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Evaluation of Esthetics and Stain Resistance of Resin Infiltration, CPP-ACPF Paste, and Adhesive on White Spot Lesions

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ABSTRACT

Aim: To evaluate the esthetic improvement and staining resistance of a resin infiltration system, CPP-ACPF-containing paste, and universal adhesive on artificially demineralized enamel using spectrophotometry.

Methodology: Thirty-two extracted human maxillary incisors were cleaned and stored in 0.1% thymol. All surfaces except the labial were covered with nail varnish. Artificial white spot lesions were created by immersing specimens in a demineralizing solution ($CaCl_2$, KH_2PO_4, acetic acid, KOH; pH 4.4) for 4 days. Teeth were randomly divided into four groups (n=8): Group 1 – Control (artificial saliva), Group 2 – Resin infiltrant (ICON), Group 3 – MI Paste Plus (CPP-ACPF), and Group 4 – Scotchbond Universal Adhesive. Treatments were applied according to manufacturer instructions, followed by 7 days of pH cycling. Spectrophotometric color measurements were recorded at baseline, after demineralization, post-treatment, and after 8-day exposure to black tea (10 minutes daily).

Results: Demineralization significantly reduced lightness (ΔL) across all groups. ICON resin infiltrant showed a statistically significant improvement in ΔL and maintained this improvement after staining. MI Paste Plus and Scotchbond adhesive did not demonstrate significant differences from the control group in esthetic improvement or stain resistance.

Conclusion: ICON resin infiltrant provides superior esthetic improvement and stain resistance for white spot lesions compared to CPP-ACPF paste, universal adhesive, and artificial saliva.

Keywords: White spot lesions; Resin infiltration; CPP-ACPF; MI Paste Plus; Scotchbond adhesive; Spectrophotometry; Esthetic dentistry; Stain resistance

INTRODUCTION

Dental caries is a biofilm-mediated, diet-modulated, multifactorial, non-communicable disease characterized by dynamic cycles of demineralization and remineralization, ultimately resulting in the net mineral loss of dental hard tissues. Enamel, composed of approximately 96% hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), undergoes daily pH fluctuations influenced by dietary acids and bacterial metabolism. When the rate of demineralization exceeds remineralization, subsurface lesions develop, appearing clinically as non-cavitated white spot lesions (WSLs). These lesions are characterized by increased enamel porosity and a change in refractive index (RI), leading to a chalky, opaque appearance that compromises esthetics, particularly in anterior teeth.

The RI mismatch between demineralized enamel (RI = 1.33 for water-filled pores) and sound enamel (RI = 1.62) affects light transmission, resulting in visible white opacities. Although saliva promotes natural remineralization, its effects are limited and insufficient to fully reverse WSLs. Fluoride-based therapies may remineralize the lesion surface but often fail to reach the lesion body, potentially leading to esthetically unsatisfactory arrested lesions.

Minimally invasive strategies are increasingly preferred over conventional restorative approaches for WSL management. Among these, casein phosphopeptide–amorphous calcium phosphate with fluoride (CPP-ACPF), found in products such as MI Paste Plus®, has shown potential in enhancing subsurface remineralization. CPP-ACPF provides bioavailable calcium, phosphate, and fluoride ions, particularly under acidic conditions, supporting deeper remineralization and potentially improving esthetic outcomes.

Another promising approach is resin infiltration (ICON®, DMG), a technique that uses low-viscosity, light-curable resins (e.g., TEGDMA) to infiltrate the porous lesion body. The infiltrant's RI (~1.52) closely approximates that of healthy enamel, reducing light scattering and effectively masking WSLs. This technique also arrests lesion progression by sealing off porosities from acid attack.

Additionally, some adhesive systems have demonstrated potential for esthetic improvement of WSLs due to their ability to penetrate and partially infiltrate enamel porosities. Scotchbond™ Universal Adhesive (3M ESPE) contains 10-MDP and Vitrebond copolymer, which contribute to moisture stability and penetration, potentially altering the RI of the affected enamel.

Despite esthetic improvements, long-term color stability of treated lesions remains a concern, as porous enamel is susceptible to staining from dietary chromogens. Agents with different penetration and sealing abilities may influence the extent to which enamel discoloration occurs post-treatment.

Aim:

This study aims to compare the esthetic improvement and stain resistance of artificially demineralized enamel lesions treated with a resin infiltration system (ICON), CPP-ACPF-containing paste (MI Paste Plus), and a universal adhesive system (Scotchbond Universal). Artificial saliva was used as the control. Spectrophotometry was employed to assess color changes before and after treatment and following exposure to staining solutions.

Materials Used:

- **Artificial saliva**
- **Demineralization solution:** 2.2 mM $CaCl_2$, 2.2 mM KH_2PO_4, 0.05 mM acetic acid, 1 M KOH (pH 4.4)

- **Remineralization solution:** 5 mM $CaCl_2$, 0.9 mM KH_2PO_4, 130 mM KCl, 20 mM HEPES, 5 mM NaN_3 (pH 7.0)
- **Test agents:**
  - Resin infiltrant (ICON®, DMG, Germany)
  - CPP-ACPF paste (MI Paste Plus®, GC Corp., Japan)
  - Universal adhesive (Scotchbond™, 3M ESPE, Germany)

Equipment:

- Spectrophotometer (MINOLTA CM 3600d)
- pH meter (EI DIGITAL pH METER-111)

Specimen Preparation:
Thirty-two extracted human maxillary central and lateral incisors with intact enamel were selected (Ref no.: 2018-MDS-BrIV-SRI-09/APDCH). Teeth with decay, enamel defects, restorations, or fluorosis were excluded. Specimens were cleaned and stored in 0.1% thymol.

Grouping and Intervention:
Teeth were randomly assigned to four groups (n=8):

- Group 1: Control (artificial saliva)
- Group 2: ICON resin infiltrant
- Group 3: MI Paste Plus
- Group 4: Scotchbond Universal Adhesive

Demineralization:
Labial surfaces were exposed, while other surfaces were coated with nail varnish. Teeth were immersed in demineralizing solution (pH 4.4) for 4 days to induce subsurface demineralization.

Treatment Protocols:

- **Group 1:** Stored in artificial saliva for 4 weeks.
- **Group 2 (ICON):**
  - Etch with Icon® Etch for 2 min, rinse and dry
  - Apply Icon® Dry for 30 s
  - Infiltrate with Icon® Infiltrant for 3 min, light cure 40 s
  - Reapply infiltrant for 1 min, light cure 40 s

- **Group 3 (Scotchbond):** Applied per manufacturer instructions.
- **Group 4 (MI Paste Plus):** Applied for 3 min, placed in artificial saliva without rinsing, repeated daily for 4 weeks.

pH Cycling:
Specimens underwent daily pH cycling for 7 days (Lagerweij & ten Cate, 2006):

- 8 h in demineralizing solution (pH 5.0)
- 16 h in remineralizing solution (pH 7.0)

Color Measurement (Spectrophotometry):
Using the CIELAB system, only L* values (lightness) were recorded to assess esthetic changes at three intervals:

- Baseline (pre-demineralization)
- Post-demineralization
- Post-treatment (after 7-day pH cycling)

Staining Procedure:
A black tea solution (25 g TATA GOLD tea in 250 mL water) was used. Specimens were immersed for 10 min daily over 8 days and stored in artificial saliva between sessions. Solutions were refreshed daily. Final L* values were measured using the spectrophotometer post-staining.

Figure.1Icon® Infiltrant was applied for 3

Figure 2.Light curing was done for 40

FIGURE 3: Specimen treated with MI Paste plus (GC tooth mousse plus, GC Corp, Tokyo, Japan) for 3 minutes daily for 4 weeks

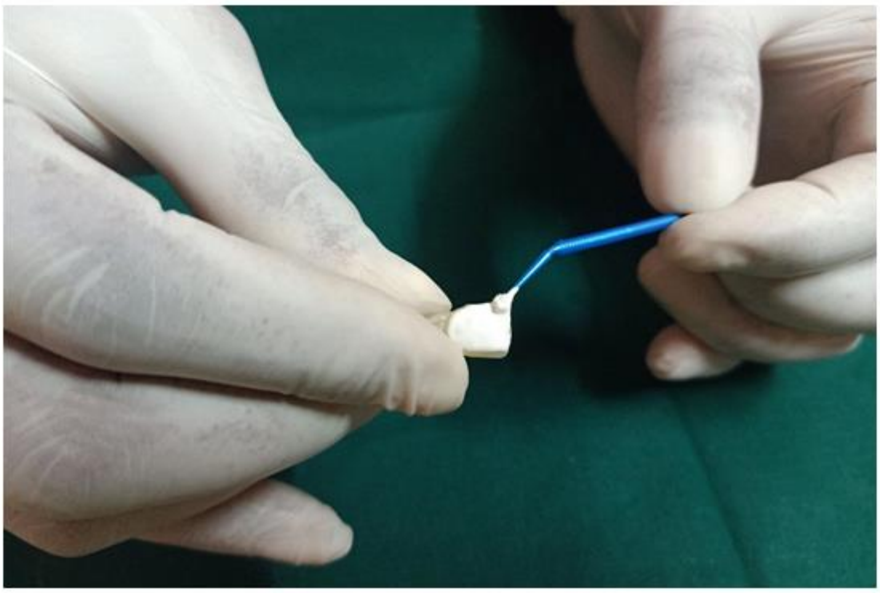

FIGURE 4: Specimen treated with Scotchbond universal adhesive (3M ESPE,Germany)

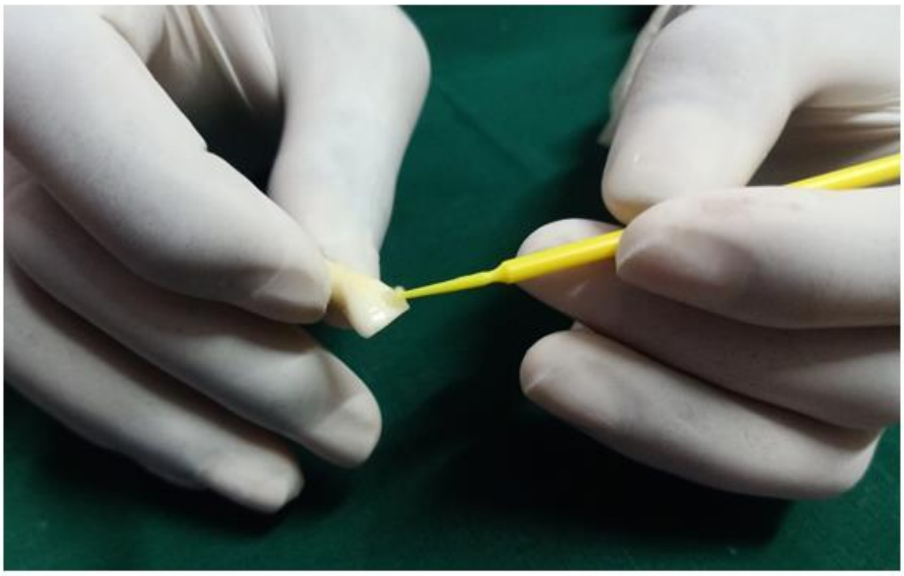

FIGURE 5: pH CYCLING-SPECIMENS WERE IMMERSED IN DEMINERALIZATION AND REMINERALIZATION SOLUTION FOR 7 DAYS

Demineralization solution Remineralization solution

FIGURE 6: SPECIMENS IMMERSED IN BLACK TEA STAINING SOLUTION

RESULTS

Lightness (ΔL) Values Across Four Time Intervals

Groups Analyzed

1. **Control Group**
2. **ICON Resin Infiltrant (DMG, Hamburg, Germany)**
3. **GC Tooth Mousse Plus**
4. **Scotchbond Universal Adhesive**

Time Intervals

- **BD**: Before Demineralisation
- **AD**: After Demineralisation
- **AT**: After Treatment
- **AS**: After Staining

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1. Change in Lightness Values (ΔL)

- **All groups showed a significant reduction in ΔL after demineralisation** (Wilcoxon test, $p = 0.000$).
- ICON group (Group 2) showed the **most significant increase in ΔL after treatment**, suggesting effective reversal of demineralisation.
- **After staining**, ICON maintained higher lightness levels than other groups, indicating better stain resistance.

2. Group-wise Mean ΔL Values

Time Interval	Group 1	Group 2 (ICON)	Group 3	Group 4
BD	78.40	78.75	78.26	78.03
AD	76.32	77.46	75.97	75.86
AT	76.20	81.00	77.63	77.14
AS	74.36	80.77	75.69	75.20

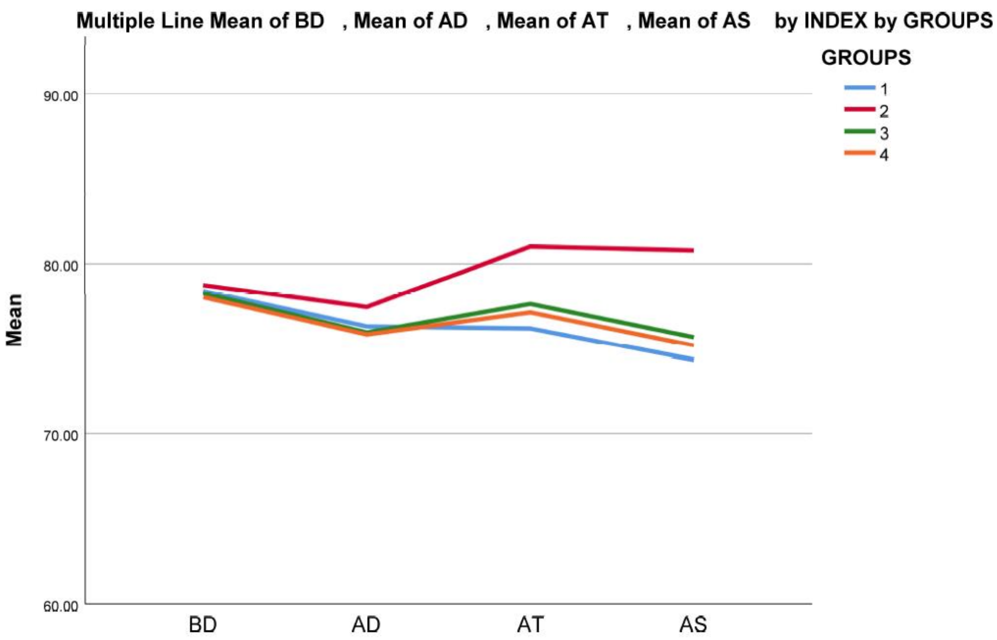
Statistical Analysis

- **Normality Tests**: Most data sets showed **non-normal distribution** → Non-parametric tests used.
- **Wilcoxon Test**: Significant reduction in ΔL from BD to AD across all groups ($p = 0.000$).
- **Kruskal-Wallis Test**:
    - **After Treatment**: Significant difference among groups ($p = 0.002$)
    - **After Staining**: Significant difference among groups ($p = 0.001$)

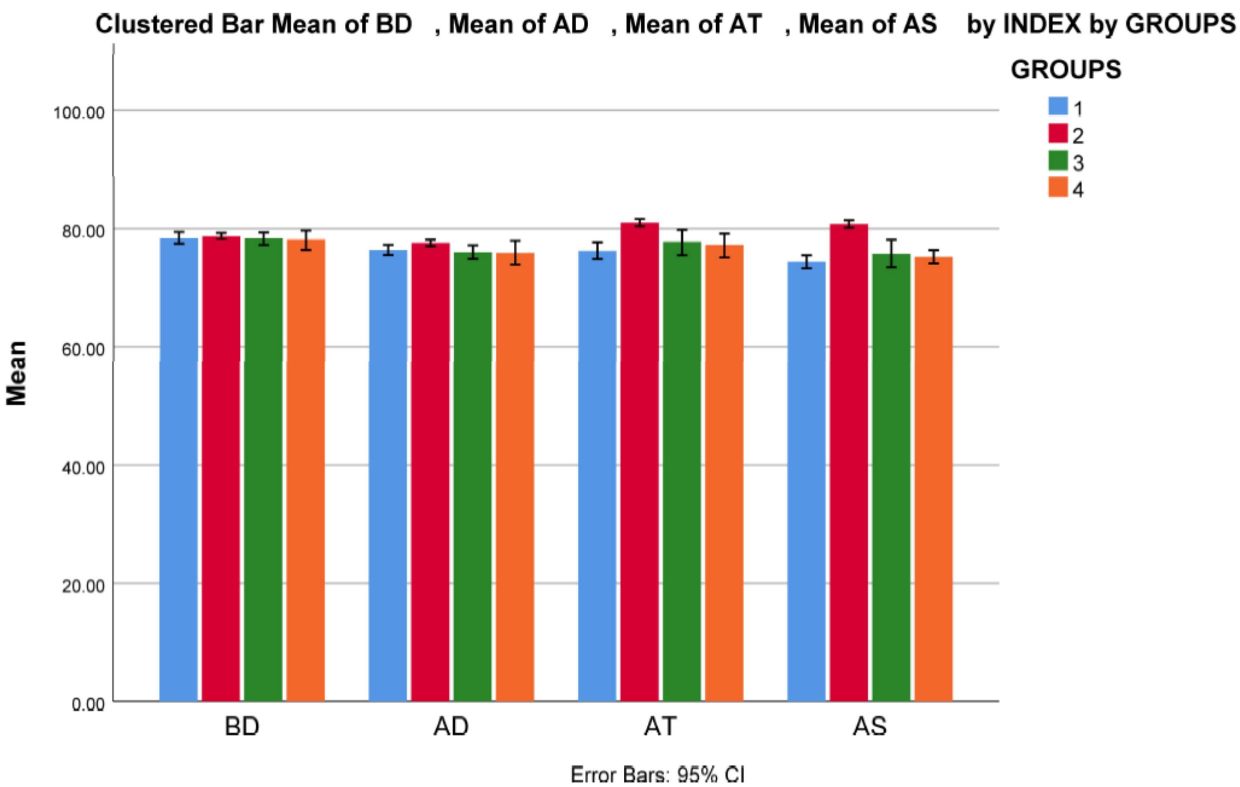
Post Hoc (Bonferroni-adjusted) Comparisons

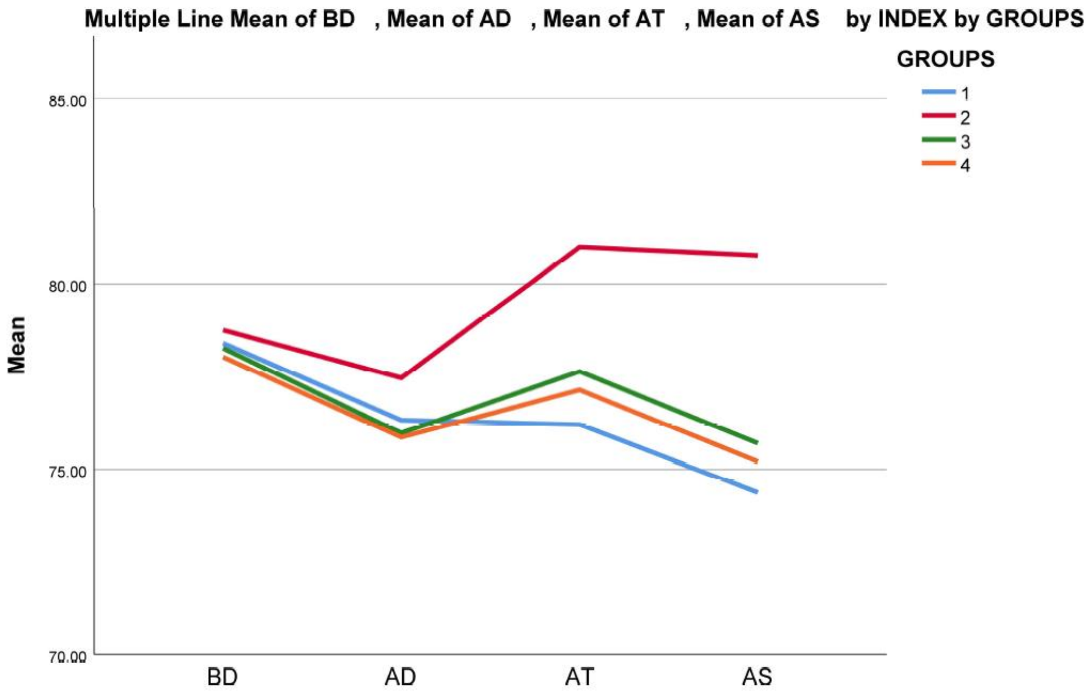
- **ICON (Group 2)** was **significantly better** than:
    - Group 1 ($p = 0.001$)
    - Group 3 ($p = 0.052$ after treatment, $p = 0.036$ after staining)
    - Group 4 ($p = 0.028$ after treatment, $p = 0.036$ after staining)
- No significant differences were found among **Groups 1, 3, and 4** after staining.

GRAPH 1: GRAPHICAL REPRESENTATION OF CLUSTERED BAR MEAN BEFORE DEMINERALISATION, AFTER DEMINERALISATION, AFTER TREATMENT AND AFTER STAINING BY GROUPS



GRAPH 2: GRAPHICAL REPRESENTATION OF CLUSTERED BAR MEAN BEFORE DEMINERALISATION, AFTER DEMINERALISATION, AFTER TREATMENT AND AFTER STAINING BY GROUPS





DISCUSSION

The increasing prevalence of dental caries is closely linked to evolving dietary patterns, particularly the rise in consumption of refined carbohydrates and processed foods. One of the earliest clinically detectable signs of caries is the white spot lesion (WSL), which presents as a chalky, opaque area on the enamel surface. These lesions signify the beginning of the demineralization process, caused by acidogenic bacteria in the plaque biofilm, leading to the dissolution of enamel apatite crystals and the subsequent loss of calcium and phosphate.

Wsls not only indicate an early carious process but also pose esthetic challenges, especially for adolescents, who may be more self-conscious due to cognitive developmental stages, as explained by Piaget's theory of adolescent egocentrism. The unsightly appearance of wsls, particularly on anterior teeth, can significantly affect social interactions and self-esteem. Thus, managing wsls is not only a preventive measure but also a crucial step in restoring esthetics and patient confidence.

Importantly, not all wsls arise from demineralization alone. Similar enamel discolorations can be attributed to developmental anomalies like fluorosis, hypomineralization, hypomaturation, or enamel hypoplasia. Differentiating the etiology is essential for selecting an appropriate and effective treatment modality.

In orthodontically treated patients, wsls are a common post-treatment complication due to challenges in maintaining oral hygiene around fixed appliances. The accumulation of plaque alters the local enamel environment, facilitating the formation of demineralized lesions. Prevalence rates of wsls in these patients range from 5% to 97%, with labial surfaces of maxillary incisors being the most affected.

The current study employed an in vitro model to simulate wsls by immersing enamel specimens in a demineralizing solution. Spectrophotometric analysis on the CIELAB scale was used to quantify changes in lightness (L* values), which effectively reflect changes in enamel translucency and, by extension, esthetics. This objective approach allowed a standardized evaluation of various noninvasive treatment modalities aimed at improving the appearance of wsls.

Among the non-invasive approaches tested—MI Paste Plus (CPP-ACPF), Scotchbond Universal adhesive, and ICON® resin infiltrant—ICON demonstrated the most significant improvement in restoring enamel translucency. The resin infiltrant effectively filled the microporosities within the enamel, altering the refractive index to closely match that of healthy enamel, thereby camouflaging the lesions. This is consistent with prior studies showing that resin infiltration not only arrests lesion progression but also improves esthetics.

MI Paste Plus, containing CPP-ACPF, showed limited efficacy in esthetic improvement. While CPP-ACP has strong remineralization potential, especially in early lesions, it primarily affects surface layers and does not significantly restore lightness values in established lesions. This finding aligns with previous reports indicating that although CPP-ACP can reverse early enamel lesions, the cosmetic masking of deeper wsls remains inadequate.

Scotchbond Universal adhesive showed moderate improvement but was inferior to ICON. Despite its potential to infiltrate porous enamel surfaces, its esthetic masking capability appears limited compared to dedicated resin infiltrants. However, its widespread availability in dental practices makes it a practical, albeit less effective, alternative.

Post-treatment staining with black tea revealed the superior color stability of ICON-treated surfaces, which retained their lightness values more effectively than those treated with MI Paste Plus or adhesive. Although some studies suggest resin infiltrated surfaces may be prone to discoloration, our findings support the notion that, with proper care, ICON resin maintains esthetic outcomes over time. Nevertheless, staining susceptibility remains a limitation of resin-based treatments, and long-term color stability should be a consideration during clinical decision-making.

The use of artificial saliva as a control group provided a baseline for comparing remineralization efficacy. As expected, the remineralization achieved through artificial saliva alone was minimal, reaffirming the necessity for active therapeutic interventions in managing wsls.

Despite promising results, this study has certain limitations. The simulated oral environment may not fully replicate the complex intraoral conditions affecting demineralization and remineralization. The staining protocol was limited to black tea, and further research using a broader range of staining agents is warranted. Moreover, the evaluation period of four weeks may not capture the long-term effectiveness and durability of the treatments.

In conclusion, ICON® resin infiltration demonstrated the most effective esthetic improvement of wsls among the modalities studied. MI Paste Plus and adhesive systems provided only limited masking effects. Resin infiltration thus stands out as a micro-invasive, clinically viable option for enhancing the appearance of wsls, especially in esthetically critical regions. However, clinicians must weigh factors such as color stability, lesion depth, and patient compliance when selecting a treatment strategy. Further long-term clinical studies are essential to validate these findings and to establish comprehensive protocols for managing wsls effectively.

CONCLUSION

Within the limitations of this in vitro study, ICON resin infiltrant showed superior esthetic improvement of white spot lesions compared to artificial saliva, MI Paste Plus, and adhesives, thus rejecting the first null hypothesis. However, MI Paste Plus and Scotchbond adhesive did not show significant improvement compared to artificial saliva, so the second null hypothesis is accepted. Moreover, ICON exhibited less staining than MI Paste Plus and adhesives, indicating better color retention, and therefore the third null hypothesis was accepted only for MI Paste Plus and adhesives.