.63 ± 0.999‡	3.94 ± 1.259‡
Recall	1.66 ± 0.653 ^{†§}	3.20 ± 1.270 ^{†§}	4.05 ± 1.356 ^{†§}

Significance by Wilcoxon's signed rank test.

* Comparison to pretreatment $P < 0.05$.

† Comparison to pretreatment $P < 0.005$.

‡ Comparison to 5 min $P < 0.005$.

§ Comparison to 10 min $P < 0.005$.

TABLE 3. MEANS AND STANDARD DEVIATIONS FOR AREA OF COLORED STAIN (SA) BY FLUOROSIS RATING

Assessment Period	Mild	Moderate	Severe
Pretreatment	0.06 ± 0.246	0.67 ± 0.547	1.60 ± 0.883
5 min	0.03 ± 0.177*	0.37 ± 0.556*	1.20 ± 0.768*
10 min	0.00 ± 0.000*	0.30 ± 0.466*	1.12 ± 0.781*
Recall	0.00 ± 0.000*	0.27 ± 0.521*	1.50 ± 0.875*

Significance by Wilcoxon's signed rank test.

* Comparison to pretreatment $P < 0.005$.

tomicrographs of all models were randomized, viewed blindly, and evaluated for surface roughness and pitting as compared to previously established standards. Four sets of criteria were used to judge the photomicrographs and they were ranked as follows:

Type of surface defect:

1 = smooth

2 = grooved

3 = pitted

4 = grooved and pitted

Depth of the surface defects:

1 = shallow

2 = medium

3 = deep

Shape/description of surface defects:

1 = discrete

2 = confluent

3 = discrete and confluent

Area affected by the defects as a function of percent of surface of tooth:

1 = < 1/4

2 = > 1/4 but < 1/2

3 = > 1/2 but < 3/4

4 = > 3/4

Depth of defects was judged according to the following criteria: a shallow defect did not have definite walls and was a disruption of the tooth surface; a medium defect had a definable margin; and a deep defect had a definable margin with identifiable shadowing.

Pretreatment rankings were compared with interim (5 min) rankings, and immediately after treatment (10 min) rankings after grouping by the degrees of severity of fluorosis using the Wilcoxon's signed rank test.

Results

The mild fluorosis category included 15 patients. Treatment was halted on five patients after two treatments (10 30-sec applications or 5 min) because all visible white spots had been removed. This treatment time was half of the potential treatment time set by the guidelines of this study. The remaining patients required four full treatments (20 30-sec applications or 10 min).

The moderate fluorosis category contained 16 patients, but one was eliminated because a processing error rendered the photographs unreadable. All 15 remaining moderate patients received four treatments (10 min) after which treatment ceased according to the project design.

The severe fluorosis category contained 11 patients,

and all received the maximum of four full treatments (10 min).

Two independent observers randomly viewed intraoral photographs and evaluated changes by rating the following: area of the tooth involved with white spot lesions, area of the tooth that was stained, and intensity of color of the stain. Changes in surface defects were evaluated by the same two independent observers by random viewing of photomicrographs, which they rated for type, depth, description, and area of surface defects. Kappa statistics were run including all possible combinations of comparisons both between raters and for each tooth for the same rater. These statistics were then averaged for inter-rater and intrarater reliability. Inter-rater reliability (kappa values ranging from 0.61–0.88) and intrarater reliability (kappa values ranging from 0.47–0.74) for all factors were determined to be in good agreement according to the criteria given by Landis and Koch.²³ All areas of disagreement between the raters were discussed and a consensus reached.

The three esthetic factors were examined in relation to the three fluorosis categories and the Wilcoxon's signed rank test was used to determine changes. There was a significant difference in the area of white spot ($P < 0.05$), and amount and intensity of stain ($P < 0.005$) from pretreatment to all successive ratings. The white spot area significantly increased from the pretreatment evaluation to the ratings at 5 min of treatment ($P < 0.05$), showed no difference from pretreatment to the 10 min rating and significantly decreased between all other treatment intervals ($P < 0.005$; Table 2). In other words, the area involved with white spots was greater at 5 min, then tended to diminish to approximately original size at 10 min, then diminish further at recall.

The area of the tooth that was stained significantly decreased from pretreatment to 5 min of treatment, pretreatment to 10 min of treatment and pretreatment to recall ($P < 0.005$). However, there were no further significant changes among any intervals (Table 3). Specifically, the area involved with stain was greater at the pretreatment evaluation than at all other times but didn't get significantly smaller after 5 min of treatment.

The changes in the intensity of the color of staining paralleled those seen in the area of the tooth staining. The stains were significantly lighter than those seen at pretreatment, at 5 min of treatment, 10 min of treatment and at recall ($P < 0.005$). There were no significant changes among any of the other rating intervals (Table 4). The stain was lighter at all times after the pretreatment evaluation, but didn't get significantly lighter after 5 min of treatment.

The Kruskal-Wallis analysis revealed a significant difference between the three groups for amount of white spot and amount and intensity of stain ($P < 0.005$). Mildly stained teeth showed the best esthetic results. Moderately stained teeth showed improvement but continued to demonstrate 25–50% of the surface involved with white spots and a small area of light to moderately colored stain remained (Fig1 a and b, Figs 2 a and b). Severely stained teeth showed some improvement but more than 50% of the surface had areas of white spot remaining and > 25% of the surface was moderately stained.

The surface changes of the maxillary central incisors treated with PREMA™ were evaluated by SEM. Statistical analyses were performed after grouping the teeth according to their original rating of fluorosis severity. For the teeth rated as having mild fluorosis, neither the types of surface defects nor the depth of these defects changed significantly as determined by the Wilcoxon's signed rank test (Table 5). The surface of the mildly stained teeth tended to be smooth or have shallow grooves. The description of the defects showed significantly more involvement by the Wilcoxon's signed rank test only for the evaluation interval from pretreatment to 5 min of treatment ($P < 0.05$). The defects tended to change

from discrete to confluent. The area involved by the defects did not change significantly during any of the rating intervals and tended to involve between one-quarter and one-half the facial surface of the tooth.

The moderately involved fluorotic teeth showed significant changes in the types of defects observed only during the pretreatment to 5 min of treatment interval ($P < 0.05$) by the Wilcoxon's signed rank test (Table 6). The defects in these teeth originated as grooves or pits and tended to become both grooved and pitted (Figs 3 a and b, Figs 4 a and b). The depth of these defects did not change for any of the rating intervals. However, the description of the defects worsened significantly from the pretreatment to 5 min of treatment ($P < 0.001$) and to 10 min of treatment ($P < 0.05$). These changes were from confluent defects to defects that were both confluent and discrete. There was a significant change in the defects between 5 min of treatment and 10 min of treatment ($P < 0.05$) where some discrete defects tended to diminish. The area involved by the defects enlarged significantly from pretreatment to both 5 min of treatment and 10 min of treatment ($P < 0.005$) as determined by the Wilcoxon's signed rank test. However, there was no difference from 5 min to 10 min of treatment. The area involved by the defects originally was

TABLE 4. MEANS AND STANDARD DEVIATIONS FOR STAIN INTENSITY (SI) BY FLUOROSIS RATING

Assessment Period	Mild	Moderate	Severe
Pretreatment	0.06 ± 0.246	0.70 ± 0.596	1.55 ± 0.510
5 min	0.03 ± 0.177*	0.33 ± 0.479*	1.25 ± 0.716*
10 min	0.00 ± 0.000*	0.30 ± 0.466*	1.12 ± 0.697*
Recall	0.00 ± 0.000*	0.23 ± 0.430*	1.20 ± 0.768*

Significance by Wilcoxon's signed rank test.
* Comparison to pretreatment $P < 0.005$.

TABLE 5. MEANS AND STANDARD DEVIATIONS OF DEFECTS FOR MILD FLUOROSIS RATING

Assessment Period	Type	Depth	Description	Area
Pretreatment	2.33 ± 1.124	1.03 ± 0.765	1.63 ± 1.159	1.60 ± 1.429
5 min	2.63 ± 1.098	1.17 ± 0.648	2.03 ± 0.999*	1.47 ± 1.106
10 min	2.27 ± 1.081	1.00 ± 0.743	1.67 ± 1.061	1.37 ± 1.159

Significance by Wilcoxon's signed rank test.
* Comparison to pretreatment $P < 0.05$.

TABLE 6. MEANS AND STANDARD DEVIATIONS OF DEFECTS FOR MODERATE FLUOROSIS RATING

Assessment Period	Type	Depth	Description	Area
Pretreatment	2.68 ± 1.278	1.32 ± 1.020	1.86 ± 1.239	1.39 ± 1.257
5 min	3.50 ± 0.882*	1.89 ± 0.737	2.75 ± 0.441†	2.29 ± 1.049‡
10 min	3.07 ± 1.120	1.61 ± 0.875	2.36 ± 0.870*§	2.11 ± 1.166‡

Significance by Wilcoxon's signed rank test.
* Comparison to pretreatment $P < 0.05$.
† Comparison to pretreatment $P < 0.001$.
‡ Comparison to pretreatment $P < 0.005$.
§ Comparison to 5 min $P < 0.05$.

TABLE 7. MEANS AND STANDARD DEVIATIONS OF DEFECTS FOR SEVERE FLUOROSIS RATING

Assessment Period	Type	Depth	Description	Area
Pretreatment	2.68 ± 1.302	1.75 ± 1.342	1.44 ± 1.263	1.06 ± 0.929
5 min	3.00 ± 1.317	1.69 ± 1.195	1.94 ± 1.340*	1.50 ± 1.317*
10 min	2.94 ± 1.237	1.75 ± 1.125	2.00 ± 1.211*	1.63 ± 1.088*

Significance by Wilcoxon's signed rank test.

* Comparison to pretreatment $P < 0.05$

less than one-quarter of the surface and then increased to as much as one-half of the facial surface.

Teeth originally rated as severe had no significant changes in either the type or depth of the defects at any of the evaluation intervals (Table 7). The defects tended to be shallow to medium grooves or pits. The description of the defects showed significant changes by the Wilcoxon's signed rank test from pretreatment to 5 min of treatment and to 10 min of treatment ($P < 0.05$). The changes tended to be from discrete defects to confluent defects. The area involved by the defects increased from pretreatment to 5 min of treatment and to 10 min of treatment ($P < 0.05$). The defective area initially was determined to involve less than one-quarter of the surface and increased to between one-quarter and one-half of the surface. These findings are demonstrated in the severely fluorosed incisors from the patient in Figs 5 a and b, 6a and b, and 7 a and b. Both teeth showed fairly substantial loss of tooth structure in the incisal quarter by 10 min of treatment. However, the initial surface roughness was improved dramatically.

Discussion

Eesthetic improvement of teeth undergoing microabrasion is the most important aspect of treatment to the patient as well as the clinician. When success is defined as the production of a normal, unfluorosed appearance or sufficient reduction in fluorosis such that no further treatment is needed, the results of this investigation are the most encouraging for patients with mild fluorosis. In most instances, patients from the moderate and severe categories were pleased with the results even though the stain was not removed completely.

The issue of treatment time is confusing. No consensus exists regarding ideal treatment time or even when treatment should cease. Some authors report that microabrasion should be abandoned after 15 5-sec treatments (1 min 15 sec) if no improvement is seen.^{10, 15} Others suggest that a "typical" clinical session consists of only five microabrasion treatments but provide no time for a "treatment".¹⁶ The PREMA™ kit instruction booklet states that improvement should be seen within 5–10 min of treatment. An included list of helpful hints, states that some stains may require 10–30 min of treatment.²⁰ Consequently, the design of this study set definite treatment lengths of 30-sec applications, with a maximum of 20 applications or 10 min. Strict guidelines

of treatment time were very important in light of observed tooth loss. Although it was not the intent of our study to measure the amount of tooth loss, the examination of the photomicrographs gave clear evidence that substantial tooth loss does occur, especially in

some moderate and severe cases.

Another reason for recommending specific treatment times is that the operator's judgment of treatment result, i.e. stain or enamel removal, is confounded by desiccation, making teeth in the study appear white and chalky. This may have resulted from the removal of the well-calcified surface layer of enamel, which allowed exposure of the more porous, subsurface enamel. The desiccation made it difficult for the PI to determine if all stains or white spots had been removed or if remaining discoloration was due to desiccation. In fact, desiccation immediately following treatment often was so severe that a proper evaluation could not be made, and it continued to be present well after treatment, although it improved over time.

A major concern with the use of this technique is the potential loss of tooth structure. Croll states that microabrasion should be discontinued when an area becomes flat or concave.²³ During this study, despite continued scrutiny of the treated area, the PI was not always able to discern when an area was becoming flat, concave, or rough. These consequences were not clinically evident until the photographs or, in some cases, the SEM photomicrographs were viewed. Croll has suggested that teeth should be evaluated while wet to determine color change.²³ The PI observed that it was easier to determine flatness or concavity when a tooth was dry. One explanation for this effect is that the moisture camouflages the actual surface of the tooth by filling in the surface defects.

Uneven enamel loss gives rise to another area of concern. How much structure would be lost if the operator concentrated the technique only on stained areas and applied heavier pressure and time, attempting complete removal? This mistake is one that the inexperienced user of microabrasion might make. With the ambiguous directions currently available, concentration at a specific site could result in inadvertent, excessive tooth loss.

The findings of the SEM evaluation revealed that the degree of fluorosis is a very important predictor for surface alteration. This is consistent with the histology of the fluorotic lesion. In mild fluorosis, porosity is found exclusively in the very outermost layer of enamel. As the severity of fluorosis increases, the pores are present in deeper layers, and in the most severe cases, the pore volume of the enamel beneath the surface can be 25% or more.^{1, 3, 4, 7} In our study, the surfaces

of mildly fluorosed teeth were either unaffected by microabrasion or became smoother. These findings are consistent with those reported by Berg and Donly in unfluorosed teeth.¹⁶ However, as the severity of fluorosis increased, the surface changes became more apparent. The subsurface porosity revealed itself in varying ways. The tooth in Fig 6 was classified as moderately fluorosed, and clinical examination indicated smooth surfaces. Photomicrographs revealed small surface defects that enlarged at 5 min but became smooth by 10 min of treatment. It would appear that in this case, the porosity was only in the outermost layers and microabrasion removed the defective superficial enamel reaching a depth with more sound structure. However, another case categorized as moderate fluorosis demonstrated a dramatically different response. Figs 3 a and b show that the photomicrographs were consistent with a clinical diagnosis of moderate fluorosis because no pitting or surface defects other than grooves were evident. Following 10 min of treatment, large areas of destruction left sizable defects (Figs 4 a and b), which were not evident clinically and were not discovered by the PI until the photographs were magnified. This patient was seen following the study at the parent's request due to staining in the defects created by the treatment (Fig 8). When Figs 2b and 8 are compared, it becomes obvious that the treatment predisposed these teeth to staining. The created defects exposed subsurface porosity, which absorbed stain at a greater rate and to a greater degree than the previously untreated enamel surface. This finding is previously unreported. It could have been anticipated, however, because discoloration in fluorosed teeth is not a characteristic of fluorosis, but rather a posteruptive phenomenon arising from exposure to the oral environment.^{4,24} One issue needing further clarification is how to identify which teeth will stain following treatment.

One of the most disturbing findings from this investigation is the apparent inability of the clinician to accurately assess the degree of fluorosis by visual clinical examination alone. The PI was standardized in the use of the Dean's index, which is the most commonly used index for classification of fluorosis. Even under optimal conditions when teeth were carefully cleaned and dried as a part of the research protocol, the clinician was unable to detect defects that would later predispose teeth to damage. When photographs were viewed during rating sessions, it was apparent that teeth had been miscategorized. Many teeth were placed into lesser categories due to the fact that surface defects were undetectable until the magnified slides were viewed. This was further validated when the photomicrographs were rated and small pits that became enlarged during treatment were seen. It is clear that a more sensitive classification system than the Dean's index is necessary for the clinician to identify teeth at risk for untoward outcomes using the microabrasion technique.

The classification system of Thylstrup and Fejerskov, which correlates the macroscopic appearance of increasing degrees of dental fluorosis with the degree of subsurface porosity, appears to be an ideal tool.²⁵ These investigators found that the order of macroscopic changes is linked closely to a progressive increase in extent and degree of subsurface porosity or hypomineralization. Our findings clearly indicate that proper tooth selection is the most critical factor determining the potential for damage. An interesting follow-up study would be to categorize teeth according to the Thylstrup and Fejerskov system and see if predictions could be made of how they would be affected by the treatment. The clinician must be able to make an accurate diagnosis prior to treatment in order to avoid exposure of significant subsurface porosity, which would be subject to stain. In addition, a tooth with pitting of any size anywhere on the surface should be treated with caution due to the potential for uncovering surfaces that are more susceptible to post-treatment stain.

The assessment of treatment result was complicated by the recommendation that it be evaluated while the teeth are wet. A more accurate determination could be made after drying the teeth; however, air drying consistently resulted in desiccation, which masked the results. Photographs in our study were made after excess moisture was blotted.

Most patients treated in this study tolerated the treatment and were pleased with the results, and several parents noted positive improvements in their child's personality. Even when microabrasion caused noteworthy enamel loss, patients expressed satisfaction with the results even though the stain was not entirely removed, often because the procedure rendered the stain less noticeable by blending the boundaries into the rest of the surface. Total stain removal may be an unrealistic goal and even a small reduction in stain may be enough to satisfy the patient.

This study did not have a long-term followup to assess the stability of the changes in the treated teeth. Increased porosity in some of the moderately and severely fluorosed teeth as a result of enamel loss make staining a possibility. A followup study would involve recall of patients in this study to determine whether the microabrasion treatment has predisposed the underlying enamel to additional staining.

This study suggests that it will be difficult for a practitioner to determine who will benefit the most from microabrasion. Croll has suggested that there is no harm in attempting microabrasion since a resin composite restoration can be placed when sufficient stain removal is unattainable.¹³ If microabrasion is attempted, the patient must be informed of the potential risks and be willing to obtain further treatment if necessary.

Conclusions

1. Mildly fluorosed teeth showed the best esthetic results with an essentially normal appearance

following up to 10 min of microabrasion and no significant surface alterations on SEM following up to 10 min of treatment.

2. Moderately fluorosed teeth showed esthetic improvement but continued to demonstrate 25–50% of the surface involved with white spots and a small area of light to moderately colored stain remained following 10 min of microabrasion with significant surface alterations on SEM following 10 min of treatment.
3. Severely fluorosed teeth showed some esthetic improvement, but more than 50% of the surface had areas of white spot remaining, and more than 25% of the surface was moderately stained following 10 min of microabrasion with no significant changes on SEM at any of the evaluation intervals.

Dr. Train is in private practice in Dallas, Texas; Dr. McWhorter and Dr. Wilson are associate professors; Dr. Seale is professor and chairman, department of pediatric dentistry, Baylor College of Dentistry; and Dr. Guo is an assistant professor in the department of public health at Baylor College of Dentistry, Dallas, Texas.

1. Fejerskov O, Thylstrup A, Larsen MJ: Clinical and structural features and possible pathogenic mechanisms of dental fluorosis. *Scand J Dent Res* 85:510–34, 1977.
2. Moller IJ: Fluorides and dental fluorosis. *Int Dent J* 32:135–47, 1982.
3. Cutress TW, Suckling GW: Differential diagnosis of dental fluorosis. *J Dent Res* 69(Spec Iss):714–20, 1990.
4. Fejerskov O, Manji F, Baelum V: The nature and mechanisms of dental fluorosis in man. *J Dent Res* 69:692–700, 1990. [Spec Iss; Discussion 721]
5. Horowitz HS: Fluoride and enamel defects. *Adv Dent Res* 3(2):143–46, 1989.
6. Fejerskov O, Johnson NW, Silverstone LM: The ultrastructure of fluorosed human dental enamel. *Scand J Dent Res* 82:357–72, 1974.
7. Fejerskov O, Silverstone LM, Melsen B, Möller IJ: Histological features of fluorosed human dental enamel. *Caries Res* 9:190–210, 1975.
8. McCloskey RJ: A technique for removal of fluorosis stains. *J Am Dent Assoc* 109:63–64, 1984.
9. Croll TP, Cavanaugh RR: Enamel color modification by controlled hydrochloric acid-pumice abrasion. I. Technique and examples. *Quintessence Int* 17(2):81–87, 1986.
10. Croll TP, Cavanaugh RR: Enamel color modification by controlled hydrochloric acid-pumice abrasion. II. Further examples. *Quintessence Int* 17(3):157–64, 1986.
11. Waggoner WF, Johnson WM, Schumann S, Schikowski E: Microabrasion of human enamel in vitro using hydrochloric acid and pumice. *Pediatr Dent* 11(4):319–23, 1989.
12. Kendell RL: Hydrochloric acid removal of brown fluorosis stains: clinical and scanning electron micrographic observations. *Quintessence Int* 20:837–39, 1989.
13. Croll TP: Enamel microabrasion for removal of superficial dysmineralization and decalcification defects. *J Am Dent Assoc* 120:411–15, 1990.
14. Welbury RR, Shaw L: A simple technique for removal of mottling, opacities and pigmentation from enamel. *Dental Update* 17(4):161–63, 1990.
15. Adams TC: Enamel color modifications by controlled hydrochloric acid pumice abrasion: a review with case summaries. *J Indiana Dent Assoc* 66(5):23–26, 1987.
16. Berg JH, Donly KJ: The enamel surface and enamel microabrasion. Chapter 7. In: *Enamel Microabrasion*. TP Croll, Ed. Lombard, IL: Quintessence Publishing Co, 1991.
17. Scherer W, Quattrone J, Chang J, David S, Vijayaraghavan T: Removal of intrinsic enamel stains with vital bleaching and modified microabrasion. *Am J Dent* 4:99–102, 1991.
18. Sundström B, Arends J, Jongebloed WL, Bouchouchi M: Morphology of outer regions of fluorosed human deciduous enamel. *Caries Res* 14:381–88, 1980.
19. Premier Dental Products Co: PREMA Enamel Microabrasion Kit—Instruction Booklet. Norristown, PA, 1989.
20. Premier Dental Products Co: PREMA Enamel Microabrasion Kit—“Helpful Hints.” Norristown, PA, 1989.
21. Dean HT: The investigation of physiological effects by the epidemiological method. *Am Assoc Adv Sci* 19:23–31, 1942.
22. Croll TP: *Enamel Microabrasion*. Lombard, IL: Quintessence Publishing Co, 1991.
23. Landis JR, Koch GG: The measurement of observer agreement for categorical data. *Biometrics* 33:159–74, 1977.
24. Sundström B, Jongebloed WL, Arends J: Fluorosed human enamel: a SEM investigation of the anatomical surface and outer and inner regions of mildly fluorosed enamel. *Caries Res* 12(6):329–38, 1978.
25. Thylstrup A, Fejerskov O: Clinical appearance of dental fluorosis in permanent teeth in relation to histologic changes. *Community Dent Oral Epidemiol* 6:315–28, 1978.