Influence of Surface Sealant on the Color-Stability of a Composite Resin Immersed in Different Beverages

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Abstract
Aim: This study evaluated the influence of surface sealant (Fortify-Bisco) on the color-stability of a composite resin (Charisma-3M) immersed in different beverages.

Methods: It was prepared resin specimens with 10 mm-diameter X 2 mm-thickness for each beverage (soft drink, coffee, tea and artificial saliva=control). Specimens were divided in 2 groups (with or without surface sealant) and afterwards divided in 4 subgroups (n=7) according to the immersion solution. After 24 hours, it was started the cycling in the solutions 3 times/day during 5 minutes for 90 days. Opacity (∆L) and color change (∆E) of specimens were analyzed with a spectrophotometer (BYK-Gardner) in the different groups in relation to the control group. This handheld portable equipment is unique.

Results: Composite resin showed statistically significant difference (p<0.05) in the solutions, and coffee promoted the higher color change, followed by tea and soft drink. There was no difference between specimens sealed or not.

Conclusions: Therefore, surface sealant was inefficient on the protection against color change and coffee promoted the higher darkening of the specimens.

Key words: Surface sealant, Color-stability, Composite resin, Beverages

Introduction
Composite resin is the election restorative material of choice when the professional wants to achieve a harmonic direct restoration with the dental structures; [1-3] however, it has not provided the desirable requirements to be considerate an ideal restorative material, due to present on disability in the resistance to abrasion, [4] polymerization contraction with marginal infiltration as consequence [5,7] and color instability caused by superficial staining and internal discoloration [8].

In laboratory studies, the color of the specimens can be analyzed with a portable colorimetric spectrophotometer (Color guide 45/0, PCB 6807 BYK-Gardner GmbH Geretsried, Germany) using an optical geometry of 45°/0°. This device evaluate the color according to the CIELa*b* color system, in which L indicates color luminosity (ranging from 0 to 100, that means black to white); a* determines the amount of red (positive values) and green (negative values); b* determines the amount of yellow (positive values) and blue (negative values).

Resin composites are susceptible to staining, in in vitro and in vivo studies, when in contact with stains substances commons on diets, mainly in drinks, such as coffee, tea and wine [8-12]. Susceptibility of resins are due to some physical properties, such as water absorption, that can influence the color-stability, e.g., the resistance to staining [13,14]. Beside this, resin porously can facilitate foods stains and tobacco residues penetration [15,16], promoting dental biofilm accumulation, that can accelerate the superficial degradation of this material [17]. Besides, composite resin can be affect during finishing and polishing and these procedures can propitiate the formation of micro cracks and superficial irregularities [18].

Color changes in esthetic restorative materials have been attributed to a wide variety of possible causes [19], as the result of physical adsorption or physic-chemical reactions of the formulation of the materials during exposure to the oral environment. In these conditions, the esthetic restorations can be exposed to combined effects of light, solutions, discoloration and mechanical wearing, that frequently results in visible color change esthetically undesirable [20].

Mechanical or chemical degradation can increase the susceptibility of the material to extrinsic staining [20,21]. Other causative factors that may contribute to the color change of esthetic restorative materials include stain accumulation, dehydration, water sorption, leakage, poor bonding and surface roughness [20,21]. Besides, the consumption of some beverages, such as soft drinks, can compromise the physical properties of esthetic restorative materials and also the enamel, which, consequently, decrease the longevity of the restorations and the esthetic aspect of the smile [22].

In an attempt to overcome this problem, the use of a thin layer of a low-viscosity resin has been investigated. The so-called surface-penetrating sealant or rebinding agent should be able to fill, by capillary action, the structural micro defects and micro fissures that are formed during the insertion technique and finishing/polishing procedures. This approach is assumed to provide a more uniform and regular surface, thereby, strengthening the surface smoothness. In addition, the coating resin would be able to penetrate deeply into the interface microgaps, thus, providing improved marginal sealing especially in the dentin/cementum margins [23,24].

Surface sealants were developed specifically to promote an increase in wear resistance and optimize the marginal sealing of resin composites applied to posterior teeth [23]. Clinical trials have reported a significant increase in marginal integrity.
and wear resistance [1,23]. In addition, in vitro investigations have concluded that the re-sealing of restorations margins may optimize restorations marginal integrity [25]. However, there are few works that analyze the influence on the resistance to staining; [16] this way; there is an expectative that an application of a resinous-surface sealant can bring benefit to this aspect of the resin restorations.

Aim
The objective of the present study was to evaluate in vitro the influence of surface sealant on the color-stability of a composite resin immersed in different beverages.

Methods
A total of 56 disks (10 mm-diameter and 2mm-thickness) were fabricated from Charisma™ composite resin (Heraeus Kulzer, Inc. 99 Business Park Drive, Armonk, NY 10504 USA) using a stainless steel rings matrix. The composite resin was inserted in a single increment and light cured for 40 seconds, using a visible light-curing unit with 500mW/cm² power output (XL 3000, 3M Dental Products, St Paul, MN 55144-1000 USA). To assure the fabrication of specimens with highly regular surfaces before light-cure, a microscopic slide with a 500g weight was placed over the resin/matrix block in order to compact the material and provide a smooth and standardized surface. After one minute, the weight was removed and the resin composite was light-cured through the slide for 20s and released from the rings [26].

Specimens were randomly divided in 2 groups: with surface sealant (Fortify-Bisco) and non-sealed control group. Afterwards, specimens were divided in four subgroups (n=7) according to the immersion solutions.

At this moment, specimens that did not receive surface sealant were immersed in artificial saliva and stored at 37°C ± 1°C. For the groups that received surface sealant (FORTIFY™, Bisco, 1100 West Irving Park Road Schaumburg, Illinois 60193 USA), this was applied according to the manufacturers’ instructions. Firstly, phosphoric acid 37% (UNI-ETCH™, Bisco, 1100 West Irving Park Road Schaumburg, Illinois 60193 USA) was applied in specimens for 15 seconds; after they were washed in distilled water for 20 seconds and dried with absorbing paper. Surface sealant was applied for 5 seconds covering all surfaces, and an air jet was applied under surface for 3 seconds with 5cm of distance and light-cured for 20 seconds. Later, the specimens were immersed in artificial saliva for 24 hours and then started the cycling in the solutions studied.

Four different solutions were utilized on the aging: 1) artificial saliva=control (Laboratory of Pharmaceutical Sciences, Ribeirão Preto Pharmaceutical Sciences School, University of São Paulo, Ribeirão Preto SP 14040-903 Brazil), 2) soft drink=Coca-Cola® (Cia. de Bebidas Ipiranga, Ribeirão Preto SP 14055-630 Brazil), 3) coffee=Serra da Grama® (Torrefação e Moagem de Café Serra da Grama Ltda, São Sebastião da Grama SP 13790-000 Brazil) and 4) natural mate tea=Mate Leão® (Mate Leão, Curitiba PR 80230-030 Brazil).

The coffee solution was standardized by preparing it with 20g of coffee powder and 40g of sugar in 250ml of filter water, which were boiled and filtered with filter paper. To obtain the tea, it was utilized the natural mate tea; utilizing 1 bag and 40g of sugar in 250ml of boiled water.

Specimens were kept in artificial saliva at 37°C ± 1°C during the cycle interval [26]. The beverages were utilized at their usual consumption temperatures: soft drink at approximately 4°C, coffee and tea at approximately 70°C. The temperatures were measured with digital thermometer. Special care was used while dispensing the soft drink. In order to maintain an acceptable level of carbonic gas, a new bottle was opened for every 24-hours of immersion in the beverage; with the unused drink remained in the bottle being discarded [27].

The following protocol was adopted to simulate high beverage intakes: specimens were initially stored in artificial saliva for 24 hours, then immersed in 50ml of beverage, stirred for 5 minutes and returned to artificial saliva. After 4 hours in saliva, the specimens were immersed again in the beverage for 5 minutes under stirring, returned to artificial saliva for additional 4 hours and then submitted to a last 5-minute immersion in the beverage, ending the cycle. These procedures were repeated for 90 days.

After the cycling period, it was analyzed the color change of the specimens comparing them with the control group. Opacity (∆L) and total color change of specimens (∆E) were analyzed in the different groups, using a spectrophotometer (Color guide 45/0, PCB 6807 BYK-Gardner GmbH, Gertesried, Germany). This handheld portable equipment is unique as it measures color and gloss attributes simultaneously. The spectro-guide spectrophotometer, with color guide 45/0 and 11 mm aperture and circumferential illumination, allows repeatable results and a convenient sample placement.

Comparisons among specimens were realized using chrome and luminosity values. The measured color variation, after 90 days of immersion in the beverages, was analyzed using the ∆E calculus, determined by the follow equation: ∆E = [(ΔL)² + (Δa*)² + (Δb*)²]½

In the first place, data were analyzed as regards their distribution. As the data displayed normal distribution, they were submitted to 2-way ANOVA (material and solution); Turkey test was used to distinguish the averages of different groups and to study their interaction.

Results
The averages and the standard deviations of luminosity/opacity (∆L*), as well as ∆E, Δa* and Δb* values are described in the Table 1.

Data analysis showed that in relation to surface sealant, it was not observed statistical difference (p>0.05) between the two groups (sealed and non-sealed) (Table 1).

For the solutions of immersion, it was observed statistically significant difference of the composite resin when immersed in the solutions tested (in relation to ∆L* and ∆E values - Figures 1 and 2 respectively), and coffee promoted the higher color alteration (p<0.05), followed by tea and Coca-Cola.

The interaction solutions X sealant showed that specimens immersed in coffee (coffee X with sealant; coffee X without sealant) presented higher color alteration comparing to the others interactions. Results on the others solutions (tea and
soft drink) were also similar inside each solution, e.g., are sealant-protection independent (Table 1, Figures 1 and 2).

**Discussion**

Different methods have been utilized to evaluate color stability of composite resins and bleached teeth. The more utilized form is through visual analysis using comparisons with different color scales (Vita Zahnfabrik or Trubyte Bioform) or using photographic/data show analyses [28-30]. It is common related the difficult on the color choice, mainly attributed to the influence of some factors, such as: clinical perception of the observer and illumination of the environment and the object. Besides this, the lack of correlation on color scales and on natural’s teeth color, such as these factors compared with the nominal colors described on the resin tube, subsidy to this difficulty [28-31].

Other methods, less subjective and also more utilized to quantify color alterations, usually use colorimeters and

<table>
<thead>
<tr>
<th>Solution</th>
<th>Without Sealant</th>
<th>With sealant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke</td>
<td>0.83 (0.55)</td>
<td>1.21 (0.62)</td>
</tr>
<tr>
<td>Coffee</td>
<td>6.47 (1.26)</td>
<td>7.14 (1.35)</td>
</tr>
<tr>
<td>Tea</td>
<td>2.35 (0.52)</td>
<td>2.67 (0.54)</td>
</tr>
<tr>
<td>Coke</td>
<td>-0.66 (0.43)</td>
<td>-0.09 (0.39)</td>
</tr>
<tr>
<td>Coffee</td>
<td>-6.32 (1.38)</td>
<td>-7.04 (1.24)</td>
</tr>
<tr>
<td>Tea</td>
<td>-2.32 (0.53)</td>
<td>-2.57 (0.58)</td>
</tr>
<tr>
<td>Coke</td>
<td>-0.05 (0.28)</td>
<td>-0.12 (0.28)</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.17 (0.31)</td>
<td>0.34 (0.42)</td>
</tr>
<tr>
<td>Tea</td>
<td>0.07 (0.16)</td>
<td>0.08 (0.37)</td>
</tr>
<tr>
<td>Coke</td>
<td>-0.69 (0.55)</td>
<td>-1.12 (0.61)</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.98 (0.89)</td>
<td>0.57 (1.17)</td>
</tr>
<tr>
<td>Tea</td>
<td>0.13 (0.41)</td>
<td>-0.57 (0.33)</td>
</tr>
</tbody>
</table>

Different letters represents statistical significant difference between the lines (solutions).
spectrum-colorimeters. In spite of colorimeter be a more objective method than comparison with color scales, the analyses is dependent on the type of illuminating. Spectrum-photometers are electronic apparatus where the sample is putted in a dark compartment with standard-illumination, which exempt it from environment light. So, the results are definitive, reproducible and likely to be expressed in various color systems, also on the universally used CIE L′a′b′ [32]. When is evaluate the staining of the material through stains absorbed after immersion in the beverages, it is observed that higher values mean higher resin pigmentation, once that dark specimens absorb more light of the spectrum-photometers [2].

In the present study, the color change was obtained through Hunter equation \( \Delta E_{ab^*} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \), while luminosity values \((\Delta L^*)\) were reached using \(L^* = L^*(tx) – L^*(t0)\), where \((tx)\) represents immersion time and \((t0)\) baseline. The literature is not in agreement with respect to the limitations of the human eye in terms of acknowledging differences in color, considering that this limit differs from individual to individual [33,34]. The adopted classification of \(\Delta E\) values was determined by the National Bureau of Standards (NBS) that considers: 0.0 to 0.5 values: extremely slight change; 0.5 to 1.5: slight change; 1.5 to 3.0: perceivable change; 3.0 to 6.0: marked change; 6.0 to 12.0: extremely marked change; 12.0 or more: change to another color [35].

For some authors [31,32,36], \(\Delta E\) values higher than 2 can be clinically detectable. Others [30] showed that, under controlled laboratorial conditions, one unit of variation on \(\Delta E\) of CIE L′a′b′ system can be detectable for 50% of persons. On the same analyses, there are relative variations to the \(\Delta E\) value that can be clinically acceptable. For Ruyter et al.[37] and Dennison & Craig [38], this value is approximately 3 to 3.3; and variations between 2.2 and 4.4 are clinically acceptable for the USPHS - Healthy Lifestyles Program of the Commissioned Corps of the United States Public Health Service, and can be higher depending on the study [39].

It was utilized, on this study, dye substances usually found on diet, because according to Burrow & Makinson [40], the main cause of resin color alteration in vitro is caused by feed diet. From the utilized, the coffee confirmed to have the power to stain composite resins [12] and it was considered a potential solution for staining tests of composites [3,9]. In the present study, it was proved that coffee caused the greatest staining of composite resin. The \(\Delta E\) values, that show specimens color alteration, were relatively high, in special for specimens immersed in coffee, where a higher darkening of resin could be visible noted. These results are according to Mutlu-Sagesen et al. [41], Lu et al. [42], and Bagheri et al. [43] which observed a small darkening of composite resin; the color alteration increased according to the immersion period [43]. Only for soft drink the \(\Delta E\) values were not within the variation spectrum perceptible to human eye (2 to 3 units) [28].

Wiltshire & Labuschagne [12] showed that the higher color change clinically perceptible occurs after 24h of fluid contact, being accented with immersion in stains, such as wine and coffee, or with the extend for one week of contact with these fluids [31]. This sorption occurs mainly in the first week of storage [44]. In the present study, it was noted an accented and perceptible color alteration for the groups in coffee and tea. The surface sealant was not able to promote protection for resin.

This fact probably occurred due to chemistry type of monomer, molecular weight and polymers macromolecular structure of the surface sealants. It is also known that urethanes don’t show complete polymerization on it polymeric chain, and this can justify the penetration of dyes in poor areas [1,2,23].

Another justified point for this result can be the layer thickness. If the sealant layer presents a big thickness, being it a resin without load, the surface becomes more susceptible to absorb stains than a surface without this resin film or with a lower thickness [2].

It could be noted that the surface sealant was not able to protect the specimen’s surface against staining; nevertheless it is important to relate that new studies are necessary to find how the staining process occurs to determinate the real utilization of surface sealant. Therefore, it must be realized new researches to better determinate the advantages of surface sealant.

Conclusions
According to the results obtained in the present study and considering the in vitro study restrictions, it can be concluded that:
- The surface sealant utilized on top of composite resin was not efficient on the protection against color alteration.
- Coffee solution promoted the higher darkening of the specimens.

Disclosure statement
“The authors do not have any financial interest in the companies whose materials are included in this article.”

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