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Colour Stability of Non-Cavitated Labial Enamel Lesion Treated by Resin Infiltration Technique with and Without Remineralization in Permanent Anterior Teeth- A Clinical Study

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KEYWORDS

Resin infiltration, white spot lesions, fluorosis, hypoplasia, CPP-ACP, remineralization

ABSTRACT:

Background: White spot lesions (WSLs) from fluorosis, enamel hypoplasia, or early caries are common esthetic concerns in children. Resin infiltration is a minimally invasive option, but color stability may vary by lesion type. The adjunctive use of casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) could enhance outcomes, though evidence is limited.

Aim: To assess the 12-month color stability of non-cavitated WSLs of different etiologies treated with resin infiltration alone or with CPP-ACP.

Methods: A prospective randomized clinical trial was conducted on 90 anterior teeth from 25 children (7–13 years) with non-cavitated WSLs. Teeth were grouped by etiology (fluorosis, hypoplasia, caries) and subdivided into two subgroups (n=15 each): resin infiltration alone or resin infiltration with CPP-ACP. Spectrophotometric color change (ΔE) was recorded at baseline, immediately post-treatment, and at 1, 2, 6, and 12 months. Data were analyzed using ANOVA and Tukey's post hoc test.

Results: Only the hypoplastic group treated with resin infiltration alone showed significant color change over time (p=0.007). At six months, intergroup differences were significant (p=0.049), though post hoc analysis revealed no pairwise significance. Carious lesions treated with combination therapy demonstrated the most stable ΔE over 12 months. Fluorosed and hypoplastic lesions showed variable and less predictable outcomes.

Conclusion: Resin infiltration provides varying color stability across lesion types. Adjunctive CPP-ACP enhances outcomes in carious WSLs but has limited benefit for fluorosed and hypoplastic lesions. Lesion structure and resin penetration dynamics may influence long-term esthetic success.

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Introduction:

Dental caries is among the most common chronic diseases worldwide, with white spot lesions (WSLs) representing its earliest visible stage. These appear as chalky, opaque areas caused by subsurface mineral loss that alters enamel's refractive index. WSLs may also result from developmental conditions such as fluorosis, due to excessive fluoride intake during tooth formation, or hypoplasia, caused by enamel matrix defects.

Conventional treatments for WSLs—including fluoride therapy, casein phosphopeptide–amorphous calcium phosphate (CPP-ACP), microabrasion, and lasers—show variable success in restoring esthetics. Resin infiltration has emerged as a minimally invasive alternative, sealing enamel microporosities with low-viscosity resin to arrest progression and mask opacities.

Despite these benefits, the long-term color stability of resin infiltration remains uncertain, particularly in fluorosed and hypoplastic lesions where resin penetration may be limited. This study aimed to assess the 12-month color stability of non-cavitated WSLs treated with resin infiltration alone or in combination with CPP-ACP.

Materials and Methods:

This was a 12-month, prospective, randomized, controlled clinical study conducted in the Department of Pediatric and Preventive Dentistry. The study protocol was approved by the Institutional Ethical Committee. (MUHS/Dental/MUHS-006731/2019) Written informed consent was obtained from the parents or guardians of all participating children. A total of 90 teeth from 25 children aged 7–13 years with non-cavitated labial enamel white spot lesions (WSLs) in permanent maxillary anterior teeth were included in the study. Participants were randomly allocated into three major groups using the coin toss method, with further subdivision by alternate allocation as follows:

- Group 1: Fluorosed Teeth (n=30)
    - Group 1A: Resin infiltration only (n=15)
    - Group 1B: Resin infiltration followed by remineralization (n=15)
- Group 2: Non-Fluorotic Hypoplastic Teeth (n=30)
    - Group 2A: Resin infiltration only (n=15)
    - Group 2B: Resin infiltration followed by remineralization (n=15)
- Group 3: Carious White Spot Lesions (n=30)
    - Group 3A: Resin infiltration only (n=15)
    - Group 3B: Resin infiltration followed by remineralization (n=15)

A split-mouth design was used whenever possible.

Inclusion Criteria

- Children meeting the following criteria were included:
  Age between 7–13 years
- Presence of non-cavitated WSLs in permanent maxillary anterior teeth
  WSLs caused by dental fluorosis, enamel hypoplasia, or early caries
- Lesions that could be categorized using the Thylstrup-Fejerskov Index (TFI) for fluorosis, Developmental Defects of Enamel (DDE Index) for hypoplasia and Early ICDAS Criteria for carious WSLs

Exclusion Criteria

- Children having cavitated lesions
- Children with pulpal exposure of teeth
- Non-vital teeth
- Teeth with extrinsic stains
- Traumatized teeth
- Children with non-cooperative behaviour or special needs

Clinical Examination and Baseline Records:

All participants underwent a detailed medical and dental history evaluation, including:

- Water source history (current residence and place of birth)
- Duration of stay at birth location
- History of fluoride supplementation

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- Oral hygiene practices (technique, agent used, frequency of flossing)

Baseline intraoral photographs were taken using a Canon digital camera (EOS 500D, Tokyo, Japan) under standardized settings: shutter speed 1/200, F29, ISO 400, auto white balance.

Treatment Protocol:

Resin Infiltration Procedure

All resin infiltration procedures were performed using ICON (DMG, Hamburg, Germany). The steps included:

1. Rubber dam isolation to protect soft tissues and maintain a dry working field
2. Cleaning of the enamel surface with pumice
3. Etching with 15% hydrochloric acid (ICON Etch) for 2 minutes
4. Rinsing with water for 30 seconds and drying with ethanol (99%)
5. Resin infiltration application (ICON Resin Infiltrant) for 3 minutes, followed by:
    - Air dispersion
    - Light curing for 30 seconds
    - Polishing

For Group B (Resin Infiltration + Remineralization), an additional step was performed: CPP-ACP (GC Tooth Mousse, Tokyo, Japan) was applied for 3–4 minutes post-infiltration.

Outcome Assessment

Spectrophotometric Analysis

Color stability was evaluated using the VITA Easyshade spectrophotometer at baseline, 1-, 2-, 6- and 12- months.

The ΔE value (color difference) was calculated using the CIELAB color system, where:

✓ L* represents lightness (0 = black, 100 = white)

✓ a* represents red-green chromaticity

✓ b* represents yellow-blue chromaticity

The color change ΔE was determined using the following formula:

$$\Delta E = \sqrt{(L_o-L_r)^2+(a_o-a_r)^2+(b_o-b_r)^2}$$

where:

- L_o, a_o, b_o = Immediate postoperative values
- Lr, ar, br = Preoperative values

Statistical Analysis

All collected data were entered into SPSS (version XX, IBM, USA). Descriptive and inferential statistical analyses were performed:

- Mean ± Standard Deviation (SD) for continuous variables
- Chi-square test for categorical variables
- Independent t-test for intra-group comparisons
- One-way ANOVA for inter-group comparisons
- Post-hoc analysis (Tukey's HSD) for pairwise comparisons

A p-value < 0.05 was considered statistically significant.

Results:

Demographic and Clinical Characteristics

A total of 25 children (aged 7–13 years) with 90 teeth were included in the study. The distribution of participants across groups was balanced, with no significant differences in age, gender, fluoride exposure, and oral hygiene practices. The mean age of participants in all groups was X ± SD years, with an approximately equal male-to-female ratio. Fluoride exposure was comparable across all groups, with no significant difference in drinking water sources or fluoride supplementation history. Oral hygiene status was assessed using plaque, stain, and calculus indices, and no statistically significant variation was noted between groups ($p > 0.05$). Baseline WSL classifications varied, with fluorosed lesions assessed using the Thylstrup Fejerskov Index (TFI), hypoplastic lesions classified based on the Developmental Defects of Enamel (DDE) index, and carious WSLs recorded using the International Caries Detection and Assessment System (ICDAS).

Variability of colour change over time was shown by the average Delta E values and their matching standard deviations in several groups and time periods. The

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highest mean Delta E observed for Group 1A was immediately following operation (10.37 ± 4.96), which dropped progressively at one month (7.46 ± 7.78) and then stabilised at 12 months (7.94 ± 4.58). Starting mean Delta E of 8.05 ± 5.66, Group 1B showed the same trend; it dropped dramatically at one month (4.00 ± 3.28) then rose at 12 months (9.18 ± 4.59).In Group 2a, the mean Delta E was 10.79 ± 6.22 immediately post-operatively, reducing at one month (7.24 ± 5.89) and two months (7.43 ± 4.43), but rising again at six months (13.36 ± 6.62) and once more at twelve months (13.04 ± 5.64). From 8.85 ± 3.92 immediately post-operatively to 12.40 ± 5.6 at 12 months, Group 2B likewise showed a rising trend in mean Delta E values over time.

Group 3A also had a mean Delta E of 10.01 ± 8.05 immediately following the operation; it dropped but then rose to 12.49 ± 7.50 at six months and dropped somewhat to 11.79 ± 9.00 at twelve months. From 8.47 ± 6.65 at one month to 9.93 ± 7.62 at 12 months, Group 3B had consistently steady mean Delta E values all through the study period, with very little variation.

Comparisons inside groups of ΔE at different time intervals

Different trends between the groups of the study were shown by the intragroup comparisons of the colour change (ΔE) at several time intervals.

Reflecting a non-significant ANOVA outcome ($F = 0.542$, $p = 0.705$), Group 1A showed no statistically significant change in ΔE over the several time intervals. Indicating minor fluctuations in colour change throughout, mean ΔE ranged from 7.46 at one month to 10.37 at the immediate post-operative interval.

Likewise, Group 1B displayed no statistically significant variations in ΔE between the time intervals ($F = 2.325$, $p = 0.065$). Although the mean ΔE seemed to drop to 4.00 at one month and increase to 9.18 at twelve months, these variations were not statistically significant.

With $F = 3.858$, $p = 0.007$ Group 2A was the only group having a statistically significant change in ΔE over time. Mean ΔE stayed high at 12 months (Mean = 13.04) rising dramatically from 7.24 at 1 month to 13.36 at 6 months. Between 1 month and 6 months, Tukey post-hoc analysis found a mean difference = -6.12, $p = 0.04$; between 1 month and 2 months, it found a mean difference = -5.9, $p = 0.05$. These findings show in this population a clear rise in colour change after six months.

Though mean ΔE grew steadily from 8.85 post-op to 12.4 at 12 months, Group 2B found no appreciable statistical difference between time intervals ($F = 1.817$, $p = 0.135$).

Significant variations in ΔE between time intervals were not shown by Group 3A ($F = 1.784$, $p = 0.142$) nor Group 3B ($F = 0.977$, $p = 0.977$). Group 3A clearly showed a ΔE increase at 6 and 12 months, but this was not statistically significant.

Between-group comparisons of ΔE over varying time intervals

At each time interval, the intergroup study revealed the following:

The six groups' ΔE at Immediate Post-Op showed no appreciable variation; $F = 0.479$, $p = 0.791$, shows similar colour change just following the surgery between groups.

As before, there were no appreciable variations between the groups at 1 Month and 2 Month ($p = 0.557$ and $p = 0.758$, respectively), so supporting consistent behaviour of colour stability at these first times periods.

At 6 Months, the groups did, however, differ statistically significantly ($F = 2.339$, $p = 0.049$). Though there was a tendency of increased ΔE in Group 2A (Mean = 13.36) and Group 3A (Mean = 12.49) compared to Group 1A (Mean = 8.23) and Group 1B (Mean = 7.77, Tukey post-hoc analysis did not find any individual pairwise differences to be statistically significant. This would suggest that the within-group variability may have limited the significance of pairwise comparisons even if there were general group differences.

Though Group 2A and 2B still displayed higher ΔE values (13.04 and 12.4, respectively), which indicated a trend towards increased colour change, statistically non-significant at 12 Months; $F = 1.509$, $p = 0.196$.

Interpretation of Summary Notes

Generally, within-group analysis revealed that only Group 2A had appreciable ΔE with time—that is, a

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clear increase following six months—that reflects a long-lasting colour change in this group. Group differences were found by between-group analysis at six months; some groups, most notably 2A and 3A, showed higher ΔE values, reflecting more intense colour change; these group differences were not significant in pairwise comparisons. No statistically significant variations were found at other times, suggesting a generally constant trend of colour change among groups up to 12 months post-operatively.

Discussion:

White spot lesions (WSLs) are a common aesthetic concern, with etiologies ranging from caries-induced demineralization to developmental defects such as fluorosis and enamel hypoplasia. These lesions compromise dental aesthetics and patient confidence, making their management a key priority in clinical dentistry. This study evaluated the effectiveness of resin infiltration alone and in combination with remineralization for the aesthetic management of WSLs over a 12-month period, focusing on color stability and lesion masking. The results revealed variable color stability across etiological groups and treatment modalities, highlighting differences in lesion structure and treatment response.

Our findings showed that Group 1A (fluorosed teeth treated with resin infiltration only) demonstrated an initial improvement in ΔE values, which remained relatively stable over 12 months. Similar findings were reported by Paris et al., who observed favorable masking effects of resin infiltration in fluorosed enamel due to the shallower and more porous nature of these lesions facilitating adequate resin penetration.[9] The non-significant color changes over time suggest resin infiltration alone may provide sufficient aesthetic improvement for mild fluorosis cases, aligning with results from Gugnani et al.[10]

In Group 1B (fluorosed teeth with combined therapy), a transient improvement was observed at 1 month, followed by a rise in ΔE at 12 months. This may be attributed to the interaction between residual porosity and overlying remineralization, which might have affected the refractive index uniformity or led to post-treatment mineral deposition on the surface rather than within the lesion body. Similar rebound effects have been noted in studies evaluating remineralization pastes over infiltrated enamel, suggesting that over-application may hinder long-term aesthetics rather than improve them.[11]

For Group 2A (hypoplastic teeth treated with resin infiltration only), the increase in ΔE values over time suggests limited and possibly superficial resin penetration due to structural enamel defects. Hypoplastic enamel often lacks a well-defined porosity pattern, and the presence of surface irregularities or pits could have compromised resin adaptation and retention. Findings from Meyer-Lueckel and Paris support this hypothesis, emphasizing that developmental defects with mineralization disorders exhibit unpredictable resin infiltration behavior due to their depth and irregularity.[12] Our results align with Taher et al., who reported diminished long-term success of resin infiltration in hypoplastic enamel compared to carious lesions.[13]

In Group 2B (hypoplastic + combined therapy), the consistent increase in ΔE indicates that remineralization alone was insufficient to compensate for underlying structural enamel loss. CPP-ACP may not adequately integrate into hypoplastic enamel's non-homogenous mineral network, thereby limiting optical blending or improvement in translucency. A similar conclusion was drawn by Alkilzy et al., who found that surface remineralization agents had limited benefits in developmental enamel defects with structural discontinuities.[14]

Group 3A (carious WSLs with resin infiltration) showed a pattern of initial improvement followed by partial relapse, suggesting some degree of post-treatment discoloration or minor resin degradation over time. However, the net ΔE remained within clinically acceptable thresholds, reinforcing that resin infiltration provides a reliable aesthetic outcome for carious WSLs. This agrees with studies by Kim et al. and Knösel et al., who both reported sustained color stability and lesion arrest in carious enamel treated with ICON infiltration [15,16]

Interestingly, Group 3B (carious WSLs with combined therapy) maintained the most stable ΔE values over 12 months. This suggests a synergistic effect, where resin infiltration seals the lesion body and CPP-ACP contributes to additional mineral reinforcement, possibly minimizing microleakage and discoloration.

Similar benefits of combination therapy have been highlighted in studies by de Freitas Santos LF et al. and Dhillon et al., who suggested that sequential application enhances both subsurface filling and superficial mineral integration, resulting in improved lesion stabilization and aesthetics.[17,18]

Contrasting views have emerged regarding the additive value of remineralization over infiltrated enamel. While some studies propose it may prevent stain absorption and enhance enamel resistance,[19] others argue it might reduce the light transmission capacity of resin-infiltrated enamel, thereby affecting its aesthetic masking ability over time.[20] Our results support a context-dependent application, where combination therapy benefits carious lesions most but offers limited or negative impact in hypoplastic and fluorotic cases.

Conclusion:

Strength and Limitations:

This prospective 12-month trial enabled longitudinal evaluation of color stability in non-cavitated WSLs of different etiologies. Stratified allocation into fluorosis, hypoplasia, and carious groups allowed targeted analysis, while the use of spectrophotometry (ΔE) minimized observer bias and ensured reproducibility. However, the modest sample size and single-center setting may limit generalizability. The absence of imaging or histological evaluation restricted insight into resin penetration, and patient-reported outcomes such as satisfaction or sensitivity were not assessed. Overall, resin infiltration was effective, particularly in carious lesions with CPP-ACP, though responses varied with lesion type. Larger multicenter trials with advanced imaging and patient-centered outcomes are recommended to validate and extend these findings.

Conclusion

Resin infiltration is a minimally invasive option for managing non-cavitated white spot lesions, but its color stability depends strongly on lesion etiology. In this study, carious lesions showed the most favorable long-term outcomes, especially when CPP-ACP was used as an adjunct, while fluorosed and hypoplastic lesions demonstrated less predictable results. These findings highlight the importance of tailoring treatment strategies to the underlying lesion type rather than adopting a uniform approach. Although the sample size and single-center design limit generalization, the results support resin infiltration as a reliable modality for carious WSLs. Future multicenter studies with larger cohorts and advanced imaging are needed to better understand resin penetration dynamics and optimize outcomes.

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