EFFECT OF REPEATED ACID CHALLENGES ON THE COLOR STABILITY OF RESIN-INFILTRATED ENAMEL WHITE SPOT LESIONS

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MASTER'S THESIS

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ABSTRACT

EFFECT OF REPEATED ACID CHALLENGES ON THE COLOR STABILITY OF RESIN-INFILTRATED ENAMEL WHITE SPOT LESIONS

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Introduction: Resin infiltration is a minimally invasive therapy to halt caries progression and to esthetically mask demineralized white spot lesions in enamel. Literature suggests that resin-infiltration protects incipient lesions from acidic exposures and halts further carious progression; however, the effect of acidic challenge on the color stability of resin-infiltrated white spot lesions remains unclear.

Purpose: To investigate the effect of repeated diet simulating acidic challenges on the color stability of resin-infiltrated white spot lesions.

Methods: Forty eight extracted human molars were mounted to expose the buccal surface and establish the baseline color assessments using spectrophotometry with the CIE L*a*b* tri-dimensional color analysis system. Teeth were immersed in a buffering acidic solution for 96 hours to create artificial white spot lesions and then divided into four treatment groups (n= 12 teeth/group) according to the surface treatment and solution exposure for 28 days: Group 1 – resin infiltration + acid challenge (pH 3.3; 1 hour/day), Group 2 – resin infiltration + water (pH 7; 24 hour/day), Group 3 – no resin infiltration + acid challenge, Group 4 – no resin infiltration + water. The changes in color and lightness from spectrophotometic measurements were analyzed by Kruskal-Wallis and Mann Whitney tests.

Results: Groups exposed to repeated diet simulating acid challenges resulted in significant changes in color (P = 0.001) and lightness (P<0.001), compared with groups without acid challenge. Group 1 (resin infiltration + acid challenge) was significantly different from all other treatment groups and exhibited the greatest alteration in color (P = 0.001) and lightness (P<0.05), however, repolishing resin-infiltrated lesions can minimize the acidic effect.

Conclusions: Repeated acid challenges showed significantly detrimental influence on the color stability of resin-infiltrated lesions. Patients treated with resin infiltration should be aware of the potential for discoloration and minimize the consumption of acidic beverages.

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INTRODUCTION

White spot lesions (WSLs) are characterized by a loss of mineral content under an intact outer enamel surface, thereby, producing a visible white spot defect in the enamel surface.[1] WSLs are a common esthetic complication found in children, adolescents and adults and may arise as a result of incipient dental caries or from developmental defects that occurred during tooth development.

Healthy enamel is the most highly mineralized tissue with 96% of its composition a mineralized hydroxyapatite and the other 4% from organic fluids.[2] The first stages of carious disease are characterized by hypomineralization without cavity formation.[10] In the presence of WSL from incipient dental caries, this mineral phase is diminished and replaced by organic fluids, hence the term "enamel hypomineralization." The law of optics indicate that when there is a difference in refractive indices between two phases, there will be an interface causing deviation of incident light rays. The refractive index (RI) of healthy enamel, composed of primarily hydroxyapatite, is $RI_{enamel}=1.62$; so as a light ray passes through the enamel there are no modifications of its trajectory until it reaches the dentin-enamel junction.[2] In hypomineralized enamel, the demineralized enamel is replaced with organic fluids and air, each with a lower refractive index than that of health enamel ($RI_{air}=1.0$ and $RI_{water}= 1.33$); therefore, as the light ray encounters multiple interfaces between the enamel, water and air, the light is deviated and reflected becoming imprisoned in an "optical maze" that is perceived as white and hence creating a WSL.[10] The lesions become clinically visible when the mineral deficit of the body of the lesion compared to healthy enamel reaches 10%. Untreated WSL may result in progression to cavities and severe esthetic problems.[3]

Traditionally, several techniques have been proposed to camouflage WSLs; bleaching, microabrasion, remineralization through fluoride-containing products, and restorative procedures. Remineralization of WSLs is the most conservative treatment option, as it aims to control extrinsic bacteria and strengthen the outer enamel surface; however, with the remineralization technique the internal microporosities within the body of the WSLs often remain and therefore the whitish appearance persists.[4] In addition, sometimes during the remineralization process, stains get incorporated into the lesion, leading to the creation of brown spots and thus further compounding the esthetic problem. Excellent esthetic results have been achieved using restorative techniques such as composite resin and ceramic materials, but they are the most aggressive treatments and result in an irreversible loss of dental tissue.[5]

Recently, resin-infiltration, a new and innovative procedure, has been proposed as a minimally invasive treatment alternative of incipient, demineralized white spot lesions in enamel. Currently, the only resin-infiltration product on the market is ICON® (DMG, Hamburg, Germany); [2] which was originally developed to prevent proximal caries lesions' progression. The resin-infiltrant was additionally found to have a positive side-effect of masking the appearance of WSLs in enamel; therefore, serving as both a preventative therapy to arrest caries and also as a restorative treatment for unaesthetic WSLs.[4] The infiltrant utilized is a low-viscosity, light cured resin composed primarily of TEGDMA resin polymers.[6] A study conducted by Paris and Meyer-Lueckel demonstrated that the resin-infiltration technique is a good conservative alternative to microabrasion and restorative treatment for WSL on esthetically demanding teeth, such as the facial surfaces of maxillary incisors.[7] Resin-infiltration technique has quickly grown to be a widely accepted new way of treating WSLs and as a minimally invasive esthetic restoration.[8]

The resin-infiltration procedure involves two stages: the first stage involves the superficial demineralization of the hypermineralized surface layer of enamel by application of a 15% solution of hydrochloric acid, which effectively aids in opening up the pores of the enamel and enables access to the subsurface hypomineralized lesion. In the second stage, an extremely fluid and un-filled resin, is infiltrated into the depth of the hypomineralized lesion and replaces the water and air filled porosities with resin material. The resulting effect of resin-infiltration treatment is two-fold: the resin filled porosities effectively decrease the diffusion of acids across the enamel surface halting carious lesion progression and effectively mask the whitish appearance of the hypomineralized enamel by replacing the air and water filled porosities with a resin material whose refractive index closely resembles natural enamel (RI_{resin}= 1.52 and RI_{enamel} =1.62). Filling the air and water filled porosities (RI_{air}=1.0 and RI_{water}= 1.33) with a material that more closely matches the RI of enamel, effectively decreases the scattering of incident light rays and therefore enables the porosity to blend with the surrounding natural enamel.

Similar to other resin-based restorations, resin-infiltration systems are subject to color alteration over time.[8] Discoloration of resin-based materials may be caused by extrinsic and/or intrinsic factors. Intrinsic stain is caused by the discoloration associated with the properties from within the resin-material itself, such as, water sorption and the presence of unreacted methacrylate in the resin matrix.[9] Extrinsic stain is typically caused by external colorants and the adsorption of dyes from exogenous sources such as beverages, foods and typically varies according to the patient's habits.[8] A study conducted by Borges et. al found that demineralized WSLs treated with resin-infiltration exhibited significantly higher susceptibility to exogenous stains when exposed to different exogenous staining solutions (wine pH = 3.4 and coffee pH = 5.0) and exhibited significantly greater color instability when compared to untreated demineralized WSLs.[8.] In this study, it was also suggested that a solution of a lower pH, could further compromise the durability of the resin-infiltrant by softening the polymeric material, resulting in greater adsorption of the extrinsic pigments and decreased color stability of the resin.[8] The TEGDMA-based resin polymers utilized in the infiltrant, when compared to other dental resin polymers, such as UDMA and Bis-GMA, have shown the highest degree of water sorption.[10,9] A high degree of water sorption due to the hydrophilicity of the TEGDMA matrix resin has long been linked to color stability issues and discoloration of resin-based materials, as this process may plasticize and soften the resin matrix reducing its intrinsic color stability and increasing susceptibility to extrinsic stains.[9]

The oral environment causes degradation and aging of dental restorations due to constant contact with food and different beverages of varying acidities. Resin matrices of dental composites are softened by organic acids from different food and liquid components; therefore, the chemical environment in the oral cavity may have a critical influence on the degradation of resin-infiltration. Several studies have investigated the color stability of resin-infiltrates to exogenous stains, but few have directly evaluated the effect of acidic dietary simulating solvents on the color stability of resin-infiltrated WSL. Therefore, there is further need to evaluate the effects of dietary simulating acidic solutions on the color stability of resin-infiltrant materials.

Although it has been shown that resin-infiltrated WSLs are more susceptible to exogenous staining solutions, the effect of solutions with lower pH on the color stability of resin-infiltrated WSLs remains currently unclear. The aim of this in vitro study therefore is to investigate the effect of a low pH, diet simulating solution on the color stability of resin-infiltrated WSL.

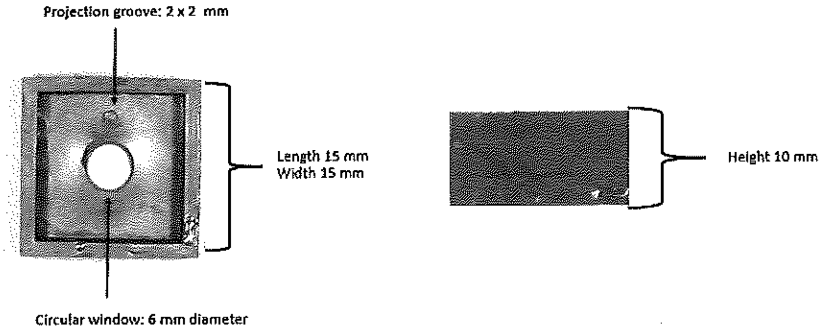
The hypothesis tested was that the color stability of resin-infiltrated WSLs would remain stable over time after exposure to pH cycling with a dietary simulating citric acid solution for 1 hour every day for 42 days.

MATERIALS AND METHODS

Specimen preparation

Forty-eight, non-carious, non-damaged extracted human molar specimens were collected from the National Institute for Dental and Craniofacial Research (NIDCR) and stored in a 0.5% chloramine-T trihydrate bacteriocidal solution for one week prior to use, then transferred and stored in demineralized deionized water (DDW) at 4° C up to the time of preparation for the study. In preparation of mounting the specimens within a silicone mold, molar specimens with a crown to root measurement greater than 15 mm in length were sectioned to remove the roots in order to permit full seating of the specimen within the dimensions of a silicone matrix (Fig 1).

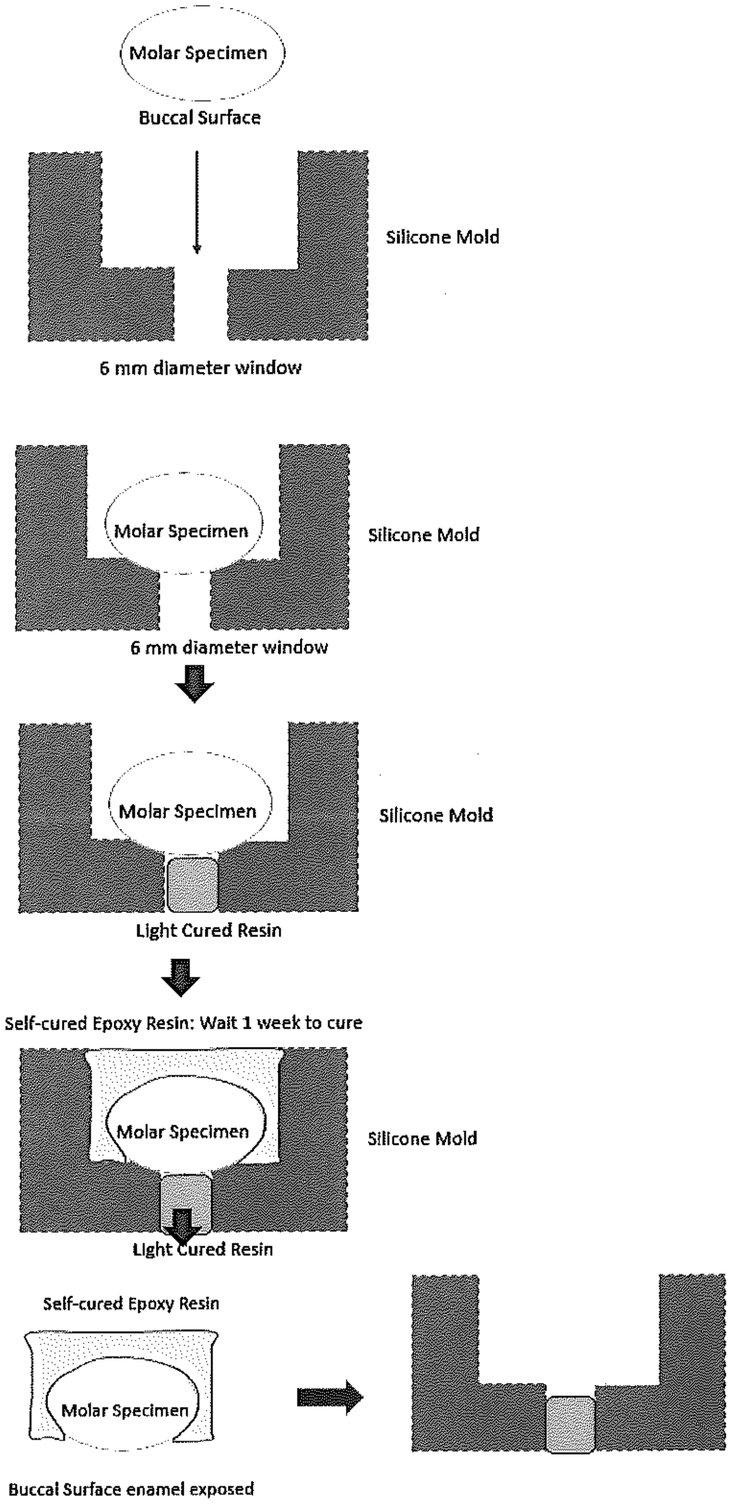
Fig 1 - Silicone mold dimensions and features



Each silicone matrix was fabricated with a 6 mm diameter window and with a 2 x 2 mm projection in the shape of a circular groove on the internal surface (Fig 1). The circular window was created to allow the buccal surface of each tooth to slightly protrude from the mold and the circular projection was utilized to create a groove to aid in repeated positioning and orientation of the specimens at the different time intervals of color read outs.

The molar specimens were positioned with the buccal enamel surface facing the bottom of the silicone matrix, pressed into the 6 mm diameter window (Fig 2). The buccal surface was then temporarily sealed through the 6 mm window with a light cured resin and then the silicone mold was filled with self-polymerizing epoxy resin and allowed to cure for 1 week. After the epoxy resin was deemed completely set, the light-cured resin within the window and silicone matrix were removed from each specimen (Fig. 2) to reveal specimens uniformly mounted within a cube of epoxy resin and 6 mm diameter window of exposed tooth enamel . The specimens' enamel surfaces were then sequentially abraded and polished with a sequence of abrasive paper disks (500, 800, 1000, 1200 granulation) by hand for 20 seconds in preparation for creation of artificial enamel lesions with a demineralizing solution.

Figure 2 – Schematic representation of specimen preparation



Experimental groups

After initial preparation, the specimens were stored in deionized and demineralized water (DDW) to prevent dehydration. The first color measurements were taken at baseline with a spectrophotometer Easy Shade® (VITA North America). Following Cohen-Carneiro et al's proposal, artificial enamel subsurface lesions were created by individually immersing and storing the specimens in a demineralizing buffer solution. The demineralizing solution was composed of 50mM acetate buffer solution containing 1.28 mM $Ca(NO_3)_2 \cdot 4H_2O$, 0.74 mM $KH_2PO_4 \cdot 2H_2O$, 0.03 ppm F from NaF at pH 5 for 96 hours in an unstirred solution at 25°C . The total volume of solution calculated for immersion of the specimens was $2mL/mm^2$ of exposed enamel area.

After the initial demineralizing treatment and creation of artificial enamel lesions, a new color measurement with the spectrophotometer, Easy Shade® (VITA North America) was performed and the specimens were then randomly divided into 4 experimental groups according to the treatment and solution employed (Table 1).

The artificially demineralized enamel lesions from G1 and G2 were selected to receive the resin-infiltration (ICON®, DMG, Hamburg, Germany) surface treatment, while the artificially demineralized enamel lesions from specimens in G3 and G4 did not receive resin-infiltration treatment of their lesions. The resin infiltration treatment administered to specimens in G1 and G2 followed the manufacturer's protocol for smooth-surface incipient caries (Table 2). To simulate repeated in vivo diet simulating acidic challenges, specimens in G1 (Resin + acid) and G3 (No resin + acid) were subjected to daily pH-cycling challenge, by alternating between DDW (pH 7.0; 23 hours) and citric acid (pH 3.3; 1 hours) for 28 days; whereas specimens in G2 (Resin only) and

G4 (No Resin/No Acid) were immersed in DDW (pH 7.0; 24 hours per day). Spectrophotometer color read outs were recorded every seven days of solution immersion for 28 days and after the final polish.

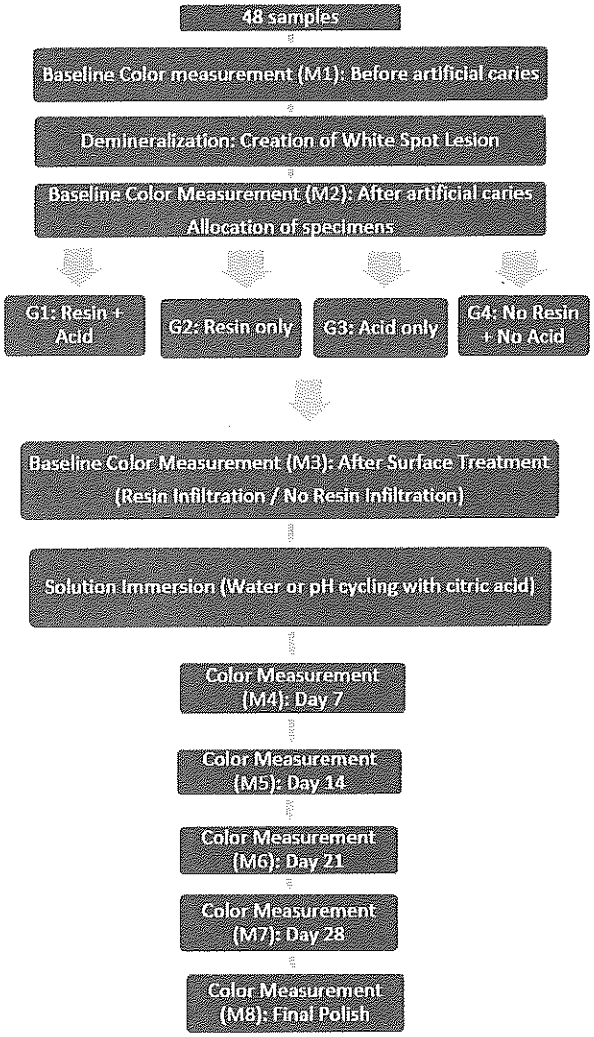
Table 1: Treatment Groups (n = 12)

Group	Surface Treatment	Citric Acid pH-Cycling (pH 3.3)	Duration
(G1) Resin + Acid	Resin Infiltration (ICON®, DMG, Hamburg, Germany)	1 Hrs/day	28 days
(G2) Resin only	Resin Infiltration (ICON®, DMG, Hamburg, Germany)	No pH cycling	28 days
(G3) Acid only	No Resin	1 Hrs/day	28 days
(G4) No Resin / No Acid	No Resin	No pH cycling	28 days

Table 2: Resin-Infiltration Protocol for Smooth Surface Incipient Lesions

Step of Procedure	Manufacturer's Protocol
1	ICON® - Etch was applied for 2 minutes
2	Specimens rinsed with water and air dried for 30 seconds
3	ICON® - Dry was applied for 30 seconds and air-dried
4	ICON® - Infiltrant applied for 3 minutes and light cured 40 seconds
5	ICON® - Infiltrant applied for 1 minute and light cured 40 seconds
6	Polish with Soflex Discs (3M ESPE)

Figure 3: Experimental Design



Color Evaluation

The primary color assessment of the specimens was done against a white background using a portable spectrophotometer EasyShade (VITA North America) for dental office use. The analysis was performed by means of the CIE L*a*b* (*Commission International L'Eclairage)* color system, which specifies color values through a tri-dimensional color space and utilizes 3 different parameters L*, a*, b*. In this system, the L* represents the quantitative measurement of lightness within a sample and ranges from 0 (black) to 100 (white), a* is a measure of green-red color (red values > 0; green values < 0) and b* is a measure of blue-yellow color (yellow values > 0; blue values < 0).[11] To standardize color evaluation, care was taken as follows: standardized ambient light conditions, placement of specimens against a white background during all color read outs; careful preparation of samples prior to color read outs (dried on table top with absorbent paper), standardization of the tip of the spectrophotometer (perpendicular and pressed flush against the buccal surface of the specimen) and repeatable positioning during read outs via the orientation groove.

The color analysis of the teeth was made before and after the production of artificial caries, 24 hours after resin-infiltration, every 7 days of solution immersion for 28 days and after the final polish (Figure 3). The L*, a*, and b* values were recorded at each color readout and the calculated change in the lightness (ΔL) and total color change ($\Delta E= [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$) of specimens was calculated. The spectrophotometry values obtained after surface treatment (resin infiltration/ no resin infiltration) were utilized as the baseline value to calculate the ΔE and the ΔL over the 28 days of solution immersion to either repeated diet simulating acidic challenges or DDW and for the final polish. Equations utilized to calculate the change in lightness and change in color after "x number of days" of solution immersion

$$\Delta L_{x\ days} = L_{x\ days} - L_{RInf}$$

$$\Delta E_{x\ days} = [(\Delta L_{x\ days} - \Delta L_{RInf})^2 + (\Delta a_{x\ days} - \Delta a_{RInf})^2 + (\Delta b_{x\ days} - \Delta b_{RInf})^2]^{1/2})$$

Baseline values and changes in L*, a* and b* after artificial caries and resin infiltration are compared between all four groups using one way analysis of variance:

Post hoc pairwise comparisons between groups are corrected for multiple comparisons using Bonferroni's method. Changes in L*, a*, b* over time (using resin infiltration measurement as the baseline) were examined using repeated measures analysis of variance: Post hoc pairwise comparisons between groups are corrected for multiple comparisons using Bonferroni's method. Given several outliers in the color (ΔE) data, differences between groups were examined using Kruskal-Wallis analysis of variance; pairwise comparisons using the Mann Whitney test were corrected using Bonferroni's method.

RESULTS

The results for the cumulative mean ΔL of all treatment groups is summarized in Table 3 and Figure 4. The change in lightness during solution immersion was calculated from the spectrophotometer L* values utilizing the "surface treatment" reading as the baseline for calculating the change in lightness over time. Over time, all treatment groups exhibited a significant decrease in ΔL ($p < 0.001$). By 28 days, the comparison of ΔL between all treatment groups was significantly different ($P<0.049$ for all comparisons), except there was no difference in ΔL between groups not exposed to repeated diet simulating acid challenges. Groups exposed to repeated diet simulating acid challenges resulted in a significant decrease in ΔL ($P<0.001$) when compared to treatment groups not exposed to diet simulating acidic challenges. The group treated with resin infiltration and acidic challenge (Group 1) exhibited the greatest overall change in lightness and decreased significantly more than the other groups ($p<0.02$ for comparisons to all other groups) Re-polishing specimens increased the lightness of all groups after solution immersion significantly ($p<0.001$ for each group) and helped to minimize the effect of solution immersion.

The results for ΔE between the treatment groups is summarized in Table 4 and Figure 6. After artificial creation of WSL in tooth specimens, there was no significant ΔE ($P=0.059$). The color of all groups after surface treatment exhibited a clinically significant change; however, there was no statistically significant difference between the four groups after resin-infiltration ($p=0.21$ for comparisons to all other groups). It should be noted that the values in Group 4, "No Resin/No Acid," were strongly affected by some large outlying numbers. The change in color during solution immersion was calculated from the spectrophotometer L*, a*, b* values utilizing the "surface treatment" reading as the baseline for calculating the change in color over time. After 28 days of solution immersion, each treatment groups exhibited a significant increase in color (ΔE) ($P=0.001$); however, the groups exposed to repeated diet simulating acid challenges resulted in statistically greater changes in color (ΔE) than treatment groups immersed in water ($P=0.001$). Of particular interest, the group treated with resin infiltration and exposed to repeated acidic challenges, exhibited the largest change in color when compared to all other groups ($p=0.02$). The final polish of specimens after 28 days of solution immersion, regardless of solution pH, significantly minimized the change in color among all treatment groups ($p<0.001$).

Table 3: Mean and Standard Deviation (SD) Data for Treatment Groups ΔL

Treatment Group	After WSL ΔL (L2-L1)	Surface Treatment ΔL (L3-L2)	Day 7 ΔL (L4-L3)	Day 14 ΔL (L5-L3)	Day 21 ΔL (L6-L3)	Day 28 ΔL (L7-L3)
G1: Resin + Acid	1.35 (5.38)	1.55 (6.72)	-7.8 (6.94)	-11.18 (9.08)	-12.78 (5.94)	-20.71 (5.19)
G2: Resin Alone	1.49 (4.77)	4.16 (4.33)	-3.33 (3.42)	-5.23 (4.15)	-3.99 (4.01)	-4.44 (4.03)
G3: Acid Alone	2.55 (4.42)	-0.28 (2.79)	-2.71 (3.26)	-4.65 (2.91)	-8.45 (4.49)	-12.13 (5.93)
G4: No Resin/No Acid	5.17 (3.99)	-2.7 (4.88)	-1.13 (1.92)	-4.27 (2.28)	-1.64 (1.44)	-2.28 (1.49)

Figure 4: Cumulative Change in Lightness (ΔL) of Treatment Groups

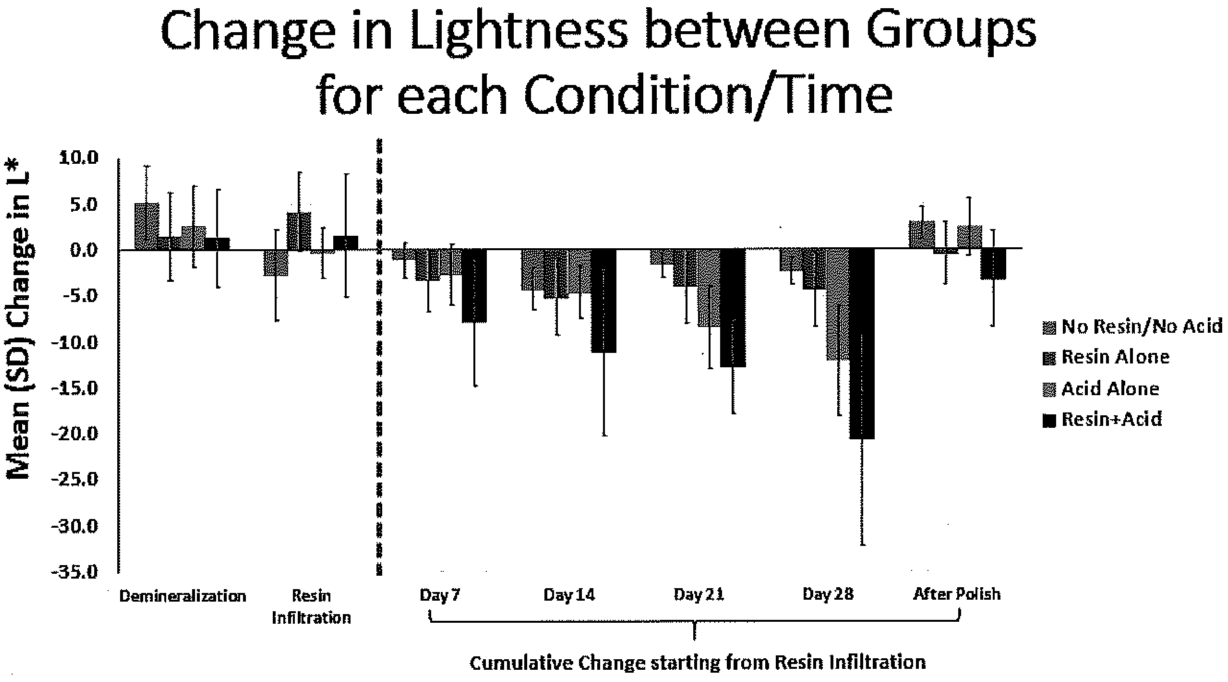
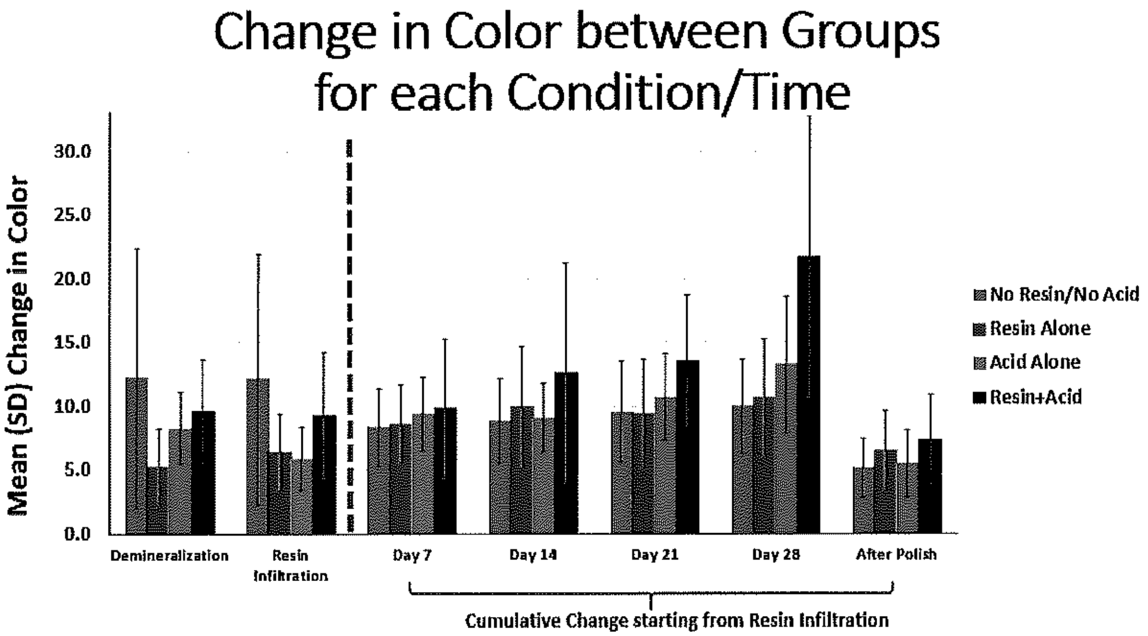


Table 4: Mean and Standard Deviation (SD) Data for Treatment Groups ΔE

Treatment Group	After WSL ΔE (E2-E1)	Surface Treatment ΔE (E3-E2)	Day 7 ΔE (E4-E3)	Day 14 ΔE (E5-E4)	Day 21 ΔE (E6-E5)	Day 28 ΔE (E7-E6)
G1: Resin+Acid	9.58 (4.04)	9.28 (4.96)	9.80 (5.47)	12.58 (8.61)	13.56 (5.09)	21.63 (11.03)
G2: Resin Alone	5.22 (3.04)	6.39 (2.97)	8.60 (3.05)	10.00 (4.72)	9.41 (4.22)	10.64 (4.59)
G3: Acid Alone	8.26 (2.82)	5.88 (2.45)	9.40 (2.90)	9.07 (2.72)	10.69 (3.42)	13.27 (5.35)
G4: No Resin/No Acid	12.22 (10.17)	12.11 (9.82)	8.31 (3.03)	8.84 (3.35)	9.55 (3.93)	9.95 (3.70)

Figure 5: Cumulative Change in Color (ΔE) of Treatment Groups



DISCUSSION

In the present study, human teeth were used and demineralized WSLs were artificially created to mimic the natural caries-like process, as done in previous in vitro studies.[12,13] However, the difference between the artificially demineralized WSL created utilizing an acidic buffer solution in vitro and the natural formation of carious lesions in vivo maybe a limitation to reflect the clinical conditions. Before and after artificial WSL creation, the change in lightness and change in color was found to increase among all groups. There was no statistically significant difference between treatment groups' ΔL or ΔE after artificial caries creation. Our findings regarding ΔE and ΔL after artificial WSLs are coincident with the findings of previous studies. The demineralization process mimics incipient caries and creates subsurface porosities, which fill with air and water and have a lower refractive index than enamel. The multiple interfaces of the subsurface porosity within the enamel increase light ray scattering, and result in the whitish optical appearance and the increase in lightness (L* value).

After artificial white spot lesions were created, treatment groups were divided to receive surface treatment with resin-infiltration or no treatment of the demineralized lesions. Changes in ΔL before and after resin-infiltration were recorded in our study and exhibited an immediate increase in ΔL after resin-infiltration; whereas groups without resin-infiltration resulted in a decrease in ΔL. These ΔL findings after resin infiltration are different than previous studies cited in the literature. The process of resin-infiltration should decrease light scattering and mask the white appearance of incipient lesions by replacing air-filled porosities with resin-material that closely matches enamel thereby exhibiting a decrease in the ΔL to baseline enamel value. Our in vitro design could have possibly affected the ΔL of teeth receiving resin-infiltration and affected the color-readout after resin-infiltration. There may have been a delay in rehydration of the teeth after etching resin-infiltrated teeth with 15% HCl due to the specimens being immersed in DDW for 24 hours versus saliva, resulting in dehydrated teeth and an increase in L* at the color-readout after resin-infiltration. Another possibility could have stemmed from potential excess residual resin left on the tooth surface after resin-infiltration, which may have potentially affected the specimen's L* value at the color-read out. All treatment groups, whether they received resin infiltration or not, exhibited an overall increase in ΔE at the color-readout taken after surface treatment; however, there were no statistically significant difference in ΔE between the groups immediately after resin-infiltration and therefore reaffirms the manufacturer's claim that resin-infiltration does not affect the tooth's overall color post resin-infiltration.

In this in vitro study, the effect of repeated diet simulating acidic challenges on the color stability of resin infiltrated lesions was evaluated and was found to have a significant impact after 28 days of solution immersion. The color stability of teeth was quantitatively evaluated utilizing the Easyshade spectrophotometer (VITA, North America) and CIE L*a*b* color assessment system to calculate the change in color (ΔE) and the change in lightness (ΔL) of tooth specimens. The color stability of treatment group G1 (resin + acid) was shown to exhibit the least color stability, as its total change in color and lightness over 28 days (+26.63 ΔE and -21.71 ΔL) was significantly greater than all other treatment groups; therefore, the hypothesis was rejected.

Literature suggests that unfilled methacrylate-based monomer TEGDMA utilized in the ICON® resin-infiltration system, was designed as such to effectively penetrate porous lesions to fill and prevent further demineralization and halt lesion progression; however, it's hydrophilic and unfilled nature leave the resin prone to water sorption and matrix degradation. [14, 15] It is thought that prolonged exposure to oral environments impacts the surface of resin-infiltrated teeth and may induce micro-cracks on the surface, rendering irregularities into the surface and increasing it's vulnerability to staining and discoloration. Surface roughness of resin-infiltrated carious lesions was reported to be as high as 6.9 μm on average using the ICON infiltration resin,[16] which is considerably higher than the 0.2 μm threshold generally regarded as acceptable for a restorative material to resist plaque accumulations. [14,15] It was further reported in the literature, that after thermocycling resin-infiltrated surfaces, to simulate one-year of clinical service, the surface roughness of resin-infiltrated lesions further deteriorated with up to a 70% increase compared to baseline.[17] The susceptibility of ICON® resin-infiltrated surface-properties to deteriorate and exhibit increased surface roughness and plaque accumulation, may additionally affect other surface properties such as the color stability of the resin-infiltration. As the surface topography of the resin-infiltrated lesion increases in irregularity and roughness, the incident light interacting with the resin-infiltrated enamel will more aggressively scatter and thereby impact the perceived color of the resin-infiltrated lesion.

Repeated diet simulating acidic challenges in the oral cavity may induce additional degradation of resin-hydroxyapatite bonds and affect the surface integrity of resin-infiltrated enamel lesions, potentially leading to increased surface roughness and increased scattering of incident light. These potential changes of the surface properties of resin-infiltrated teeth may lead to increased discoloration by the absorption of exogenous stains and pigmentation but also due to the increased scattering and reflection of incident light. Citric acid and other dietary solutions may accelerate the degradation of the surface resin-hydroxyapatite bonds and thereby increase the surface roughness of the resin-infiltrated enamel, resulting in increased light scattering and differences in the perceived color of the surface as detected by the Easyshade spectrophotometer. The findings of the present study are in agreement with recent reports that ICON resin-infiltrated carious lesions were prone to discoloration under staining challenges.[10, 8]

Discoloration of resin-based restorative materials may arise from intrinsic and/or extrinsic stains. Intrinsic stain is associated with the properties of the polymeric networks such as water sorption and the presence of unreacted methacrylate in the resin matrix, while extrinsic stain is caused by external colorants such as those in beverages and foods.[18] The ICON infiltration resin is primarily a TEGDMA-based polymer with high penetration efficiencies. Compared to other resin polymers commonly used in dentistry, TEGDMA has the highest degree of water sorption owing to the presence of hydrophilic ether linages. A high degree of water sorption has long been linked to color stability issues and discoloration of resin-based materials. On the other hand, surface roughness was recognized as the most important extrinsic factor for discoloration of resin-based dental materials. Most modern resin composite materials for esthetic restorations could achieve a high glossy finish with surface roughness below the acceptable threshold of 0.2 μm after finishing and polishing. Such a high degree of polishability appears to be difficult to achieve with the infiltration resin, as its surface roughness was not improved even after polishing with the Soflex finishing and polishing system.[19] The mechanisms underlying the discoloration of infiltration resin are likely twofold: one is intrinsically associated with its primary constituent TEGDMA, which has a high degree of water sorption and the other is extrinsically related to a less than ideal surface polish that deteriorates with time in the oral cavity. Further research is warranted to improve surface polish and esthetic outcomes of resin infiltration especially when smooth surface white spot lesions are involved in the esthetic zone.

Within the limitations imposed by an in vitro environment of the present study, it is observed that the dietary simulating solutions of citric acid has a significant effect on the resin-infiltrant color stability. As in the case of all in vitro studies, properties measured on a laboratory bench cannot be accurately extrapolated to in vivo clinical conditions; however, patients who have WSL in esthetic areas treated with resin-infiltration should be aware of the possible detrimental effects of citric acid and other acidic beverages and foods such as lemons, soda drinks and fruit juices. Therefore, clinicians might advise their patients to limit the intake of these kinds of acidic beverages and food when WSL within the esthetic zone are treated with resin-infiltration.

CONCLUSIONS

Within the limitations of this study, it may be concluded that dietary simulating solutions of citric acid showed significant detrimental influence on the color stability of resin-infiltrant material; however, re-polishing resin-infiltrated lesions can minimize the acidic effect. Resin-infiltrated WSL exposed to continuous pH cycling with citric acid showed a statistically significant decrease in both lightness and in total color change over time when compared to all other treatment groups.

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