

## Original Article

# Clinical Performance of a Combined Approach for the Esthetic Management of Fluorosed Teeth: Three-year Results

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### ABSTRACT

**Objective:** The long-term clinical performance of combined therapy including enamel microabrasion and vital bleaching is debatable due to the abrasion of outer enamel surface. The aim of this longitudinal cohort study was to evaluate the 3-year clinical performance of enamel microabrasion in combination with vital tooth bleaching for the esthetic management of fluorosed teeth. **Materials and Methods:** Fifteen patients with 176 fluorosed incisors and canines were included in this study. All the teeth were treated with enamel microabrasion (Opalustre, Ultradent), and at-home bleaching technique (10% Opalescence PF, Ultradent). Fluorosed teeth were evaluated at baseline, after microabrasion, after combined therapy, and at 3-year follow-up in terms of esthetic criteria (esthetic appearance, brown stains, and opaque white areas), side effects, and patient satisfaction using visual analog scales. The data were statistically analyzed ( $\alpha = 0.05$ ). **Results:** Fluorosed teeth revealed significantly better esthetic appearance after microabrasion and combined therapy and at 3-year follow-up compared to those at baseline ( $P < 0.05$ ). There was a significant relapse in the esthetic appearance and brown stains at 3-year follow-up ( $P < 0.05$ ). **Conclusions:** The combined therapy was effective in the esthetic management of fluorosed teeth. However, a significant relapse was observed in the esthetic appearance and brown stains of these patients after 3 years, which also reduced patient satisfaction.

**KEYWORDS:** Clinical trial, dental fluorosis, enamel microabrasion, relapse in bleaching, vital bleaching

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## INTRODUCTION

Dental fluorosis accompanied by white opaque areas, brown stains, or porosities on the enamel surface leads to mild to severe esthetic problems requiring esthetic treatment.<sup>[1,2]</sup>

Many treatment modalities have been proposed for the esthetic management of dental fluorosis, ranging from bleaching techniques such as enamel microabrasion, vital bleaching, or a combination of both, to restorative approaches such involving the use of composite or ceramic veneer or crowns.<sup>[3-5]</sup> The treatment choice depends on the severity of dental fluorosis. In fluorosed teeth, opaque white areas formed due to the demineralization of enamel while brown stains occurred because of the discoloration of these dysmineralized areas.<sup>[6]</sup> Enamel microabrasion and vital bleaching produced successful

results in improving clinical appearance of mild cases with opaque white areas.<sup>[4,7]</sup> But in moderate and severe cases, the most popular conservative technique is the combination of enamel microabrasion and vital bleaching.<sup>[3,8]</sup> Where severe dental fluorosis with deep enamel defects is present, the treatment will involve restorative techniques.<sup>[5]</sup>

Enamel microabrasion, which is performed by applying a hydrochloride acid (HCl) gel, removes the porous subsurface of the enamel layer together with entrapped stains.<sup>[6]</sup> This technique was first described by Croll

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and Cavanaugh in 1986, since then, numerous case reports and a few clinical trials have been published about the clinical performance of this technique in fluorosed teeth.<sup>[3,4,8-10]</sup> However, this technique has some disadvantages which limit its application alone. The first one is that it is difficult to remove a deep opaque white area or brown stain from the tooth completely by this technique. They often are improved, but they cannot always be eliminated. The other disadvantage of this technique is that teeth will have a slightly yellowish color after enamel microabrasion because this process decreases the enamel thickness and furthermore the appearance of the tooth is generally not uniform after the treatment.<sup>[6]</sup>

Vital bleaching has been rarely preferred in the treatment of dental fluorosis alone. In the literature, this technique was only employed in the mild cases with opaque white areas.<sup>[7,11]</sup> The main use of this technique is in combination with enamel microabrasion to whiten the microabraded teeth and to improve the uniform appearance.<sup>[3,8]</sup> This combined therapy including enamel microabrasion followed by vital bleaching was reported to be effective in the esthetic management of mild to severe fluorosed teeth.<sup>[3,8,12]</sup>

In literature, there are limited data on the long-term performance of different techniques used for the management of dental fluorosis. Enamel microabrasion removes approximately 10–200 µm of the outer enamel layer, depending on the pressure and number of applications, HCl acid concentration, and abrasive particles.<sup>[13]</sup> The bleaching process causes alterations on the enamel surface depending on the concentration of the gel used.<sup>[14,15]</sup> The variety of alterations that may result from enamel microabrasion and vital bleaching techniques increase the concerns about the long-term clinical performance of this combined approach. Although the successful long-term results were reported after a 2–23 years follow-ups of the enamel microabrasion technique in two case reports,<sup>[12,16]</sup> there is a lack of longitudinal clinical trial evaluating the long-term performance of the combined approach.

The aim of this longitudinal cohort study was to evaluate the 3-year clinical performance of enamel microabrasion in combination with vital tooth bleaching for the esthetic management of fluorosed teeth. The correlation between the relapse in esthetic criteria at follow-up and severity of fluorosis, demographic factors, oral hygiene, and diet variables was also assessed. The null hypothesis tested was that there is no difference among the esthetic criteria recorded at baseline, after enamel microabrasion, after combined therapy, and at 3-year follow-up.

## MATERIALS AND METHODS

### Study design

This was a longitudinal cohort study which was performed in an urban area of Isparta, Turkey with a high concentration of fluoride in drinking water.

Fifteen patients were treated between December 2010 and May 2011. Enamel microabrasion and at-home bleaching therapy were consecutively performed on all patients. The fluorosed teeth were assessed in terms of various criteria regarding esthetics and side effects at different evaluation periods: (a) Baseline, (b) after enamel microabrasion, (c) after combined therapy (enamel microabrasion and at-home bleaching), and (d) 3-year follow-up. The flow chart of patients and fluorosed teeth through each stage of the study is given in Figure 1.

The study protocol was approved by the committee for medical ethics of Suleyman Demirel University in Isparta, Turkey and the procedures followed were in accordance with the Helsinki Declaration of 1975, as revised in 2000. An informed consent form was signed by each patient at the beginning of the study after patients had been advised about the nature and objectives of the clinical trial.

### Study size

The study size was determined with the PASS Sample Size Software (NCSS, LLC, Kaysville, Utah, USA). At least 154 teeth were required to determine the  $F = 0.30$  effect difference between the study groups with 95% power and an alpha error of 5%. Due to the long follow-up period, 176 fluorosed teeth, including an additional 20% of the number of teeth required, were included in the study. Twenty patients were assessed for the eligibility, but five patients were excluded due to smoking or poor dental health.

### Participants

The participants were selected from the patients referred to the university clinic for the management of fluorosed teeth. Fifteen patients (eight male and seven female), with a mean age of 27 years (range: 18–45 years) were enrolled in this longitudinal cohort study.

### Inclusion criteria

- Minimum of eight vital fluorosed incisors and canines with scores of 1–4, according to Dean's Fluorosis Index (DFI) (0 - normal, 0.5 - questionable, 1 - very mild, 2 - mild 3 - moderate, and 4 - severe)<sup>[17]</sup>
- No caries or restoration on the teeth to be treated
- Return for follow-up.

### Exclusion criteria

- Poor general or dental health
- Smoking

- Hypersensitive teeth
- Previous use of bleaching agents
- Pregnant or lactating
- Any fixed orthodontic appliances
- A history of allergies to bleaching agents
- Age of <18 years.

Symptoms of pulpitis or severe periodontal disease such as tooth mobility or extensive loss of periodontal attachment or alveolar bone.

Before assessing teeth according to the DFI, a calibration training session was performed. Fifteen dental fluorosis pictures of 160 fluorosed teeth of varying severity from previous studies were used.<sup>[3,4]</sup> The examiners evaluated the pictures until they reached a consensus ( $k > 0.70$ ).

### Measurement

Once patients enrolled into the study, they completed a questionnaire assessing their medical history, oral hygiene habits (frequency of tooth brushing), and diet (frequency of discoloring drink consumption and frequency of acidic drink consumption). The baseline demographics, clinical characteristics, and oral hygiene and diet habits of the patients are presented in Table 1.

Prior to the treatment, all teeth were cleaned with pumice in a rubber cup, and initial photographs were taken [Figures 2a-4a]. A digital camera (Coolpix 8800; Nikon, Tokyo, Japan) was used to take standardized images of the teeth. The images were taken at the same distance in a dark room under controlled lighting conditions. The same camera and light source were used. The rubber dam was used for isolation during microabrasion process. Slurry composed of 6.6% hydrochloric acid and silicon carbide microparticles (Opalustre, Ultradent Products, Inc., South Jordan, UT, USA) was used for microabrasion according to the manufacturer's instruction. A fine-grit water-cooled diamond bur was used on the stained or white opaque enamel region for 5–10 s in order to provide effective penetration of the slurry into the enamel. A 1 mm thick layer of the slurry was applied to the affected tooth surfaces. OpalCups™ prophylaxis cups (Ultradent Products, Inc.) attached to a gear-reduction contra-angle were used to microabrade the surfaces of the teeth using slight pressure for 60 s. This procedure was repeated five times for very mild to mild lesions and ten times for moderate and severe lesions during the same session.<sup>[18]</sup> The teeth were rinsed between each 60 s application. Mean application duration of enamel microabrasion was 8.5 min. Photographs were taken 24 h after treatment [Figures 2b-4b].

An at-home bleaching agent (10% carbamide peroxide, Opalescence PF, Ultradent Products, Inc.) was applied to all patients 24 h after the enamel microabrasion procedure. After alginate impressions of both maxillary and mandibular arches were taken, cast models were created. A block-out material (LC Block-Out Resin, Ultradent Products, Inc.) was used to form a 1 mm buccal reservoir on cast models. Custom-fitted trays were prepared from Sof-Tray® sheets (Ultradent Products, Inc.). A scalloped design was preferred for the custom trays. At-home bleaching gel was used overnight for 2–4 weeks, until no differences were observed between two consecutive 1-week visits. The mean application duration of the at-home bleaching gel was 2.9 weeks. The teeth were polished with abrasive discs (fine to extra fine, OptiDics, Kerr, Bioggio, Switzerland), and fluoride gel (Sultan Topex Neutral Fluoride gel, Englewood, NJ, USA) was applied for 5 min after bleaching. Photographs were taken 24 h after treatment [Figures 2c-4c]. The patients were re-evaluated at 3-year follow-up [Figures 2d-4d].

### Quantitative variables

All fluorosed teeth were evaluated at baseline, after enamel microabrasion, after combined therapy, and after 3 years by two calibrated and blinded examiners, who did not perform the bleaching treatments, from images of the teeth for esthetic appearance, brown stains, and white opaque areas using VAS ranging from 1 to 7 per tooth [Table 2]. VAS ranging from 1 to 7 was also used for getting information from patients regarding patient satisfaction, tooth sensitivity, and gingival issues (per patient) [Table 2]. Twenty images were randomly selected and used to test for intra- and inter-examiner reliability.

### Statistical methods

The statistical analysis was performed using the SPSS software system, version 20.0 (IBM Corporation, New York, USA). The Shapiro–Wilk test was used to test the likelihood that the distribution of data was normal. The differences in all criteria assessed by VAS throughout different evaluation periods were analyzed using the Friedman one-way ANOVA test. Twelve restorations could not evaluate at follow-up, thus 167 data were analyzed instead of 176 data at follow-up.

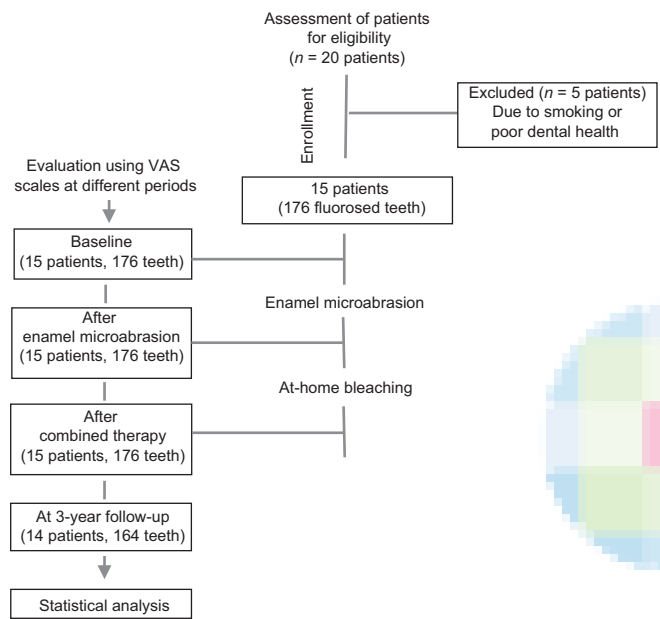
The severity of fluorosis, demographics, oral hygiene, and diet variables of all participants were analyzed for relationships with the relapse in the esthetic criteria after 3 years using a Spearman's rho nonparametric correlation [Table 3]. During evaluation, teeth in “very mild” and “mild” groups of severity of fluorosis variable, teeth in “1–2 times each day” and “less than once a day” groups of frequency of discoloring drink consumption variable,



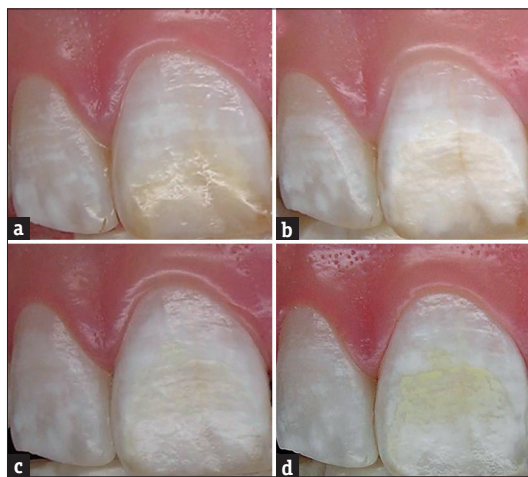
and teeth in “1–2 times each day” and “3–4 times each day” groups of frequency of acidic drink consumption variable were combined as the number of teeth in these groups was low. For all tests, the probability level for statistical significance was at  $\alpha = 0.05$ .

### RESULTS

Fourteen of 15 patients returned for follow-up so that 164 of 176 teeth were re-evaluated, and the recall rate was 93%. One patient with 12 fluorosed teeth could not be re-evaluated as he moved to another city. The test of intra- and inter-examiner agreement resulted in a Cohen’s kappa statistic of 0.79 and 0.82, respectively.



**Figure 1:** The flow chart of the study protocol

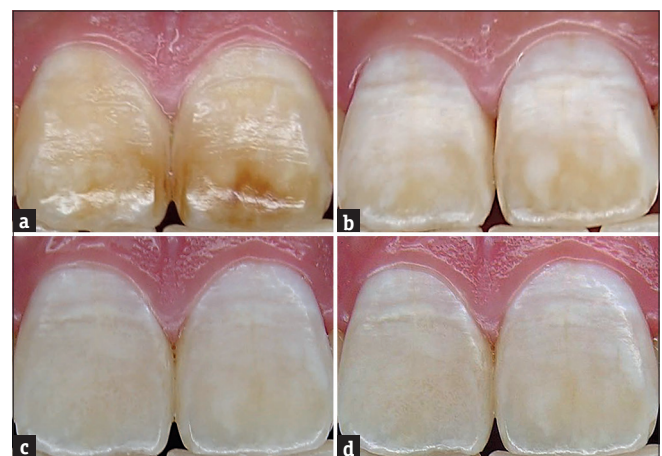


**Figure 2:** Baseline and posttreatment views of fluorosed teeth managed by the combined approach; (a) baseline, (b) after microabrasion, (c) after vital bleaching, and (d) after 3 years. A slight relapse like a yellowish stain on the buccal surface existed on the maxillary incisor at 3-year follow-up

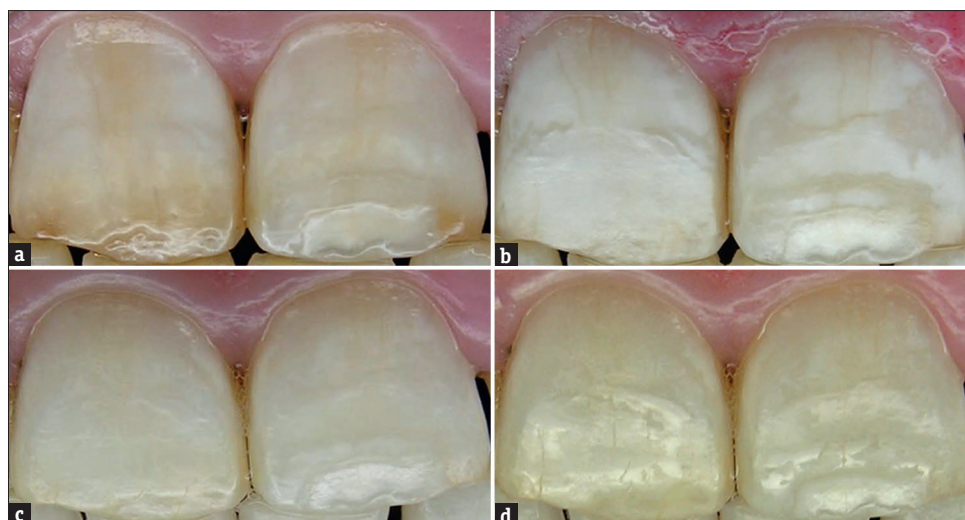
**Table 1: The baseline demographic, clinical characteristics, oral hygiene, and diet habits of patients**

	Number of patient	Number of teeth (%)
Gender		
Male	8	95 (54)
Female	7	81 (46)
Age (years)		
18-30	10	118 (67)
31-40	2	24 (14)
41-50	3	34 (19)
Oral hygiene		
Moderate	4	48 (27)
Good	11	128 (73)
Severity of fluorosis (DFI)		
Very mild	4	9 (5)
Mild	8	43 (24)
Moderate	14	95 (54)
Severe	7	29 (17)
Frequency of tooth brushing		
<once a day	-	-
Once a day	6	70 (40)
Twice a day	6	72 (41)
>Twice a day	3	34 (19)
Frequency of discoloring drink consumption		
>5 times each day	8	95 (54)
3-4 times each day	3	36 (20)
1-2 times each day	3	33 (19)
< Once a day	1	12 (7)
Frequency of acidic drink consumption		
>5 times each day	-	-
3-4 times each day	2	24 (14)
1-2 times each day	2	23 (13)
<once a day	13	129 (73)

DFI=Dean’s fluorosis index



**Figure 3:** Baseline and posttreatment views of fluorosed teeth managed by the combined approach; (a) baseline, (b) after microabrasion, (c) after vital bleaching, and (d) after 3 years. There was an evident discoloration on the whole surfaces of maxillary incisors at 3-year follow-up



**Figure 4:** Baseline and posttreatment views of fluorosed teeth managed by the combined approach; (a) baseline, (b) after microabrasion, (c) after vital bleaching, (d) after 3 years. There was no relapse in the esthetic appearance of these maxillary incisors at 3-year follow-up

**Table 2: Visual analogue scales used for each criterion**

Criteria	Description and scores			
Esthetic appearance	Very bad 1	Unacceptable 2-3	Acceptable 4-5	Exceptional 6-7
Brown stains or opaque white areas	Very distinct 1	Moderate 2-3	Slight 4-5	Indistinct 6-7
Tooth sensitivity or gingival problems	No side effects 1	Slight 2-3	Moderate 4-5	Severe 6-7
Patient satisfaction	Nonsatisfied 1	Slight 2-3	Moderate 4-5	Very satisfied 6-7

**Table 3: Spearman's rho correlations between the relapse in esthetic criteria and severity of fluorosis, demographic, oral hygiene, and diet variables**

	Esthetic appearance	Brown stains	Opaque white areas
Gender			
$\rho$	0.454**	0.547**	-0.144
<i>P</i>	0.000	0.000	0.065
Age			
$\rho$	-0.042	-0.098	-0.125
<i>P</i>	0.592	0.238	0.082
Oral hygiene			
$\rho$	0.154	0.130	-0.036
<i>P</i>	0.072	0.094	0.646
DFI			
$\rho$	0.175*	0.205*	-0.065
<i>P</i>	0.025	0.013	0.412
Frequency of tooth brushing			
$\rho$	0.034	-0.161	0.109
<i>P</i>	0.666	0.052	0.166
Frequency of discoloring drink consumption			
$\rho$	-0.142	-0.138	0.151
<i>P</i>	0.070	0.096	0.072
Frequency of acidic drink consumption			
$\rho$	-0.230*	-0.388**	0.128
<i>P</i>	0.003	0.000	0.103

$\rho$ =Spearman-Rho coefficient; \*Correlation is significant at  $P < 0.05$ ; \*\*Correlation is significant at  $P < 0.01$ . DFI=Dean fluorosis index

**Esthetic improvements**

Table 4 shows the VAS scores of fluorosed teeth for each criterion at different evaluation periods and their statistical comparisons. There were significant differences in the esthetic appearance of fluorosed teeth and in the brown stains and opaque white areas on fluorosed teeth at different evaluation periods ( $P = 0.000$ ). Fluorosed teeth revealed a significantly better esthetic appearance and significant reduction in VAS scores of brown stains after microabrasion, after combined therapy, and at 3-year follow-up compared to those at baseline ( $P < 0.05$ ). However, they displayed a significant reduction in white opaque areas just after combined therapy and at 3-year follow-up when compared with those at baseline ( $P < 0.05$ ).

After microabrasion, the scores for the esthetic appearance and for the brown stains and white opaque areas were significantly lower than those after combined therapy and at 3-year follow-up ( $P < 0.05$ ). The best

esthetic appearance and the least pronounced brown stains were recorded after combined therapy ( $P < 0.05$ ). There was a significant relapse in the esthetic appearance and in the brown stains at 3-year follow-up when compared to those after combined therapy ( $P < 0.05$ ).

**Table 4: Visual analog scale scores of fluorosed teeth for each criterion at different evaluation periods**

	<b>Esthetic appearance</b>	<b>Brown stains</b>	<b>Opaque white areas</b>	<b>Tooth sensitivity</b>	<b>Gingival problems</b>	<b>Patient satisfaction</b>
Baseline						
Minimum-maximum	1-6	1-6	1-6	1-1	1-1	1-3
Mean (SD)	3.5 (1.4)	3.4 (1.6)	4.4 (1.4)	1.0 (0.0)	1.0 (0.0)	1.7 (0.8)
Median (IQR)	4.0 (3.0) <sup>a</sup>	4.0 (3.0) <sup>x</sup>	5.0 (1.0) <sup>a</sup>	1.0 (0.0) <sup>o</sup>	1.0 (0.0) <sup>o</sup>	1.0 (1.0) <sup>n</sup>
After microabrasion						
Minimum-maximum	1-6	1-7	1-7	2-4	1-2	3-7
Mean (SD)	3.9 (1.3)	4.3 (1.3)	4.3 (1.2)	2.6 (0.6)	1.9 (0.4)	4.8 (1.3)
Median (IQR)	4.0 (2.0) <sup>b</sup>	4.0 (2.0) <sup>y</sup>	4.0 (2.0) <sup>a</sup>	3.0 (1.0) <sup>xx</sup>	2.0 (0.0) <sup>o</sup>	5.0 (2.0) <sup>z</sup>
After combined therapy						
Minimum-maximum	2-7	3-7	2-7	1-4	1-2	5-7
Mean (SD)	5.8 (0.9)	5.9 (1.0)	5.9 (1.0)	2.8 (0.9)	1.8 (0.4)	6.5 (0.7)
Median (IQR)	6.0 (1.0) <sup>c</sup>	6.0 (2.0) <sup>z</sup>	6.0 (2.0) <sup>o</sup>	3.0 (2.0) <sup>e</sup>	2.0 (0.0) <sup>o</sup>	7.0 (1.0) <sup>v</sup>
After 3-year follow-up						
Minimum-maximum	2-7	1-7	2-7	1-1	1-1	4-7
Mean (SD)	5.5 (1.0)	5.4 (1.2)	6.0 (1.0)	1.0 (0.0)	1.0 (0.0)	5.4 (1.2)
Median (IQR)	5.0 (1.0) <sup>d</sup>	6.0 (1.0) <sup>t</sup>	6.0 (2.0) <sup>o</sup>	1.0 (0.0) <sup>o</sup>	1.0 (0.0) <sup>o</sup>	5.5 (2.0) <sup>z</sup>
<i>P</i>	0.000	0.000	0.000	0.000	0.000	0.000

SD=Standard deviation; IQR=Interquartile range. Medians with same superscript in a column are not statistically significant different at  $P < 0.05$

Nevertheless, no significant differences were noted between the VAS scores for the white opaque areas which were recorded after combined therapy and at 3-year follow-up ( $P > 0.05$ ).

### Tooth sensitivity, gingival problems, and patient satisfaction

All patients reported no tooth sensitivity or gingival problems at baseline and at 3-year follow-up. Tooth sensitivity and gingival problem levels of patients after microabrasion and after combined therapy were slight, and there were no significant differences between these scores. They were also significantly higher compared to the baseline and follow-up scores ( $P < 0.05$ ).

Patient satisfaction was "slight" at baseline, "moderate" after microabrasion and at follow-up, and "very satisfied" after combined therapy. Patient satisfaction level was the lowest at baseline and the highest after combined therapy ( $P < 0.05$ ). At 3-year follow-up, satisfaction was significantly lower than that after combined therapy ( $P < 0.05$ ). However, satisfaction was similar after microabrasion and at 3-year follow-up.

### Relationship between the relapse in the esthetic criteria and severity of fluorosis, demographic factors, oral hygiene, and diet variables

A number of variables were correlated with the relapse in the esthetic appearance at the 3-year follow-up. The relapse was positively correlated with gender ( $\rho = 0.454$ ,  $P = 0.000$ ) and severity of fluorosis ( $\rho = 0.175$ ,  $P = 0.025$ ) but negatively correlated with frequency of acidic drink consumption ( $\rho = -0.230$ ,  $P = 0.003$ ).

The relapse in brown stains at different evaluation periods was also correlated with various variables. Gender ( $\rho = 0.547$ ,  $P = 0.000$ ) and severity of fluorosis ( $\rho = 0.205$ ,  $P = 0.013$ ) had a positive correlation, but frequency of acidic drink consumption had a negative correlation ( $\rho = -0.388$ ,  $P = 0.000$ ) with the relapse in brown stains.

## DISCUSSION

The null hypothesis was rejected. In the esthetic management of fluorosed teeth, the combined therapy including the enamel microabrasion followed by vital tooth bleaching was found effective. But a significant relapse was occurred in the esthetic appearance and brown stains of the patients subjected to the combined therapy after 3 years.

In the present study, enamel microabrasion in combination with vital tooth bleaching for the management of tooth discoloration caused by fluorosis was evaluated in terms of esthetic criteria, side effects, and patient satisfaction using VAS scales. The implementation of enamel microabrasion alone or in combination with vital bleaching procedures is a commonly used and effective method for removal of fluorotic stains on tooth surfaces. Enamel microabrasion alone was satisfactory in most of the mild fluorosis cases, but when the severity of fluorosis increased, more satisfactory results were reported with the combined approach.<sup>[3,4,8]</sup> In this study, first enamel microabrasion then vital bleaching are employed. The reason for this sequence was that enamel microabrasion causes a microreduction on the enamel surface, and, in some cases, teeth submitted to microabrasion may appear



a darker or yellowish color because the thin remaining enamel surface can reveal some of the dentinal tissue color. Vital bleaching procedure eliminates this color change due to enamel microabrasion.<sup>[6]</sup> For enamel microabrasion, a well-known product including 6.6% hydrochloric acid and silicon carbide microparticles was used. A bleaching agent with 10% carbamide peroxide was preferred for at-home bleaching.

In this study, modifications of visual scales used in previous articles on the management of dental fluorosis were preferred.<sup>[3,4,19]</sup> VAS is still the most common approach used to assess the effectiveness of dental fluorosis treatments, even though it is a subjective technique. This is because a detectable color change in fluorotic areas based on CIELAB system is not enough in fluorosed teeth, as the main targets are to remove all fluorotic stains and to improve the mottled surface.

The long-term success of bleaching therapy is as important as its immediate success. Several studies evaluating the long-term efficacy of bleaching agents on physiological discolorations have reported a varying degree of bleaching relapse over time.<sup>[20,21]</sup> However, there is limited information on the long-term success of bleaching techniques used for the esthetic management of fluorosed teeth.<sup>[12,16]</sup>

The findings of this study are very important because there is no long-term prospective clinical trial on the management of fluorosed teeth. However, there are some limitations of this study. One of the limitations was to use VAS, a subjective scale for assessing the performance of combined therapy because there is no good objective method to evaluate the removal of fluorotic stains. The other limitation was the evaluation periods. The patients were evaluated at baseline and at 3 years depending on the previous researches which also performed evaluations at two time periods.<sup>[22,23]</sup> However, annual evaluation periods may also show exact relapse time.

In the present study, enamel microabrasion significantly improved the esthetic appearance and significantly reduced the brown stains compared to baseline, but it could not sufficiently eliminate the opaque white areas. In addition, better results were observed after combined therapy compared to those obtained after enamel microabrasion for all esthetic criteria. Previous articles also reported that the combination of enamel microabrasion and vital bleaching techniques resulted in better performance in all esthetic criteria compared to the technique in which the enamel microabrasion was employed alone.<sup>[3,4,8]</sup> It was claimed that enamel microabrasion was a good way to eliminate opaque white areas and brown stains; however, vital bleaching

can provide a uniform tooth shade.<sup>[24]</sup> Similar to the findings of the present study, enamel microabrasion yielded more improvement in brown stains than in opaque white areas in a previous study.<sup>[4]</sup> The reason for the insufficiency of enamel microabrasion for removal of white opaque areas might be attributed to the depth of these dysmineralizations. The opaque areas might extend through the whole enamel structure depending on the severity of fluorosis. Brown stains, however, are formed by the discoloration of the dysmineralized subsurface area, and the depth of brown stains is probably associated with the penetration capacity of staining agents. In enamel microabrasion, the outer enamel surface is removed; thus, removing all brown stains might have been easier than eliminating whole opaque white areas.

There was a significant relapse in the esthetic appearance and in the brown stains after 3 years, but no significant relapse was reported for the white opaque areas. In addition, patient satisfaction also reduced from “very satisfied” to “moderate” after 3 years. Limited information exists in the literature on the long-term clinical performance of techniques used for the management of enamel dysmineralization. Ashkenazi and Sarnat<sup>[21]</sup> did not report any staining 4 years after microabrasion of enamel demineralization in a case report evaluating the performance of microabrasion. Sundfeld *et al.*<sup>[16]</sup> reported no relapse in the esthetic appearance at 23 years follow-up after bleaching the white enamel demineralization areas with 18% hydrochloric acid/pumice and dental bleaching with 15% carbamide peroxide.

The reason for the relapse in the present study may be explained by three facts: (a) The structural and permeability changes, and surface porosity in the enamel surface caused by enamel microabrasion and vital bleaching, (b) prolonged bleaching duration in severe cases, and (c) demographic factors, oral hygiene, and diet variables of the patients. Enamel microabrasion removes the outermost layer of enamel and forms a densely compacted prism-free layer on the enamel surface. This method is believed to smooth surface irregularities and results in a more regular, lustrous enamel surface.<sup>[6]</sup> However, at-home bleaching agents applied after enamel microabrasion may produce an irregular surface,<sup>[14,15,25]</sup> and use of bleaching agents for a prolonged period may increase these effects. Likewise, some degree of rebound effect has been observed within days or weeks following the bleaching procedure in many cases in the literature.<sup>[20,21]</sup> In the present study, the application duration of at-home bleaching gel was 2.9 weeks, but in severe cases, it was applied up to 4 weeks. In addition, gender, an increase in the severity of fluorosis, and frequent consumption of acidic drinks

such as coke and orange juice were correlated with the relapse in the esthetic appearance and brown stains. The prolonged application of both enamel microabrasion and at-home bleaching agents in severe cases may produce more a porous surface compared to their counterparts in the other groups. In addition, the frequent use of acidic drinks may lead to enamel loss with increased surface roughness.<sup>[26,27]</sup> The coloring pigments may readily accumulate in the rough surface, and a rough enamel surface with pores or superficial defects may discolor easily.<sup>[28]</sup> Gender may have an indirect effect on relapse because gender was also positively correlated with the severity of fluorosis and negatively correlated with the frequency of acidic drink consumption. Females had more severely fluorosed teeth and consumed acidic drinks more frequently.

## CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

- The null hypothesis was rejected; different results were recorded in all esthetic criteria at different evaluation periods
- The combined therapy was more effective than enamel microabrasion in the esthetic management of fluorosed teeth
- A significant relapse was observed in the esthetic appearance and brown stains of patients after 3 years, which also reduced the patient satisfaction
- Gender, severity of fluorosis, and frequency of acidic drink consumption were correlated with the relapse in the esthetic appearance and brown stains after 3 years.

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## Conflicts of interest

There are no conflicts of interest.

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