Resin Infiltration for Esthetic Improvement of Mild to Moderate Non-pitted Fluorosis Stains in 6–12-year-old Children: A Randomized 6-month Interventional Study

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Abstract

Background: Dental fluorosis is the hypomineralization of tooth enamel due to excessive fluoride, resulting in opaque white areas or discoloration of teeth. The available treatment modalities to improve the esthetics affected due to fluorosis include non-invasive and invasive methods. Nowadays, a newer non-invasive treatment that is resin infiltration (RI) is gaining increasing popularity. The present study evaluated and compared the clinical success in esthetic improvement (EI) and changes in white/brown opacities/stains (SC) of RI on non-pitted fluorosis stains.

Materials and methods: A total of 18 patients in the age range of 6–12 years with the unesthetic appearance of upper anterior teeth due to non-pitted fluorosis were randomly selected and subjected to an RI procedure. Evaluation for EI and changes in white/brown opacities/stains (SC) was done on the visual analog scale (VAS).

Results: The results were statistically highly significant (p < 0.01) for the mean VAS score values of EI (p = 0.001) and SC (p = 0.001) between the follow-up time intervals with the highest values at time interval 6 months followed by 3 months, 1 month, and least at immediate postoperative. Furthermore, inter-grade comparison of fluorosis showed a highly significant difference (p < 0.01) for the VAS scores for both EI and SC with the highest mean VAS score values in a very mild degree of fluorosis, followed by mild and moderate degrees.

Conclusion: Resin infiltration is a promising procedure that demonstrated remarkably successful EI in mild to moderate non-pitted fluorosis with a stable long-term positive outcome.

Keywords: Esthetic improvement, Non-pitted fluorosis, Resin infiltration.

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Introduction

Fluoride has a vital role in the prevention of dental caries. However, if the total systemically ingested fluoride levels go beyond the optimal limits, dental fluorosis results.1

The treatment choices available for esthetic improvement (EI) of fluorosis teeth include non-invasive and invasive methods. Non-invasive modalities include removing the stained tooth surface by way of dental bleaching, microabrasion; while invasive options include restoring the discolored teeth with veneers, laminates or crowns. However, the extensiveness of the treatment procedures, reduction of tooth structure for esthetic correction and associated tooth sensitivity are the drawbacks associated with the conventional approaches. Nowadays, newer non-invasive treatment approaches have been advocated by various authors, especially resin infiltration (RI) for masking of mild to moderate fluorosis stains as conservatively as possible.2

Recently, RI technique, originally recommended for arresting initial caries and for EI of white spot lesions, has also been reported to manage fluorosis stains. It is a micro-invasive treatment of incipient caries confined to enamel without loss of healthy tooth structure. The principle of RI is to fill the incipient enamel pores with resin by capillary action which blocks further diffusion pathways for the bacteria by creating barriers and stops the lesion progression. Resin infiltration, with its near similar refractive index (RI = 1.46) to that of healthy enamel (RI = 1.62) creates a chameleon effect—a blend shading of the teeth lesions with the tooth surface.3,4

The present study was done to evaluate the EI of RI over mild to moderate non-pitted fluorosis stains in 6- to 12-year-old children on visual analog scale (VAS).

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presenting with non-pitted fluorosis seeking dental treatment and whose parents gave informed written consent for participation. Children with non-fluoride opacities and pitted fluorosis, history of known allergy toward any dental material, systemic illness (mental retardation/severe psychotic disorders), severe sensory and/or motor impairment and those unwilling for participation were excluded from the study.

The “fluoride” and “non-fluoridated” enamel opacities were differentiated following Russell’s criteria⁵ according to which all bilaterally symmetrical and diffuse opaque areas of enamel are fluorosis. The baseline standardization of dental fluorosis condition was done as per Dean’s Fluorosis Index (DFI)–Modified Criteria (1942)⁶ according to which participants were classified for severity of fluorosis. The participants with DFI score of 0.5, 1, 2, 3 (non-pitted fluorosis) were taken in the study. Since fluorosis usually affects more than one tooth in the dentition, in such cases the most severely affected anterior tooth with maximum DFI score was incorporated in the study.

Sample Size
As per 80% power analysis, 14 patients were needed for the study with expected mean difference of 1.3 and accepted alpha error of 5%. For estimated drop out, four subjects were added (25% drop out). Henceforth, a total of 18 subjects were incorporated in the study.

Clinical Procedure
Resin infiltration kit marketed under the trade name Icon was used for the treatment intervention as per manufacturer’s instructions (Fig. 1). Prior to the beginning of treatment procedure, all the participants underwent supervised teeth brushing. Subsequently, a standardized preoperative photograph was carried out.

The procedure consisted of the placement of a rubber dam to attain a clean and saliva-free working field (Fig. 2A). In the first step, 15% hydrochloric acid (HCl) gel was applied for 2 minutes using special applicator tip provided in the kit and stirred with a micro brush to achieve a uniform “etchy” pattern (Figs 2B and C). Next, the etching gel was rinsed away with spray of water for 30 seconds (Fig. 2D). In the second step, the enamel lesion was desiccated by application of 99% ethanol to remove the water retained in the microporosity of lesion body (Fig. 3A). This was followed by air-drying of the tooth surface (Fig. 3B). The last step comprised of application of low viscosity resin infiltrant which was left for 3 minutes to permit its deeper penetration into the lesion (Figs 3C and D). After 3 minutes, the excess resin on the tooth surface was removed with cotton rolls. It was then followed by light cure polymerization of the resin for 40 seconds (Figs 3E and F). Moreover, a second layer of infiltrant was applied and cured for additional 1 minute (Figs 4A and B). This was followed by polishing the enamel surface (Fig. 4C).

Follow-up of the Study Participants
In all the participants, preoperative, immediate postoperative, and after 1, 3, and 6 months postoperative standardized photographs were taken by the operator using Canon IXUS 185 digital camera in fixed light conditions from a set distance (Figs 5 and 6). All photographs were stored in a computer and evaluated later for EI and changes in white or brown opacities and/or stains (SC) by two independent observers for each subject using a VAS ranging from 1 to 7 (Table 1). Cohen’s kappa statistics for inter examiner reliability was calculated to be 0.78 indicating substantial agreement.

Statistical Analysis
The data collected were entered in Microsoft Office Excel to prepare a master chart. Data were put through statistical analysis using the Statistical Package for Social Sciences (SPSS v 21.0, IBM). Repeated measures ANOVA test was applied at different follow-up intervals for both the evaluation parameters EI and SC. Pairwise comparison was done using the Scheffe post hoc test for both EI and SC at follow-up time intervals. Moreover, an unpaired student t-test was used for inter-grade comparison of fluorosis for both EI and SC. For all the statistical tests, p ≤ 0.05 was considered to be statistically significant.

Results
The results showed that a highly significant difference (p < 0.01) was seen statistically for values of EI (p = 0.001) and changes in white/brownish opacities/stains (SC) (p = 0.001) between the follow-up time intervals with higher mean VAS score values at time interval 6 months followed by 3 months, 1 month, and least at immediate postoperative (Table 2).

Pairwise comparison for EI at follow-up intervals revealed highly significant difference statistically (p < 0.01) for values of EI after RI procedure between immediate vs 3 months postoperative (p = 0.001), immediate vs 6 months postoperative (p = 0.001), and 1 month vs 6 months postoperative (p = 0.002) (Table 3).

Similarly, pairwise comparison for SC showed a highly significant difference (p < 0.01) between immediate vs 3 months postoperative (p = 0.01) and immediate vs 6 months postoperative (p = 0.003) (Table 3).

Inter-grade comparison of fluorosis showed that there was a highly significant difference statistically (p < 0.01) for VAS score values after RI with higher mean VAS score values in a mild degree of fluorosis for both EI and SC (Table 4).

Fig. 1: Resin infiltration kit consisting of Icon etchant (15% hydrochloric acid), Icon dry (99% ethanol), and resin infiltrant (methacrylate-based resin matrix, initiators, and additives)
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**Discussion**

The RI technology was first introduced at the Charite Berlin and the University of Kiel as a micro-invasive method to inhibit demineralization in incipient proximal caries and mask white spot lesions on intact smooth surfaces. It is commercially available under the trade name Icon (introduced by company DMG, Germany). Resin infiltration works on the principle of perfusing the enamel pores with resin by capillary forces rendering the white spots negligible because the refractive index of porous enamel becomes nearly similar to that of healthy enamel (1.52). Recently, RI has also been described in the esthetic management of fluorosis stains. The rationale for using resin infiltrant in fluorosis spots is that these lesions imitate white spot demineralization since they already have hypomineralized enamel subsurface under a relatively well-mineralized area that can be easily penetrated by the resin.3,4

Subjective parameters for evaluation in our study were scoring for “esthetic improvement (EI)” and “changes in white/brown opacities/stains (SC)” on a VAS ranging from 1 (No improvement) to 7 (Exceptional improvement). VAS was adopted from similar studies done by Loguercio et al.7 and Price et al.6 and can truly measure the overall improvement in the appearance of the mottled tooth surface as stated by Celik et al.9

The results showed a highly significant difference statistically ($p < 0.01$) for mean VAS score values of EI and SC between the follow-up time intervals with highest values at time interval 6 months followed by 3 months, 1 month, and least at immediate postoperative. Our findings were in accordance with Auschill et al.,6 Cocco et al.,10 Owda and Sancakli,11 and Garg and Chavda12 who have reported long-term positive outcomes of RI. Improvement in esthetics by RI could be attributed to blending of enamel lesions with the surrounding sound enamel, based on changes in the refractive index.13

The infiltrant resin product used in the present study was based on triethylene glycol dimethacrylate (TEGDMA), a monomer with hydrophilic features, low viscosity, and a high penetration coefficient, which promotes rapid penetration of the resin into the enamel pores.14 Tooth surface mineralization is a prerequisite for the resin to penetrate the enamel, therefore etching was done via the application of 15% hydrochloric acid. Ethanol at 99% concentration was used to eliminate water from the pores, facilitating the penetration of resin.14 Two-time application of resin is recommended because in the first application the monomers convert to polymers causing contraction of the material and generation of spaces. These spaces must get filled with the second application of resin.15 In our study, EI was noted over the follow-up time span with best clinical results seen at 6 months time frame, possibly due to the absorption of water by resin over time, which was not completely removed by ethanol. As a result of this absorption, the optical interfaces in the light path are reduced, as mentioned by Attal et al.16 and Cocco et al.10 in their case reports. The polymerization of the last layer of resin is generally incomplete due to oxygen inhibition in the superficial layer.17 Hence, polishing of the enamel surface was done in the final step to removing the excess resin. Moreover, polishing helped to prevent future staining.

Furthermore, inter-grade comparison of fluorosis showed a highly significant difference ($p < 0.01$) for the VAS scores for both the parameters (EI and SC) with higher mean VAS score values in a mild degree of fluorosis followed by moderate degree. This
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Figs 3A to F: (A and B) Dehydration with 99% ethanol (Icon-Dry) for 30 seconds and air drying; (C and D) Application of low viscosity resin infiltrant (Icon infiltrate) for 3 minutes; (E) Light cure polymerization of resin infiltrant for 40 seconds; (F) Postoperative after first light cure

Figs 4A to C: (A and B) Second layer of resin infiltrant application for 1 minute followed by light cure polymerization for 40 seconds; (C) Postoperative after polishing of the enamel surface
difference could be attributed to the volume and depth of the subsurface pores that increase as the severity of dental fluorosis increases. Mild cases are characterized by white lines, following the perikymata of enamel, whereas in moderate cases the whole enamel surface may be white and opaque. The less the degree of fluorosis, the less porous is the enamel surface and better is the penetration of resin.

Resin infiltration is a micro-invasive treatment approach with several advantages. It erodes only 30–40 μm of enamel surface as part of etching procedure which thereby gets infiltrated with resin. This is in contrast with the treatment of microabrasion, composite fillings, veneers or crowns, which require a greater portion of the tooth structure to be removed. Second, the technique is a relatively quick and pain-free procedure to perform compared to other restorative options that may require local anesthetic and healing process. Third, it is a less expensive procedure than more invasive, tooth-destructive treatments. Furthermore, no need of special maintenance precautions and favorable esthetic results along with increased patient acceptance and compliance are other major advantages of RI technique.

LIMITATION
The follow-up time span of the study was 6 months. Longer durations of follow-up are necessary to evaluate the sustainability of the results based upon which the time of re-application can be established.

CONCLUSION
Resin infiltration showed significant improvement in esthetics and changes in opacities/stains on non-pitted fluorosis stains in 6–12-year-old children. Moreover, greater EI was observed in subjects with a mild degree of fluorosis over follow-up time intervals.
Figs 6A to D: Six-month follow-up of four study participants after resin infiltration procedure in tooth 21: (A) Case 1; (B) Case 2; (C) Case 3; (D) Case 4

Table 1: Visual analog scale (VAS) scores used for evaluating improvement in esthetics and improvement in white/brown opacities/stains

<table>
<thead>
<tr>
<th></th>
<th>No improvement</th>
<th>Slight</th>
<th>Moderate</th>
<th>Exceptional improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement in esthetics (EI)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Improvement in brown stains/change in white opacities (SC)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
### Table 2: Comparison of mean esthetic improvement (EI) and improvement in white/brownish opacities/stains (SC) scores over follow-up time intervals at immediate postoperative 1, 3, and 6 months

<table>
<thead>
<tr>
<th>Follow-up time</th>
<th>Study subjects (N)</th>
<th>No. of dropouts</th>
<th>Mean score of EI</th>
<th>Std. deviation</th>
<th>p value of RM ANOVA</th>
<th>Mean score of SC</th>
<th>Std. deviation</th>
<th>p value of RM ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>18</td>
<td>0</td>
<td>3.61</td>
<td>0.698</td>
<td>0.001</td>
<td>4.00</td>
<td>0.970</td>
<td>0.001</td>
</tr>
<tr>
<td>1 month</td>
<td>16</td>
<td>2</td>
<td>4.31</td>
<td>0.793</td>
<td></td>
<td>4.63</td>
<td>0.957</td>
<td></td>
</tr>
<tr>
<td>3 months</td>
<td>15</td>
<td>3</td>
<td>4.93</td>
<td>0.799</td>
<td></td>
<td>5.13</td>
<td>0.915</td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>15</td>
<td>3</td>
<td>5.40</td>
<td>0.632</td>
<td></td>
<td>5.27</td>
<td>0.799</td>
<td></td>
</tr>
</tbody>
</table>

There was a statistically highly significant difference (p < 0.01) seen for the values of EI and SC between the follow-up time intervals with higher mean VAS score values at time intervals 6 months followed by 3 months, 1 month and least at immediate postoperative. (p = 0.001)

### Table 3: Pairwise comparison using Scheffe post hoc test for esthetic improvement (EI) and for improvement in white/brownish opacities/stains (SC) at follow-up time intervals

<table>
<thead>
<tr>
<th>(I) Time</th>
<th>(J) Time</th>
<th>Mean difference (I–J)</th>
<th>Std. error</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For esthetic improvement (EI)</td>
<td>Immediate</td>
<td>1 month</td>
<td>−0.701</td>
<td>0.252</td>
</tr>
<tr>
<td></td>
<td>Immediate</td>
<td>3 months</td>
<td>−1.322</td>
<td>0.256</td>
</tr>
<tr>
<td></td>
<td>Immediate</td>
<td>6 months</td>
<td>−1.789</td>
<td>0.256</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>3 months</td>
<td>−0.621</td>
<td>0.263</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>6 months</td>
<td>−1.088</td>
<td>0.263</td>
</tr>
<tr>
<td></td>
<td>3 months</td>
<td>6 months</td>
<td>−0.467</td>
<td>0.268</td>
</tr>
<tr>
<td>For improvement in white/brownish opacities/stains (SC)</td>
<td>Immediate</td>
<td>1 month</td>
<td>−0.625</td>
<td>0.315</td>
</tr>
<tr>
<td></td>
<td>Immediate</td>
<td>3 months</td>
<td>−1.133</td>
<td>0.320</td>
</tr>
<tr>
<td></td>
<td>Immediate</td>
<td>6 months</td>
<td>−1.267</td>
<td>0.320</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>3 months</td>
<td>−0.508</td>
<td>0.329</td>
</tr>
<tr>
<td></td>
<td>1 month</td>
<td>6 months</td>
<td>−0.642</td>
<td>0.329</td>
</tr>
<tr>
<td></td>
<td>3 months</td>
<td>6 months</td>
<td>−0.133</td>
<td>0.335</td>
</tr>
</tbody>
</table>

There was a statistically highly significant difference (p < 0.01) seen for the values of
- EI between the time interval for RI between immediate vs 3 months postoperative (p = 0.001), immediate vs 6 months postoperative (p = 0.001) and 1 month vs 6 months postoperative (p = 0.002)
- SC between the time intervals for RI between immediate vs 3 months postoperative (p = 0.01) and immediate vs 6 months postoperative (p = 0.003)

### Table 4: Inter-grade comparison for esthetic improvement (EI) and improvement in white/brownish opacities/stains (SC) at 6 months follow-up

<table>
<thead>
<tr>
<th>Grade of fluorosis</th>
<th>Study subjects (N)</th>
<th>Mean VAS score</th>
<th>Std. deviation</th>
<th>T value of t test</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esthetic improvement (EI)</td>
<td>Mild</td>
<td>8</td>
<td>5.11</td>
<td>0.405</td>
<td>5.356</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>7</td>
<td>4.11</td>
<td>0.283</td>
<td></td>
</tr>
<tr>
<td>Improvement in white/brownish opacities/stains (SC)</td>
<td>Mild</td>
<td>8</td>
<td>5.50</td>
<td>0.250</td>
<td>6.683</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>7</td>
<td>4.14</td>
<td>0.476</td>
<td></td>
</tr>
</tbody>
</table>

There was a statistically highly significant difference (p < 0.01) seen for the VAS scores between the grades of fluorosis after resin infiltration treatment with higher mean VAS score values in mild fluorosis

**REFERENCES**

9. Celik EU, Yildiz G, Yازkan B. Clinical evaluation of enamel microabrasion for the aesthetic management of mild-to-severe
Resin Infiltration for Esthetic Improvement of Mild to Moderate Non-pitted Fluorosis Stains


