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Colour stability of enamel surface after treatment of white spot lesion with resin infiltration: In vitro study

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***Abstract*---**Background: The current research was done to assess the impact of multiple staining solutions on the colour stability of enamel surface after treatment of white spot lesions with resin infiltration. Assessments were made immediately following resin infiltration and after exposure to various staining solutions. Materials & Methods: Fourty sound extracted premolars were subjected to acidic solution to induce formation of white spot lesion (WSLs). WSLs were then treated

with icon resin infiltration. Using different staining solutions, teeth were divided into 4 groups at random based on the staining solution in which they were immersed: pepsi immersion group (PS), coffee immersion group (CF), orange juice immersion group (OJ) and finally a control group (CT). Spectrophotometric analysis was done four times: at baseline (T0), following induction of the WSLs (T1), following application of resin infiltration (T2), and following subjected to various staining solutions (T3) for each group. Results: Pepsi immersion group showed the greatest colour difference (17.10 ± 6.07). While the coffe immersion group had much samaller coller colour change than pepsi (11.95 ± 4.2). Furthermore, the orange juice immersion group produced the least clinically detectable colour difference (6.21 ± 2.2). While the control group showed the only clinically undetectable colour difference (2.63 ± 0.6). Conclusions: Colour stability after rein infilteration treatment of enamel surface with white spot lesions was less than ideal.

***Keywords*---**colour stability, enamel surface, treatment, white spot lesion, resin infiltration.

Introduction

White spot lesions have been descriped as subsurface enamel porosity resulting from an imbalance between demineralization and remineralization, represented as a milky white opacity when located on smooth surface. These are areas of local decalcification of enamel without cavity formation. [1] While early carious enamel lesions are detected clinically as a white opaque spot, slightly softer than the adjacent sound enamel. Two early phases of enamel caries have been identified:

- Surface softening- This is characterized by preferential removal of the interprismatic substance, the mineral loss being most pronounced at the enamel surface.
- Subsurface lesion- The deeper portion of the enamel is where the dissolving mostly takes place. A layer that is permeable yet nonetheless rich in minerals covers the low mineralized body of the lesion.

Among the most common side effects of orthodontic treatment which can have a permanent negative effect on dental aesthetics is White spot lesions (WSL.[2] The WSL prevalence has been found to range from 2% to 96%.[2] The most common teeth affected are the maxillary anterior teeth, lateral incisors, canines, premolars, and central incisors in that sequence of occurrence.[3,4,5]

WSL is considered to be the precursor of frank enamel caries. In orthodontics, it can be due to the difficulties in carrying out the oral hygiene measures with prolonged plaque accumulation on tooth surfaces, resulting in a pH reduction that tips the demineralization-remineralization balance toward mineral loss (demineralization), which can result in development of WSL then leading to surface cavitation and extension of caries deeper into the dentin.[6] Furthermore, WSL is considered as a broad term that can include developmental enamel lesions

as in enamel hypoplasia (thinner development of the enamel on teeth) or due to fluorosis (over exposure of fluoride to the teeth), localized areas of demineralization or caries related to orthodontic appliances.[2]

These WSLs are characterized by their opaque appearance, loss of minerals, and reduced fluorescence radiance, when compared to healthy intact enamel surfaces. Most initial enamel caries look whitish in color owing to an optical phenomena resulting from loss of minerals from the surface and sub-surface which modifies the refraction index and promotes the dispersion of light within the region it affect, this all leads to increased visible enamel opacity.[6] This is a clinical issue that leads to an unpleasant esthetic appearance which it can need restorative treatment in very extreme circumstances.[7]

Formation of these lesions can occur quickly, with the initial clinical sign detection two weeks following initial biofilm development.[8] Once orthodontic therapy has concluded and the fixed appliances removed, the cariogenic challenge ceases. Over time, remineralization of the outer surface of the lesion inhibits the penetration of calcium and other ions into the deeper parts of the lesion, arresting the remineralization process.[9,10,11] WSLs regress within the initial three months following removal of orthodontic appliances, predominately, owing to salivary remineralization and toothbrush abrasion. however lesions existing after this time are expected to persist and complete regression does not occur for most lesions.[12,13]

There are several treatment options available for treating WSLs. Topical remineralization therapy with fluoride,[14] has shown mixed success and are often clinically insignificant at producing cosmetic improvement.[15,16] Bleaching offers minimal esthetic enhancement and correlated with hypersensitivity of the teeth and reduced enamel microhardness.[17-19] Microabrasion is effective for shallow WSLs,[20] however it can result in considerable enamel removal.[21,22] Likewise, traditional restorative options including composite restorations, veneers, or ceramic crowns lead to substantial loss of dental hard tissue, despite potentially excellent cosmetic results.[23,24] As white spot WSLs contain a little quantity of demineralized enamel, less invasive treatment approaches are preferable.

Recently, with new materials and techniques, the infiltration concept has been implemented in the dental field. The micro-invasive property of the new low viscosity resin helps it to infiltrate the inter-crystalline spaces of enamel to arrest enamel lesions. The WSL must be acid-etched before infiltration to remove the hypermineralized pseudo-intact surface layer of enamel which enables the resin to infiltrate into the core of the lesion.[25,26] With a refractive index of (1.48) of the resin infiltration compared to (1.65) for enamel, the resin can totally mask the opaque color of miled to moderate inactive WSLs and partially conceals the look of moderate to severe WSLs.[27]

Spectrophotometry is used to determine color by taking precise measurements expressed either quantitatively or graphically. The Commission Internationale de l'Eclairage (CIE) has developed a calculating system that mesures the difference between two colors. A formula is used for the process ($\Delta E = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]1/2$, yeilding one single value for the color difference (ΔE).[28] The majority of

studies set a value of 3.7 units to accept color matching and higher values are clinically noticeable.[29] Previously in literature, [30,31] the spectrophotometer proved to have precise measurement and high accuracy. In previous studies,[30,31] the spectrophoto-meter demonstrated a high accuracy and precise measurement.

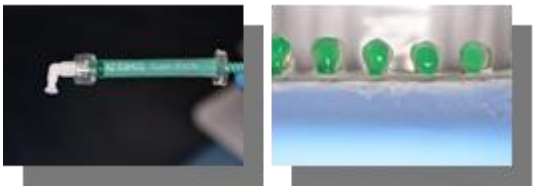
Materials & Methods

A sample size of 40 extracted premolars, with 10 teeth per group, was required to evaluate colour change of resin infiltrated enamel surface after exposure to different staining solutions. Inclusion criteria: 1-sound teeth free from caries, 2-no pre-treatment with chemical agents, 3-intact buccal surfaces without any cracks, stains or restoration.

Teeth Preparation

Following extraction, all teeth were cleaned with tap water then kept in artificial saliva solution for storage (20 mmol/l NaHCO3, 3 mmol/l NaH2PO4, and 1 mmol/l CaCl2) at 37 °C and pH 7 in order to replicate the oral environment.[32] The solution was changed every day.

1. At the beginning of the study, all teeth roots were immersed in a dental stone with 10 teeth each.
2. All teeth were then immersed in a solution incorporating 200 ml artificial caries solution (2.2 mmol/l KH2PO4, 2.2 mmol/l CaCl2, 50 mmol/l acetic acid) at pH 5 for a whole day.[32] On each day, a fresh solution was used till the development of the frosty white appearance.
3. Resin infiltration ICON® (DMG, Hamburg, Germany) was subsequently administered to the created white spot lesions following the guidelines provided by the manufacturer:
   a. Appling "ICON-Etch" (15% HCL) for 2 min, FOLLOWED by a 30 s water spray rinse and then dried.



   b. After that application of "ICON-Dry" (ethanol) for 30s, then dried with air.

c. Application of ICON then left on the tooth surface for 3 min. A cotton roll was used to remove any excess resin , followed by light curing for 40s.

d. Another layer of ICON was applied again for 1 min, then cured with light for 40s.

e. Finally, enamel surface that had been roughened was polished using a 1-µm aluminium oxide paste and soft felt wheel.

4. Teeth were randomly divided into 4 groups, with 10 teeth each according to the staining solution in which they were immersed: Pepsi immersion group, Coffee immersion group, Orange juice immersion group and finally a control group was immersed in distilled water throughout the experiment (CT). Teeth were exposed to their respective staining solutions for 2 weeks and the solutions were replaced every 24 Hs.

Teeth Storage: All teeth were stored in an incubator at 37 °C to simulate the oralenvironment.

Colour assessment

"VITA Easy Shade" intraoral spectrophotometer was used to measure Spectrophotometric colour for the samples L*, a*, b* colour values. Spectrophotometric assessments were performed at baseline (T0), after induction of white spot lesions (T1), after WSLs infiltration (T2) and finally after immersion in staining solution for14 days (T3).

$$\Delta E^* = \left[(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2\right]^{1/2}$$

The Spectrophotometer was positioned in relation to the buccal surface of all teeth using a custom made tray at a fixed, standardized, and repeatable location for every measurement. Utilizing the L*a*b* CIELAB colour notation method (Commission International de L'Eclairage), instrumental colour readings were taken.[28]

The Vita Easy Shade was calibrated in compliance with the company's guidelines. From L*, a*, b* colour values, the resulting colour difference (ΔE^*) among every pair of time intervals was computed as subsequent [24]:

Statistics evaluation

The collected data were tabulated, and statistically analysed using Statistical Package for Social Science 20th edition (SSPS Inc., Chicago, III) software. Following the after assessment of data normality, one sample t-test was utilized for comparison the mean colour difference ΔE to the clinical detecting threshold ΔE = 3.7. To evaluate the difference in mean ΔE between the groups, a post hoc test was conducted after the one-way analysis of variance (ANOVA). A significant threshold of P < 0.05 was established.

Results

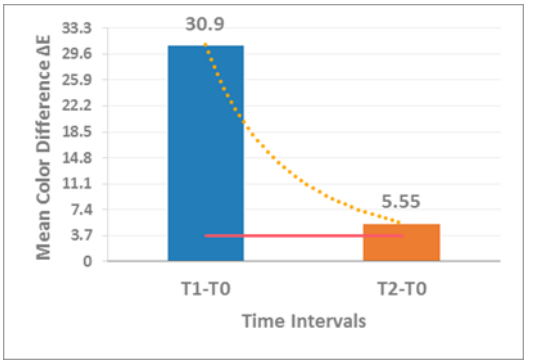
Comparing colour changes following infiltration of white spot lesions

Table 1 displays the mean colour difference ΔE between two time intervals. The 1st time from T0 (at baseline) to T1 (after induction of WSLs) and the 2nd one from T0 (at baseline) to T2 (after infiltration of WSLs).

Time Interval	Mean ΔE ± SD	Critical ΔE	t	P
T1 – T0 (N=40)	30.9 ± 9.6	3.7	17.9	0.001*
T2 – T0 (N=40)	5.55 ± 3.6		3.25	0.002*

Significant (p ≤ 0.05) ns; non-significant (p >0.05)

One sample t-test displayed a highly significant difference between the 1st time interval and the threshold of clinical detection and a significant difference with P value less than 0.05, between the 2nd time interval and the clinically detectable threshold.



Colour change comparisons following the exposure to different staining solutions.

Table 2 shows the mean colour difference ΔE between T2 (after infiltration of WSLs) and T3 (after exposure to different staining solutions) in Pepsi, coffee, orange juice and artificial saliva group.

Staining Solution	Mean ΔE ± SD	Critical ΔE	t	P
PS (N=10)	17.1 ± 6.9	3.7	6.5	0.001*
CF (N=10)	11.9 ± 4.2		6.2	0.001*
OJ (N=10)	6.2 ± 2.2		3.6	0.005*
CT (N=10)	2.6 ± 0.6		5.6	0.001*

Significant (p ≤ 0.05) ns; non-significant (p >0.05)

One sample t-test showed that; Ps, CF and CT groups demonstrated highly significant differences, while OJ immersion group showed a significant difference with a P value less than 0.05 when compared with the clinically detectable threshold.

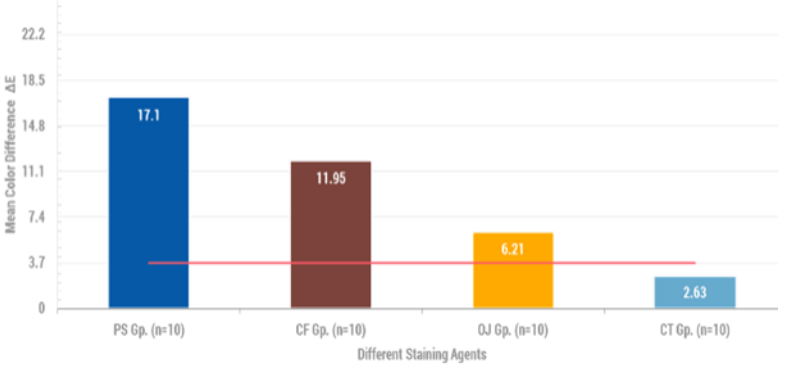


Table 3 shows comparison between the mean colour difference ΔE (T3-T2) of the different staining groups.

Staining Solution	Mean ΔE ± SD	F	P
PS (N=10)	17.1 ± 6.9	23.05*	0.001*
CF (N=10)	11.95 ± 4.2		0.001*
OJ (N=10)	6.2 ± 2.2		0.001*
CT (N=10)	2.6 ± 0.6		0.001*

Significant ($p \leq 0.05$) ns; non-significant ($p > 0.05$)

One-way ANOVA test showed highly significant differences between the different staining solutions. However, multiple comparisons showed that: PS immersion group demonstrated highly significant difference when compared with OJ immersion group and significant difference when compared with the CT group, while the CF immersion group demonstrated highly significant difference when compared with the CT group. When comparing the other groups with each other, no significant differences were found.

Discussion

When oral hygiene maintenance has failed, especially in moderate to high-risk patients, the enamel subsurface lesions is forms and is called a white spot lesion (WSL) which quickly develops around orthodontic brackets. There are four stages of treatment of WSLs after bracket removal: 1) Natural remineralization, 2) Camouflage, 3) Micro abrasion, 4) Restorative treatment. Enamel infiltrated with ICON resin shows an immediate aesthetic improvements of the WSL compared with untreated lesions but is believed to be more prone to staining than untreated enamel areas.

Nevertheless, many popular beverages, including coffee, Coca-Cola and tea may result in staining of the WSLs despite being treated.[33] Hence, the current study aimed to assess the colour stability of treated artificial WSLs with resin infiltration after immersion in different staining solutions. To avoid potential subjective mistakes in colour evaluation, spectrophotometers were employed in the research analysed, which provides precise quantitative data for proper objective assessment. Spectral dispersion of light is measured using the spectrophotometer and transforms it into colour values or numerical values using the CIE L*a*b* system, also known as CIELAB. The later system was developed in 1978 by the Commission Internationale de l'éclairage (CIE).[28] In such system, the value L* denotes brightness (L + = brightness and L− = darkness and differs between 0 = black and 100 = white), the coordinate a* represents the red/green axis (a* + = redness and a* − = green), and the b* denotes the yellow/blue axis (b* + = yellow and b* − = blue). The values of the a* and b*, if the number approaches zero, show neutral colours (Gray and white). The value of the parameter (ΔE) indicates the overall colour change.[28] This method was selected to evaluate the colour change (ΔE) because it is suitable for determining even the smallest changes.[34, 35, 36.] To enhance the durability of resin infiltration in aesthetically relevant areas, patients should refrain from ingesting coloured drinks and nutrients.

Conclusion

The current study's results lead to the conclusion that:

- Resin infiltration was able to significantly improve the appearance of WSLs in vitro.
- Colour stability of resin infiltrated WSLs was less than ideal.
- Different staining solutions produced variable changes, the greatest staining occurred with Pepsi while CF, OJ and water had little effect.

Recommendation

- Evaluation of patient's compliance with oral hygiene is essential before treatment with ICON resin infiltration.
- More studies could be done to compare between colour stability of resin infiltrated WSLs and non-resin infiltrated WSLs.

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