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Clinical Evaluation of Different Minimal Invasive Treatment Modalities of Mild to Moderate Dental Fluorosis Using an Intra-oral Spectrophotometer

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Abstract

BACKGROUND: Various treatment modalities are available to improve esthetics of fluorosed teeth based on its severity.

AIM: The aim of the study was to evaluate the clinical performance of different minimal invasive treatment protocols on mild to moderate fluorosed teeth.

METHODS AND MATERIALS: Before the interventions, tooth color coordinates L, a and b were recorded for 160 fluorosed teeth by Vita Easyshade V. Participants were randomly allocated in eight treatment protocols with 20 teeth (n = 20) included in each protocol. Protocol one (P_1) Opalescence boost PF 40%. Protocol two (P_2) Opalustre. Protocol three (P_3) MI-Paste Plus. In protocol four (P_4) teeth were treated with Opalustre followed by Opalescence boost PF 40%. In protocol five (P_5) Opalescence boost PF 40% was applied followed by MI-Paste Plus, while in protocol six (P_6) Opalustre was applied followed by MI-Paste Plus whereas protocol seven (P_7) teeth were treated with Opalustre, followed by Opalescence boost PF 40% and finally MI-Paste Plus. Protocol eight (P_8) control. All teeth were evaluated immediately for color change (ΔE) after treatment (T_1), after 14 days (T_2), after 3 months (T_3) and after 6 months (T_4). Color change (ΔE) was calculated from ΔL, Δa, and Δb recorded at each evaluation time point.

STATISTICAL ANALYSIS: Two-way ANOVA was applied to test the interaction between different variables. ANOVA repeated measures were followed by Duncan multiple range tests (DMRTs) to compare between groups.

RESULTS: In accordance to time, all treatment protocols showed significant color change can be recognized by unexperienced eye ($\Delta E \geq 3.7$). Immediately after application (T_1), the highest color change (ΔE) was recorded in P_7. While at 14 days and 3 months follow ups, color change in P_4 exceeded P_7. After 6 months the highest ΔE was recorded in both P_4 and P_7 with no significant difference between them. Meanwhile, in Accordance to treatment Protocol, The highest color change was recorded at 3 months (T_3) in all treatment protocols. These records were preserved at 6 months follow-up (T_4) for all treatment protocols except P_1 and P_3.

CONCLUSION: Combined treatment protocols of Opalustre and Opalescence boost PF 40% have the highest effect on ΔE regardless of using MI-Paste Plus. MI-Paste Plus provides stability of ΔE results at 6 months' follow-up.

Introduction

Dental fluorosis is a chronic condition of hypomineralization, where enamel development is disturbed by high levels of fluoride particularly at maturation stage that gives rise to a specific esthetic disturbance [1]. Mild cases of dental fluorosis are characterized by a white opaque appearance of the enamel, caused by increased subsurface porosity. The earliest sign is a change in color, showing many thin white horizontal lines running across the surfaces of the teeth. While in moderate fluorosis, the entire tooth can be chalky white and lose transparency [2]. Enamel fluorosis incidence has increased in the past two decades in conjunction with the worldwide decline of caries [3]. This can be explained by excessive ingestion of fluoride from drinking water, infants' formulas or in the form of topical fluoride supplements of toothpastes, mouth rinses, gels, and varnishes [4].

The treatment options available to improve esthetics are based on fluorosis severity, non-invasive and minimal-invasive treatments of bleaching, micro-abrasion, remineralization technology as: Casein phosphopeptide amorphous calcium phosphate (CPP-ACP) and combination between them can be used for mild to moderate fluorosis [5]. Bleaching is an effective treatment in removing stains and management of mild fluorosis that requires repeated visits to achieve the optimum esthetic improvement. Microabrasion removes opacities in superficial enamel layer of 100−200 micron through abrasion-erosion procedure, but unfortunately resulted in exposing more of yellowish color of underlying dentin. Both techniques are effective in very mild and mild fluorosis [6].

Moderate opacities can be treated with combination of microabrasion and bleaching especially when the patient cannot come to multiple visits. Whereas

microabrasion removes superficial enamel stains, bleaching provides more homogenous and whiter shades. This technique is effective in deep opacities where esthetic improvement cannot be achieved with one of these treatments alone. Remineralization particularly with CPP-ACP decreases tooth sensitivity and the risk of stain absorption and esthetic relapse after microabrasion or bleaching procedure [7].

There was a lack of controlled, randomized, and longitudinal clinical trials comparing the efficacy of these treatments [4], [8]. Therefore, this study was carried out to evaluate the clinical performance of different minimal invasive treatment modalities and combination between them in esthetic improvement of mild to moderate fluorosed teeth. The null hypothesis was that there is no significant difference in color change between different treatment protocols used for treatment of mild-moderate fluorosis.

Materials and Methods

Patients and study design

Only patients of age range 20−35 years having at least 8 fluorosed teeth free of caries or restorations with good oral hygiene were involved in this study. This study excluded patients having a history of hypersensitive teeth, allergies to tooth whitening treatments, pregnant or breastfeeding women, smoking habits, and present or recent bleaching product use. 160 fluorosed teeth in total (maxillary and mandibular incisors, canines, and premolars) were selected. Before enrolling in the study, each patient received and signed an informed written agreement that detailed the study idea and the role played by each patient. The study was carried out after approval of faculty Research Ethics Committee (approval number #202/2019). The study was a randomized controlled clinical trial that followed The Consort Statement's standards (http://www.consort-statement.org/consort-statement/) and registered on https://clinicaltrials.gov/ (NCT05204277).

160 fluorosed teeth were randomly allocated into eight groups of 20 teeth each (seven intervention groups and one control group). The creation of a random sequence was completed through web page (http:/www.randomization.com/) using block randomization method. Using sequentially numbered opaque sealed envelopes (SNOSE), ensured the concealment of allocations.

Sample size calculation

Sample size was calculated according to G*Power software version 3.1.9.2. It was found that a minimum sample size of 136 would be sufficient to detect the effect size of 0.18, a power (1-β = 0.95) of 95% at a significance probability level of $p < 0.05$ partial eta squared of 0.032. A total sample size of 160 samples would be applied. Each group would be represented by 20 samples [9], [10].

Interventions

Before the interventions oral prophylaxis was carried out for each participant using ultrasonic scaler followed by polishing with abrasive discs and pumice. Tooth color coordinates were clinically recorded using Vita EasyShade V based on the color system of the Commission International de l'Luminism (CIE Lab). Subsequent to baseline records, Participants with mild to severe fluorosis (TFI 1-4) were assigned to one of eight treatment procedures, each consisting of twenty teeth, at random (n = 20) Table 1. All treatment modalities were carried out in a single treatment session.

Table 1: Variables of the study and levels of investigation

Variable	Level	Referred to
Treatment protocol (P)	P_1	In-office bleaching
	P_2	Micoabrasion
	P_3	Remineralization
	P_4	Microabrasion+in-office bleaching
	P_5	In-office bleaching+remineralization
	P_6	Microabrasion+remineralization
	P_7	Microabrasion+in-office bleaching+remineralization
	P_8	No treatment (control)
Time (T)	T_0	Baseline
	T_1	Immediate after application
	T_2	After 14 days
	T_3	After t3 months
	T_4	After 6 months

In-office bleaching procedure

To prevent the exposed lip surfaces from harm caused by hydrogen peroxide, cheek retractors were positioned and petroleum gel was applied before the application of the in-office bleaching [6]. A 4-6 mm high and 1.5−1 mm thick coating of gingival protector gel (OpalDamTM, Ultradent Products, Inc., South Jordan, UT, USA) was applied along the gingival margin, overhanging approximately 0.5 mm onto the cervical section of enamel. Using a scanning motion, it was light-cured for 20 s per arch. Attach both syringes for mixing, 0.5−1 mm thick layer of 40% hydrogen peroxide gel (Opalescence™ boost™ PF 40%, Ultradent Products, Inc., South Jordan, UT, USA) was applied on the labial surfaces of the teeth. The gel was removed using a suction tip after 20 min [11]. A total of three applications were performed with a total time of 60 min in a single visit. At the end of bleaching procedure, using a large amount of water, the teeth were rinsed and cleansed and the gingival barrier was removed by a probe. Teeth were polished with abrasive discs and potassium nitrate desensitizing gel (UltraEZ™, Ultradent products, Inc., South Jordan, UT, USA) was applied for 5 min. For the following 24 h after treatment, the patient was instructed to avoid any food or drinks that would leave a stain on a white shirt.

Enamel microabrasion procedure

Before starting microabrasion, the mucosa was coated with petroleum gel, teeth were isolated with a rubber dam, and floss ligatures were applied around each tooth to displace the rubber dam apically and improve access. An approximately 1 mm thick layer to an approximately 3 × 3 mm of 6.6% hydrochloric slurry with silicon carbide microparticles (Opalustre™, Ultradent Products, Inc., South Jordan, UT, USA) was implemented on the labial surfaces of fluorosed teeth. With rubber prophycups (Opalcups™, Ultradent Products, Inc.) attached to gear-reduction contra-angel handpiece, these surfaces were microabraded with slight pressure for 20 s by the same operator. Teeth were washed with water spray after each treatment and examined for progress. During the same session, this step was repeated up to 5 times for mild/moderate lesions until there was no additional improvement between two successive applications. Potassium nitrate gel (UltraEZ™, Ultradent products, Inc., South Jordan, UT, USA) was applied for 5 min [12]. For the following 24 h after treatment, the patient was instructed to avoid any food or drinks that would leave a stain on a white shirt.

Remineralization procedure

In protocols using remineralizing agent, home-application started at the same night after treatment session. Participants were instructed to apply crème of Casein phosphopeptide amorphous calcium fluoride phosphate (MI-Paste Plus®, GC America Inc., USA) on labial surfaces of fluorosed teeth for 4 weeks. They were asked to apply a pea-sized amount to the teeth using cotton swap or clean finger and left undisturbed for 5 min at night and after brushing their teeth. After using the paste, the participants were instructed to spit, not swallow, or rinse their teeth [13].

Color change evaluation (∆E)

For standardization, all the measurements were taken in the same environment close to a non-tinted window between 10.00 am and 2.00 pm for daylight. Before measurements, the labial surfaces of teeth were polished with polishing brushes and paste then rinsed with water. The color measurement was carried out 3 consecutive times with the same evaluator. The collected values were transformed to the manufacturer's equivalent L, a, and b values at each time, and the average of three readings was taken [14]. All teeth were clinically evaluated before application of treatment as baseline readings. Subsequently, Teeth were assessed immediately after treatment (T1), 14 days later (T2), 3 months later (T3), and 6 months later (T4). Color change was calculated from the formula $\Delta E=\sqrt{(\Delta L)^2+(\Delta a)^2+(\Delta b)^2}$, where ∆L (change in tooth lightness), ∆a (change in redness and greenness), and ∆b (change in yellowness and blueness) were the difference between readings mean values at different evaluating times from the baseline readings [15].

Statistical analysis

Using Microsoft Excel 2016, data were collected, checked, edited, and organized in tables and figures. Data were checked for normality using Kolmogorov-Smirnov at 0.05. Two-way ANOVA was applied to test the interaction between different variables. ANOVA repeated measures were followed by Duncan multiple range tests (DMRTs) to compare between groups.

Results

The ∆E values of different treatment protocols (P_1-P_8) and different time points (T_1-T_4) were evaluated by a two-way ANOVA Table 2. It revealed that protocols and time induced highly significant changes in ∆E, and the interaction between protocols (P_1-P_8) and time (T_1-T_4) were highly significant ($p \leq 0.001$***). Differences were assessed using one-way ANOVA. Data represented as mean ± SD standard deviation Figure 1.

Table 2: The∆E mean values of different treatment protocols (P_1-P_8) at different time points (T_1-T_4)

Protocol	Time				
	ΔE_1	ΔE_2	ΔE_3	ΔE_4	Significant
P_1	$4.77^{C4} \pm 0.82$	$8.18^{C3} \pm 0.51$	$13.51^{CD1} \pm 0.69$	$11.04^{C2} \pm 0.55$	≤ 0.001***
P_2	$4.23^{C2} \pm 0.52$	$5.88^{C2} \pm 0.46$	$6.88^{E1} \pm 0.62$	$6.44^{D1} \pm 0.73$	≤ 0.001***
P_3	$3.68^{C3} \pm 0.50$	$10.72^{B1} \pm 0.83$	$15.91^{C1} \pm 0.83$	$8.15^{D2} \pm 1.04$	≤ 0.001***
P_4	$8.28^{B3} \pm 0.82$	$15.52^{A2} \pm 1.45$	$25.02^{A1} \pm 1.42$	$22.39^{A1} \pm 1.56$	≤ 0.001***
P_5	$4.17^{C2} \pm 0.43$	$6.96^{C2} \pm 0.42$	$14.55^{C1} \pm 0.96$	$13.90^{B1} \pm 0.79$	≤ 0.001***
P_6	$4.74^{C3} \pm 0.54$	$8.09^{C2} \pm 0.66$	$11.77^{D1} \pm 0.90$	$11.41^{BC1} \pm 0.63$	≤ 0.001***
P_7	$12.17^{A2} \pm 0.80$	$12.28^{B2} \pm 1.17$	$19.91^{B1} \pm 1.16$	$20.65^{A1} \pm 1.09$	≤ 0.001***
P_8	$0.86^{D4} \pm 0.10$	$2.21^{D3} \pm 0.13$	$4.86^{E1} \pm 0.19$	$3.73^{E2} \pm 0.25$	≤ 0.001***
Significant	≤0.001***	≤0.001***	≤0.001***	≤0.001***	
∆E Source		Two-way ANOVA			
		df	*F*	Significant	
Corrected model		31	55.4	≤0.001***	
Protocol (P)		7	143.4	≤0.001***	
Time (T)		3	176.0	≤0.001***	
Protocols×time		21	8.8	≤0.001***	

*Significant at $p \leq 0.05$; **.***Highly significant at $p \leq 0.010, 0.001$, nonsignificant at $p > 0.05$. Means followed by different letters within the same column (vertically) are significantly different. However, means followed by different numbers within the same row (horizontal) are significantly different according to Tukey's HSD at 0.05. HSD: Honest significant difference.

In accordance to time

All treatment protocols showed significant color change over control group that can be recognized by unexperienced eye (∆E≥3.7).

Immediately after application (T1)

The highest ∆E mean values were recorded in P7 followed by P4 with no significant difference between other treatment protocols.

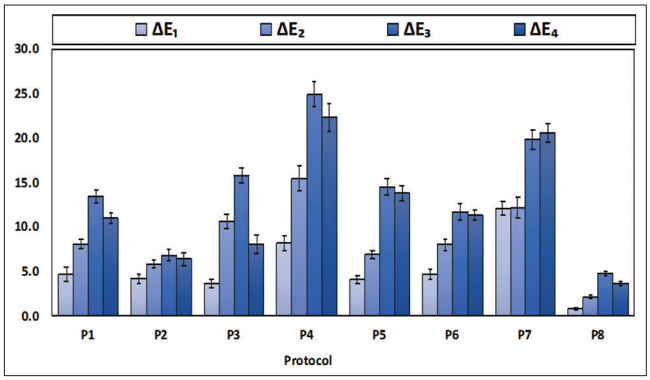

Figure 1: The ΔE mean values of different treatment protocols (P_1-P_8) at different time points (T_1-T_4). Differences were assessed using one-way ANOVA. Data represented as mean ± SD standard deviation, error bars represent the standard deviation

After 14 days (T2)

The highest ΔE mean values were recorded in P4 followed by P7 and P3 with no significant difference between P7 and P3. Non-significant difference was recorded between other treatment protocols.

After 3 months (T3)

The highest ΔE mean values were recorded in P4 followed by P7. The lowest ΔE mean values were recorded in P2 and P8 with no significant difference between them.

After 6 months (T4)

The highest ΔE mean values were recorded in P4 and P7 with no significant difference between them.

In accordance to protocol

The highest color change was recorded at 3 months (T_3) in all treatment protocols. These records were preserved at 6 months follow-up (T_4) for all treatment protocols except P_1 and P_3.

Protocol 1 bleaching (P1)

The highest ΔE mean values were recorded at T3 followed by T4 and T2. The lowest ΔE mean value was recorded at T1.

Protocol 2 microabrasion (P2)

The highest ΔE mean values were recorded at T3 and T4 with no significant difference between them and the lowest Δno significant difference between them with no significant difference between them.

Protocol 3 remineralization (P3)

The highest ΔE mean values were recorded at T3 and T2 with no significant difference between them. The lowest ΔE mean value was recorded at T1.

Protocol 4 microabrasion and bleaching (P4)

The highest ΔE mean values were recorded at T3 and T4 with no significant difference between them. The lowest ΔE mean value was recorded at T1.

Protocol 5 bleaching and remineralization (P5)

The highest ΔE mean values were recorded at T3 and T4 with no significant difference between them. The lowest ΔE mean values were recorded at T2 and T1 with no significant difference between them.

Protocol 6 microabrasion and remineralization (P6)

The highest ΔE mean values were recorded at T3, T4 with no significant difference between them. The lowest ΔE mean value was recorded at T1.

Protocol 7 microabrasion, bleaching and remineralization (P7)

The highest ΔE mean values were recorded at T4 and T3 with no significant difference between them. The lowest ΔE mean values were recorded at T2 and T1 with no significant difference between them.

Protocol 8 control (P8)

The highest ΔE mean values were recorded at T3 followed by T4. The lowest ΔE mean values were recorded at T2 and T1.

Discussion

Dental fluorosis is an esthetic condition in which enamel formation has been disrupted, resulting in hypomineralized enamel. The treatment options for improving aesthetics are determined by the severity of the condition. Non-invasive and minimal-invasive treatments are used for mild to moderate cases [6].

In-office bleaching oxidize transparent organic matrix of enamel into an opaque whiter material camouflaging opaque white areas or lines of fluorosis [16]. Enamel microabrasion by chemical and mechanical abrasion slurry removes the outer 25−200 μ of surface enamel depending on number

of applications, time of application and pressure [17]. Remineralization by CPP-ACFP precipitates newly formed crystals in enamel subsurface porosities and regenerates homogenous, thick, uniform surface layer that is more acid-resistant [13].

Color change in treatment protocol of CPP-ACFP only reached its maximum after 3 months, this may be elucidated by the supersaturated levels of bioavailable calcium, phosphate, and fluoride ions close to tooth surface that promotes remineralization process at acid attacks (pH ≤ 5.5), besides the supersaturated supragingival plaque with these minerals increased light reflection of enamel [18]. While 6 months' follow-up records showed relapse in ΔE, this may be due to the limited diffusion of CPP-ACFP through the hypermineralized superficial layer of fluorosed enamel without the aid of microabrasion or acid etching [19], [20].

The highest Δ**E** of in-office bleaching protocol was recorded at 3 months this may be clarified by oxidizing organic matrix that causes degradation of chromophores and blocking underlying dentin through opaque white enamel matrix [5], [21]. Relapse in Δ**E** after 6 months may be explained by stains resulting from increased irregularities and surface roughness following in-office bleaching and the limited ability of natural saliva to restore surface integrity [22]. Color stability at 6 months follow-up was noted on combining of CPP-ACFP after in-office bleaching with no adverse effect on bleaching efficiency. This may be explained by higher acid resistance, homogeneity, and smoothness of enamel surface layer formed by CPP-ACFP in comparison to surface layer formed by natural saliva [18], [22].

Enamel microabrasion effect on Δ**E** reached its maximum after 3 months with stability in the results at 6 months follow-up. This effect may result from removal of the 25−200 μ superficial layer of fluorosed enamel containing stains, surface irregularities and formation of a highly polished, smooth prismless enamel through surface remineralization by natural saliva that caused a slight detectable Δ**E** in comparison to other protocols [17]. Color change was enhanced in combined protocol of microabrasion and CPP-ACFP through the higher diffusion of CPP-ACFP into deeper enamel layers after microabrasion and the superiority of CPP-ACFP over natural saliva in remineralization of subsurface porosities and precipitation of more homogenous, thicker compact prismless surface layer compensating loss in enamel thickness after microabrasion [13], [18].

The highest Δ**E** of all treatment protocols was recorded in combining of microabrasion and in-office bleaching regardless of using CPP-ACFP. This may be explained by the action of microabrasion on removing superficial enamel increasing its permeability allowing diffusion of bleaching agent into deeper layers of enamel porosities enhancing bleaching effect. This allows either natural saliva or CPP-ACFP to remineralize deeper layers of enamel through removal of superficial fluoride-rich layer through microabrasion and oxidizing of organic matrix by bleaching that allowed continuous diffusion of mineral ions down concentration gradient for remineralization of larger thickness of enamel porosities [16]. Thus, the resultant enamel was more acid resistant to demineralization cycles in oral environment prohibiting relapse in tooth color [19].

Conclusion

Under the limitations of the current study, the following could be concluded:

1. The combined treatment protocol of Opalustre™ and Opalescence™ boost™ PF 40% has the highest effect on Δ**E** in treating mild to moderate fluorosed teeth regardless of using MI-Paste Plus®.
2. MI-Paste Plus® provides stability of Δ**E** and patient satisfaction results at 6 months' follow-up.

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