Comparative evaluation of esthetic changes in nonpitted fluorosis stains when treated with resin infiltration, in-office bleaching, and combination therapies

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Abstract

Objectives: Dental fluorosis leads to esthetic deviation and varies from nonpitted white opacities, dark brown stains to pitting or structural breakdown of enamel surface. Treatment for fluorosis depends on the severity of condition and includes both noninvasive methods and invasive methods. Recently resin infiltration has been proposed as an alternative treatment for nonpitted fluorosis. This study was done to evaluate the esthetic changes in nonpitted fluorosis stains when treated with resin infiltration, in-office bleaching and combination therapies.

Materials and methods: The present study is a randomized, single blinded controlled trial with four parallel arms with 1:1 allocation ratio. The intervention arms included bleaching with 35% hydrogen peroxide, resin infiltration, resin infiltration with increased infiltration time and a combination approach of bleaching and infiltration. Immediate esthetic changes were evaluated for two parameters including, ‘Change in esthetics’ and ‘Improvement in opacities/stains’ using a VAS scale by two independent observers. Kruskal-Wallis test and Mann-Whitney U-test were done for intergroup comparisons.

Results: Best results for both the parameters were observed among patients treated with resin infiltration with increased infiltration time. Mann-Whitney U test revealed significantly better results for resin infiltration groups (alone or combination with bleaching) as compared to bleaching alone (P < .001).

Conclusions: Resin infiltration procedure with tailored etching times and increased infiltration time exhibited best results in terms of change in esthetics and improvement in stains.

Clinical significance

White and brown opacities due to fluorosis have always been a concern for esthetics. In our study, resin infiltration technique with tailored etching times and increased infiltration time exhibited best immediate esthetic improvement for nonpitted fluorotic opacities and stains. These esthetic outcomes reaffirm the applicability of RI technique for nonpitted fluorosis, which was originally advocated only for white spot lesions due to early caries. This will in turn help the dentists to plan the esthetic management of nonpitted fluorosis in a micro-invasive manner.

1 | INTRODUCTION

Fluoride plays a key role in the prevention and control of dental caries; however, if the total amount of ingested fluoride exceeds the optimal limits, it results in dental fluorosis. Histologically, fluorosis is
characterized by relatively well mineralized outer surface layer, beneath which a diffused hypomineralization or porosity in subsurface enamel is seen while clinically it leads to esthetic deviations depending on the severity of fluorosis.\textsuperscript{2,3}

The clinical presentations for mild fluorosis are seen as narrow white lines following the parenchymata, cuspal snow capping and a snow flaking appearance that lack a clear border with the unaffected enamel\textsuperscript{4} while in severe fluorosis, there is yellow to dark brown staining, and the most severe cases shows pitting of the surfaces due to extrinsic mechanical breakdown.\textsuperscript{5,6}

In fact the classification systems used for fluorosis, including Dean’s fluorosis index and Thylstrup and Fejerskov index (TF index), are based on grading the severity of fluorosis and use esthetic deviation as a parameter for classifying fluorosis.\textsuperscript{7–9}

The treatment options available to improve the esthetics affected by fluorosis are also based on the severity of fluorosis.\textsuperscript{10,11} In reference to TF index, various treatment options include noninvasive and minimal-invasive methods for TF scores 1–4 while invasive methods for pitted fluorosis with TF scores ≥5.\textsuperscript{12}

Noninvasive methods include removing the surface stained areas through teeth bleaching, using micro-abrasion techniques, combination approaches, using ACP-CPP technology while invasive approaches include using veneers, laminates or crowns.\textsuperscript{11,12,14} These techniques have shown varying degrees of success and have been used with different protocols. Among the noninvasive methods, bleaching with H\textsubscript{2}O\textsubscript{2}, or carbamide peroxide has been considered the least invasive approach and has been successfully used in children and adolescents.\textsuperscript{15}

In addition to these, recently resin infiltration, a technique originally advocated for arresting early caries and for esthetic management of white opacities associated with early caries, have also been reported to treat fluorosis stains.\textsuperscript{16–18} The rationale for using RI in fluorosis stains is that, these lesions mimic white spot demineralization since they also involve subsurface hypomineralization under a relatively well-mineralized surface which can be infiltrated.\textsuperscript{16,19}

All the published case reports published so far have reported ‘good’ to ‘excellent’ esthetics changes with RI in mild to moderate fluorosis stains, however to the best of our knowledge no randomized controlled trial has been conducted comparing the esthetic improvements as achieved by RI with bleaching, the most conventional procedure.

With this background the present study was conducted with the null hypothesis that there is no difference in the esthetic improvement when treating nonpitted fluorosis with resin infiltration, in-office bleaching and their combination approaches.

2 | METHOD
2.1 | Study design
The present study is a randomized, single blinded controlled trial with four parallel arms with 1:1 allocation ratio. The four interventions included; in-office bleaching with 35% H\textsubscript{2}O\textsubscript{2} (B), resin infiltration (RI), resin infiltration with double application of infiltrant (2RI) and lastly in-office bleaching followed by resin infiltration (B + RI). This trial was conducted at a single centre in a fluoride endemic area in Northern India (Faridkot district, Punjab).\textsuperscript{20} The study was registered at Clinical-Trials.gov (NCT01733888; registration date: 11/14/2012). The present report is a subset of data obtained from this registered trial.

2.2 | Participants
Children in the age range of 6–12 years were randomly selected from different public and private schools of Faridkot district. Initially, the children were screened for white opacities in the anterior teeth which were classified as ‘fluoride’ and ‘Nonfluoride’ opacities according to Russell’s criteria.\textsuperscript{21} Anterior teeth, including central and lateral incisors were included in the screening process. The participants with fluorosis were further classified for severity of fluorosis as per Thylstrup-Fejerskov Index, and those with T-F score 1–4 (nonpitted) were included in the study. In fluorosis, usually more than one tooth is involved; in such cases the anterior tooth which was most severely affected as judged clinically and also exhibiting maximum TF score was finally included. The selection of the tooth was done before the randomization. The selected tooth and the baseline TF scores were finally recorded in the clinical record form for future reference.

Children with nonfluoride opacities (as per Russell’s criteria), pitted fluorosis (TF score more than 4), history of allergy towards any dental material, tooth fracture, teeth with direct or indirect restorations, with any systemic and local conditions not permitting the intervention, or with history of treatment for dental fluorosis were excluded from the study.

After screening, parents of the eligible children were informed about the study in detail explaining them about treatment options and the risks associated in vernacular language. Informed written consent was sought from the parents after explaining them about the procedure and the risks associated. Assent was also taken from the children participating in the study. After recording the baseline characteristics the children were randomly allocated in four different groups using block randomization. The random sequence generation was done using the website http://www.randomizer.org. The allocation concealment was ensured by using the sealed envelopes, made by an independent person prior to the start of the study. The sequence generation table was kept sealed and secured till the end of the study. The participants were allocated to different treatment groups by independent personnel, not involved in the sequence generation.

Before the start of the procedure all the included subjects were made to brush their teeth by a dental professional. Following that, standardized preoperative photograph was taken using the Nikon D 3000 camera. All the photographs were taken by a professional photographer in natural light conditions from a fixed distance.

The first arm of the study consisted of in-office bleaching with 35% hydrogen peroxide. In-office bleaching was carried out using the Pola Office bleaching kit [SDI-Australia], which is a powder-liquid system with 35% hydrogen peroxide as the active ingredient. Treatment was performed as per manufacturer’s instructions. Cheek retractors were placed and the exposed lip surfaces were covered with petroleum gel to protect from injury due to hydrogen peroxide. The tooth
involved in the study was then isolated using the rubber dam which provided a clean and dry field and also protected the gum tissues. The powder-liquid was mixed until gel was homogeneous and a thick layer was applied on the teeth using the applicator tip. The gel was left on the teeth for 8 minutes. Thereafter the gel was suctioned off using a surgical aspirator tip and the tooth surface was washed off with water and the gingival barrier was removed by lifting it at one end.

In the second arm, the fluoresced teeth were treated with resin infiltration. Resin infiltration was done using the commercially available resin infiltration kit (ICON (DMG, Germany)). The ICON kit contains 3 syringes, that is, 15% hydrochloric acid gel (ICON Etch), ethanol-drying agent (ICON Dry), and resin infiltrant (ICON Infiltrant).

As per the manufacturer instructions, rubber dam was initially applied to achieve clean and dry working conditions and to protect the soft tissues followed by resin infiltration procedure. First step included the application of 15% HCl gel (ICON Etch) for 2 min. The etchant gel was applied using the special applicator tip provided in the kit. Subsequently, the etching gel was washed away with water spray for 30 seconds. This was followed by the application of ethanol (ICON Dry). The tooth was then checked for improvement in opacity and if the homogeneity in shade was not seen; etching was repeated. Etching was repeated for maximum of three times. Last step involved the application of low viscosity resin infiltrant (ICON Infiltrant), which was also applied with the special applicator tip and was then left for 3 min to allow its penetration deep into the lesion. After 3 min, the excess resin on the tooth surface was wiped away with cotton rolls and dental floss and finally light cure polymerization for 40 seconds was done. The infiltrant was again applied for 1 more minute followed by light cure polymerization for 40 s. This is done to fill up the superficial enamel porosities.

In Group III, the intended teeth were again treated with resin infiltration as in Group II, however additional application of the infiltrant was done for 3 min.

For the fourth arm, in-office bleaching using 35% hydrogen peroxide was done at the initial visit (as explained for Group I) and after a period of 20 days resin infiltration was done (as in Group III) and postoperative photographs were taken.

2.3 | Evaluation

In all the four groups, immediately after the procedure standardized photographs were again taken under the same lighting conditions. As explained earlier, both the preoperative and postoperative images for all the participants were taken by the same personnel, trained in dental photography and were saved in computer as .jpg files (Figures 1–4, preoperative and postoperative). All the teeth depicted in photographs from four different groups exhibited a pre-operative score of 3 on TF index. The photographs were later assessed for esthetic changes (EC) achieved and improvement in white/brown opacities/stains (SC) by
two independent observers. Both EC and SC were assessed using a Visual Assessment Scale (VAS) and a score ranging from 1 to 7 was given (Table 1). To ensure blinding of the outcome evaluators (initials), the preoperative and postoperative images were stored with a unique ID and the evaluators were not disclosed about the participant’s treatment group. Cohen’s Kappa statistics were calculated for intraexaminer and interexaminer reliability.

Data was entered into the MS Excel 2010. SPSS software 11.0 was used for all the statistical calculations. The data could not be assumed to follow a normal distribution. Hence, nonparametric tests were used for evaluating statistical inferences. Kruskal-Wallis test was used to detect differences in the groups for both the parameters (EC and SC) while the Mann-Whitney U test was used for binary comparisons between each of the groups for both the parameters individually. The P values ≤ .05 were accepted as statistically significant.

3 | RESULTS

The sample size calculations were based on the basis of our pilot study. As per power analysis, a total of 16 patients were required in each group with expected mean difference of 3 and accepted alpha error of 95%, with power of 90%. However, a total of 80 teeth from 80 participants were selected for the purpose of the study. Figure 5 show the participants flow during the trial and final figures used for analysis.

The mean of the baseline TF for different groups were recorded to be 2.15, 1.90, 1.80, and 2.20 and exhibited a nonsignificant difference (P = .078). Cohen’s Kappa statistics calculated for intra-examiner and inter-examiner reliability was recorded to be 0.78 and 0.76 respectively. Best results for both the parameters, that is, ‘Change in esthetics’ (EC) and ‘Improvement in white/brown opacities/stains’ (SC) was observed in Group III which included resin infiltration with double application of infiltrant. The mean scores and their standard deviation for both parameters, EC and SC, are given in Table 2. Kruskal-Wallis test showed highly significant difference (P < .001, Table 2) for inter-group comparisons between the four intervention groups.
Further, when binary comparisons were done, Mann-Whitney U test revealed significantly better results for 2RI, RI, or RI in combination with bleaching as compared to bleaching alone while nonsignificant differences were seen for both the evaluation parameters when RI was compared 2RI or with RI + B (Table 3).

4 | DISCUSSION

Conditions that cause staining of teeth, including dental fluorosis are known to affect facial esthetics. Some studies suggest that the mildest forms of fluorosis (TF score 1,2) may not be of much esthetic concerns...
for the patients\(^2^2\) while many others report that even in its mildest forms, fluorosis can lead to deviations in the esthetic appearance of teeth.\(^3,^2^3\)

Not only this, dental fluorosis has also been reported to affect the individuals psychosocially wherein such individuals report embarrassment to smile, have difficulties pursuing relationships, and lack self-esteem.\(^2^4,^2^5\) Hence the treatments should be able to provide appreciable change in the esthetics of the patients to help them regain their self-esteem.

Subjective evaluation parameters used in our study included scoring for "Change in esthetics" and "improvement in brown stains/opaque white areas" on a Visual Analog Scale. These VAS scales were adopted from similar studies done for evaluating the esthetic improvements in fluorosis patients.\(^2^6-^2^8\) Similar VAS scales have also been used by other researchers for fluorosis and other stain removal studies.\(^2^7,^2^8\)

Celik et al. reported that this scale can truly quantify the overall improvement in the appearance of the mottled surface and a quantitative evaluation of ΔE only on fluorotic area of the tooth may not be sufficient.\(^2^6\)

Color change studies usually do include evaluation of the long term stability of the results achieved, however immediate pleasing results are a must for both, instilling the confidence among the treating dentist and patients and also as these changes become the 'starting point' to evaluate the long term stability. Likewise, one of research papers has detailed on 'immediate esthetic changes in fluorosis' and have shown that many a times patients do get 'satisfied' with immediate esthetic changes itself without requesting for any further treatment.\(^2^9\) Moreover, one of the main intervention strategy used in this study was RI, which has already demonstrated its efficacy for bringing immediate esthetic changes for carious opacities with stable results on long term basis too and using RI for fluorosis is adding a new indication for this novel technique.\(^1^7,^3^0\) Hence, it was considered important to study the immediate esthetic changes initially.

This immediate change in esthetics was evaluated using preoperative and immediate postoperative photographs using above mentioned VAS scales. Outcome evaluators were blinded to avoid any bias during the scoring of esthetic changes.

Resin infiltration with recommended application strategy or with increased time of infiltrant application showed significantly better results than bleaching, for both the evaluation parameters, that is, change in esthetics and change in opacities/stains.

<table>
<thead>
<tr>
<th>Group comparisons</th>
<th>Change in esthetics</th>
<th>Improvement in stains/opacities</th>
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<tbody>
<tr>
<td>I vs. II</td>
<td>(P &lt; .001)</td>
<td>(P &lt; .001)</td>
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<tr>
<td>I vs. III</td>
<td>(P &lt; .001)</td>
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<td>I vs. IV</td>
<td>(P &lt; .001)</td>
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<tr>
<td>II vs. III</td>
<td>(P = .838)</td>
<td>(P = .584)</td>
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<tr>
<td>II vs. IV</td>
<td>(P = .837)</td>
<td>(P = .378)</td>
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<tr>
<td>III vs. IV</td>
<td>(P = .612)</td>
<td>(P = .160)</td>
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The efficacy of resin infiltration in arresting caries and improving the esthetics of white spot lesions on facial surfaces has been proven in many studies including a systematic review.\(^3^0-^3^2\) Stains/opacities caused due to fluorosis are considered to mimic white spot lesions (WSLs), as histologically fluorosis is also a deep-seated hypomineralized porous lesion covered by a thick surface layer.\(^1^9\) Hence similar to any early caries lesions, the esthetic changes in fluorosis can also be attributed to the change in refractive index that occurs, after the resin infiltrates the porous body of the lesion causing the opaques to blend better with the tooth.\(^1^8\)

Further, increased etching time might also have contributed to better masking results of fluorosis stains. Recommended clinical procedure for resin infiltration includes acid etching with 15% HCl for 120 seconds. However these recommendations are for active early carious lesions while Munoz proposed that fluorosis stains simulates inactive lesions.\(^3^3\) It employs that unlike thin and porous surface layers as seen in active caries fluorosis stains exhibit 'hypomineralized' zone may be deep seated, hence more resistant to the infiltration procedure. Hence to ensure the erosion to the depth of hypomineralized zone and subsequent penetration of infiltrant till the deep hypomineralized zones, etching of the 'inactive' sound surface was repeated. This was done in accordance with Trilet et al. such that, after etching and application of drying agent, visual change in color was observed. Etching was repeated in case no change in the color was seen.\(^3^4\) The etching step was repeated for maximum of three times, depending on the clinical evaluation. This might have helped in deeper penetration of the infiltrant and subsequent better change in esthetics.

Kruskal-Wallis test was used to test the Null hypothesis. Inter-group comparisons were made for all the four interventions for both the parameters and as the \(P\) value for the statistical test was observed to \(< .001\) (\(df = 3, v = 41.994\)) we could reject the null hypothesis, thus concluding that there was significant difference in the esthetic improvement of nonpitted fluorosis when treated with resin infiltration, in-office bleaching and their combination approaches.

Further Mann-Whitney U-test was applied for binary comparisons. Better scores were seen among Group III participants, involving resin infiltration with double application of infiltrant, which differed nonsignificantly (\(P = 0.838\) for EC and \(P = 0.584\) for SC) than application of resin infiltration alone. In case of an early carious lesion, a 3 + 1 minute of infiltrant application has been recommended. Additional one minute application of infiltrant is done to minimize the superficial enamel porosities.\(^3^5\) However, as the porosities/hypomineralized zones are deep seated in case of fluorosis, infiltrant was applied for an additional time 3 min to ensure the ‘adequate’ filling of superficial porosities. Thus repeated etching and additional time of infiltrant application may have contributed to the best esthetic changes and masking of stains, due to the similarity in the refractive index of the infiltrant and sound tooth zones.

Least scores for both the parameters were recorded for bleaching group. Bleaching was done with 35% \(\text{H}_2\text{O}_2\). \(\text{H}_2\text{O}_2\) in bleaching gel has been reported to produce free radicals which diffuse through enamel and dentine, leading to breaking of the double bonds of pigment.
molecules which changes the pigment molecule configuration and/or size. Such changes alter the optical properties of tooth structure, creating the perception of a whiter tooth color.\(^{15}\)

Our findings are in accordance with Knoesel et al. who found that a single 1-hour session of in-office bleaching with 30% hydrogen peroxide does not significantly affect the color and luminosity of fluorotic teeth and these changes were found to be in accordance with the patients’ recorded self-perception scales.\(^ {26}\) Further Shanbhag et al. compared the effects of bleaching with 35% H\(_2\)O\(_2\) among different grades of fluorosis and found better immediate shade improvement in moderate fluorosis as compared to milder cases.\(^ {37}\) However, our inclusion criteria included all cases of mild to moderate fluorosis (TF scores 1–4), hence the overall results might have been lessesthetic.

Our findings were also in accordance to one of the recent case reports by Bertassoni et al. who had to proceed with micro-abrasion after bleaching, as bleaching procedure did not show full effectiveness.\(^ {28}\)

In-office bleaching with high H\(_2\)O\(_2\) concentrations can cause tissue burns upon contact,\(^ {15}\) however, no case of tissue burns was reported during our study.

The last approach used by us was a combination of bleaching and resin infiltration, with bleaching preceded by 20 days. This was in accordance with Trilet et al. who recommended that bleaching should precede erosion/infiltration, since the resin may not be permeable to bleaching agents.\(^ {24}\) This combination approach performed better than bleaching alone. This may be explained by the dehydration-rehydration effects of bleaching. Bleaching also lead to dehydration of enamel which results in accentuated temporary whitening, however such whitening effect dissipates after few days upon the rehydration of the enamel.\(^ {15}\)

RI application in rehydrated enamel might have mimicked infiltration of active carious lesion leading to deeper penetration of infiltrant, resulting in more homogenous change in esthetics as compared to bleaching alone.

The results can be generalized to mild to moderate fluorosis cases among children and adolescents, with caution as still more studies with both subjective and objective parameters are required. Moreover, studies to show the long term stability of the results obtained with resin infiltration and combination therapies are also needed.

One of the limitations of wide acceptance of RI procedure by the clinicians for fluorosis stains might be low predictability of the outcome. However, our study suggested that resin infiltration procedure, if done with tailored etching times, increased contact time of infiltrant exhibits best results in terms of change in esthetics and improvement in stains. The results were observed to be significantly better than in-office bleaching alone, while nonsignificant in comparison to resin infiltration and bleaching + RI strategies.

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**CONFLICT OF INTEREST**

The authors do not have any financial interests in the products used in this study.

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