Influence of a Bleaching Agent on the Color Stability of Indirect Composite Resins Immersed in Dyes

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Abstract: This study aimed to evaluate the effect of a bleaching agent on the color of extrinsically pigmented indirect composite resins. Samples of five resins (Adoro, Resilab, Cristobal, Sinfony, Epricord) were manufactured and divided into five groups: red wine, coffee, orange juice, Coca-Cola, and artificial saliva (control). The stained samples were immersed in a 38% hydrogen peroxide solution for 30 min per week, over three weeks. Color readings were performed at the initial state (L0), after 21 days of dye immersion (ΔE1, L1), and after 7 (ΔE2, L2), 14 (ΔE3, L3), and 21 days (ΔE4, L4) of bleach immersion. Data were subjected to ANOVA and Tukey’s honestly significant difference (HSD) test (α = 0.05). The color alteration was greater in ΔE1, regardless of color solution, indicating extrinsic pigmentation. The Resilab group exhibited greater ΔE1 values than the other resins. The bleaching agent promoted bleaching action on the surfaces of the materials studied, removing the previously impregnated pigments.

Keywords: composite resins; bleaching agents; color; staining

1. Introduction

Beauty standards directly influence dental esthetics. Therefore, dental procedures that involve esthetics, such as restorations with composite resins and bleaching treatments, are under constant development [1].

The chromatic alteration of composite resins can be caused by intrinsic or extrinsic factors. The intrinsic factors are related to chemical and physical reactions in the deepest portions of the restoration, in addition to changes in temperature and humidity. The extrinsic factors are related to the adsorption or absorption of colored substances. In addition, the presence of hydrophilic particles within the resinous matrix, with the capacity to absorb water, and the size and distribution of the particles could provoke chromatic alterations of the restoration [2,3].

A material must have a natural appearance, biocompatibility, and longevity to be used in dental applications [4]. Indirect resin composites incorporate some advantages of porcelain into the composite resins without presenting inherent limitations [5]. In addition to having lower costs than porcelains, they possess better properties than direct resins: reduced polymerization shrinkage, increased flexural strength, resistance to abrasion and fracture, and increased color stability, presenting excellent clinical results [2,3,6].

Despite mechanical polishing being able to remove superficial stains from restorations made from composite resins [7], the use of bleaching agents could give better results in the removal of stains from these materials [8,9]. Different substances can be used as bleaching agents, such as carbamide peroxide.
and hydrogen peroxide [9]. For in-office application, Opalescence Xtra Boost is a hydrogen peroxide gel with a chemical activation that has a neutral pH, can be used efficiently and safely, and provides appropriate results in a short period of time [10].

Therefore, the objective of this study was to evaluate the efficacy of the use of bleaching agents on the color stability of extrinsically pigmented indirect composite resins. The null hypothesis was that the bleaching agent was not effective for removing impregnated pigments, originating from staining solutions from the surfaces of the tested indirect composite resins.

2. Materials and Methods

Five different brands of B2 (dentine)-colored indirect composite resins were evaluated (Table 1): Adoro (Ivoclar Vivadent Ltda., São Paulo, São Paulo, Brazil), Resilab Master (Wilcos do Brasil, Indústria e Comércio Ltda., Petrópolis, Rio de Janeiro, Brazil), Cristobal (Dentisply Ceramco, Burlington, NJ, USA), Sinfony (3M, Campinas, São Paulo, Brazil), and Epricord (Kuraray Noritake Dental, Tokyo, Japan) (Figure 1) [11]. Twenty-five samples from each brand were manufactured and divided into five groups, according to the type of staining solution (red wine, coffee, orange juice, and Coca-Cola) or artificial saliva (control group) (Table 2).

<table>
<thead>
<tr>
<th>Table 1. Indirect composite resins used for specimen confection.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brand</strong></td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>Adoro</strong></td>
</tr>
<tr>
<td><strong>Resilab Master</strong></td>
</tr>
<tr>
<td><strong>Cristobal</strong></td>
</tr>
<tr>
<td><strong>Sinfony</strong></td>
</tr>
<tr>
<td><strong>Epricord</strong></td>
</tr>
</tbody>
</table>
2.1. Manufacturing of Samples

The samples were manufactured in a cast stainless steel matrix (10 mm length × 5 mm width × 1.5 mm thickness) according to the recommendations of the manufacturers (Table 1) [10]. After the final polymerization, the samples were polished in a semi-automatic polishing machine (Ecomet 300PRO, Buehler, Lake Bluff, IL, USA), running at 300 rpm, with metallographic sandpaper of 240, 400, 800, and 1200 grit (Buehler, Lake Bluff, IL, USA), under constant irrigation with water. The polishing of the samples was finalized using a felt disc with diamond solution (Buehler, Lake Bluff, IL, USA). Each sample had its thickness checked, with the assistance of a digital caliper (500-171-20B, Mitutoyo, Tokyo, Japan), in order to ensure the correct dimensions. All samples were stored in a digital bacteriologic incubator (CIENLAB Equipamento Científicos Ltda., Campinas, São Paulo, Brazil), in distilled water at 37 ± 1 °C for 21 days. When not immersed in the bleaching solution, they were stored in artificial saliva [13].

Each sample was placed in a flask containing 1 mL of a specific solution (Table 2), and sealed to prevent its evaporation. Immersed in the solutions, which were substituted daily, the samples were stored in an incubator at 37 ± 1 °C for 4 hours per day for 21 days. When not immersed in the solution, they were stored in artificial saliva [12].

After the immersion, all samples were subjected to the 38% hydrogen peroxide bleaching agent (Opalescence Xtra Boost, Ultradent, South Jordan, Utah, USA) for 30 min per week, for 3 weeks, according to the recommendation from the manufacturer [13]. During this period, the samples continued to be stored in the incubator at 37 ± 1 °C for 21 days. When not immersed in the bleaching solution, they were stored in artificial saliva [13].

Table 2. Immersion solutions used in the study.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Brand</th>
<th>Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red wine</td>
<td>Periquita dry red wine, José Maria Da Fonseca Vinhos S.A., Azeitão, Portugal</td>
<td>Red grape varieties, conservative INS 220 (sulfur dioxide, SO₂), sulphurous acid, and 12.7% alcohol.</td>
</tr>
<tr>
<td>Coffee</td>
<td>Coffee Pilão, Sara Lee, Jundiaí, São Paulo, Brazil</td>
<td>Roasted and ground coffee.</td>
</tr>
<tr>
<td>Orange juice</td>
<td>Coca-Cola, Ribeirão Preto, Brazil</td>
<td>Orange juice, water, sugar, orange pulp, natural flavors, ascorbic acid, and citric acid.</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>Coca-Cola, Ribeirão Preto, Brazil</td>
<td>Carbonated water, sugar, cola nut extract, yellow dye IV, acidulant INS 338, and natural flavors.</td>
</tr>
<tr>
<td>Artificial saliva</td>
<td>Farmácia de Manipulação Apothecário, Araçatuba, Brazil</td>
<td>[KCl (0.4 g·L⁻¹), NaCl (0.4 g·L⁻¹), CaCl₂·2H₂O (0.906 g·L⁻¹), NaH₂PO₄·2H₂O (0.690 g·L⁻¹), Na₂S·9H₂O (0.005 g·L⁻¹), and urea (1 g·L⁻¹)].</td>
</tr>
</tbody>
</table>
2.3. Reading of the Color Alteration

The readings of the color alteration were performed in the following periods: initial (L0), after 21 days of immersion in the color solutions (ΔE1 and L1), after 7 days of immersion in the bleaching agent (ΔE2 and L2), after 14 days of immersion in the bleaching agent (ΔE3 and L3), and after 21 days of immersion in the bleaching agent (ΔE4 and L4). The readings of the color alteration (ΔE) and luminosity (L*) of the samples were performed with the assistance of a reflection spectrophotometer (UV-2450, Shimadzu Corp., Kyoto, Japan) [14,15]. Color alterations (ΔE) were calculated by means of the L*a*b* system, as established by the CIE—Commission Internacionale de l’Eclairage [16].

2.4. Statistical Analysis

The data describing the color alteration (ΔE) and the L* (CIELab) coordinates obtained were subjected to the three-way analysis of variance (ANOVA) with repeated-measure factors, and the Tukey honestly significant difference (HSD) test (α = 0.05), in order to detect statistically significant differences between the analyzed factors.

3. Results

From the results, it was observed that interactions between the type of resin, the staining solution used, and the period of analysis significantly affected the color alteration (ΔE) (P < 0.001) (Table 3) and the L* coordinate (P < 0.001) (Table 4).

The color alteration was greatest at ΔE1, regardless of the staining solution and the composite resin analyzed, indicating pigmentation of the materials after immersion. The Resilab group exhibited the greatest values of ΔE1, when compared to the other resins. From the analyses of ΔE2, ΔE3, and ΔE4, it was concluded that the bleaching agent produced a bleaching action on the surfaces of the materials studied, removing the previously impregnated pigments (Tables 5–9).

By considering the L* coordinate (Figures 2–6), it was verified that the bleaching agent permitted an increase in the lightness of the materials studied, after the immersion in the coloring solutions. This indicates a bleaching action on the surface.

![Figure 2](image-url)

**Figure 2.** Mean values of L* coordinates of Adoro resin for each color solution used, in each period evaluated. Different small letters indicate statistically significant differences (P < 0.05) between different color solutions in the same period. Different capital letters indicate statistically significant differences (P < 0.05) between different periods for the same color solution.
4. Discussion

The null hypothesis tested, that the bleaching agent was not effective for the removal of pigments originating from staining solutions from the surface of indirect resins, was rejected. This is because the
bleaching agent produced a bleaching action on the surfaces of the materials studied, removing the previously impregnated pigments (Tables 5–9, Figures 2–6).

It can be verified, through the results (Tables 5–9), that the delta of the color for all samples was greater than 3.3 in all color solutions. This indicates, by spectrophotometric analysis, an alteration of color which is visually perceptible and clinically unacceptable from the point of view of esthetics ($\Delta E < 3.3$) \[17,18\].

It is known that the alterations of the color of composite resins are multifactorial, involving intrinsic and extrinsic factors \[19–21\]. The intrinsic factors are related to the chemical stability of the material, which depends on the fractional conversion of the monomers present in the resinous matrix. The presence of residual monomers in the resinous material induces susceptibility to pigmentation by absorption of external substances \[22\].

![Figure 4](image1.png)

**Figure 4.** Mean values of $L^*$ coordinate of Epricord resin for each color solution used, in each period evaluated. Different small letters indicate statistically significant differences ($P < 0.05$) between different color solutions in the same period. Different capital letters indicate statistically significant differences ($P < 0.05$) between different periods for the same color solution.

![Figure 5](image2.png)

**Figure 5.** Mean values of $L^*$ coordinate of Cristobal resin for each color solution used, in each period evaluated. Different small letters indicate statistically significant differences ($P < 0.05$) between different color solutions in the same period. Different capital letters indicate statistically significant differences ($P < 0.05$) between different periods for the same color solution.
Figure 6. Mean values of L* coordinates of Sinfony resin for each color solution used, in each period evaluated. Different small letters indicate statistically significant differences ($P < 0.05$) between different color solutions in the same period. Different capital letters indicate statistically significant differences ($P < 0.05$) between different periods for the same color solution.

Table 5. Mean values of color alterations ($\Delta E$) of Adoro resin for each staining solution, before and after bleaching treatment.

<table>
<thead>
<tr>
<th>Resin</th>
<th>Staining Solution</th>
<th>Red Wine</th>
<th>Coffee</th>
<th>Orange Juice</th>
<th>Coca-Cola</th>
<th>Saliva</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adoro</td>
<td>$\Delta E1$</td>
<td>6.59 Aa</td>
<td>5.99 Aab</td>
<td>5.42 Ab</td>
<td>6.14 Aab</td>
<td>0.57 Bc</td>
</tr>
<tr>
<td></td>
<td>$\Delta E2$</td>
<td>2.79 Bb</td>
<td>5.05 Ba</td>
<td>1.89 Bc</td>
<td>2.20 Bbc</td>
<td>0.45 Bd</td>
</tr>
<tr>
<td></td>
<td>$\Delta E3$</td>
<td>3.40 Ba</td>
<td>2.47 Cb</td>
<td>1.89 Bb</td>
<td>2.47 Bb</td>
<td>1.96 Ab</td>
</tr>
<tr>
<td></td>
<td>$\Delta E4$</td>
<td>0.76 Ca</td>
<td>0.66 Da</td>
<td>1.20 Ba</td>
<td>1.22 Ca</td>
<td>0.85 Ba</td>
</tr>
</tbody>
</table>

Means followed by the same capital letter in column do not differ ($P < 0.05$; Tukey).
Means followed by the same lowercase letter in the line do not differ ($P < 0.05$; Tukey).

Table 6. Mean values of color alterations ($\Delta E$) of Resilab resin for each staining solution, before and after bleaching treatment.

<table>
<thead>
<tr>
<th>Resin</th>
<th>Staining Solution</th>
<th>Red Wine</th>
<th>Coffee</th>
<th>Orange Juice</th>
<th>Coca-Cola</th>
<th>Saliva</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resilab</td>
<td>$\Delta E1$</td>
<td>13.49 Ad</td>
<td>29.44 Ac</td>
<td>35.64 Aa</td>
<td>34.53 Ab</td>
<td>33.68 Ab</td>
</tr>
<tr>
<td></td>
<td>$\Delta E2$</td>
<td>8.15 Ba</td>
<td>4.61 Bb</td>
<td>1.18 Dc</td>
<td>1.87 Cc</td>
<td>1.34 Cc</td>
</tr>
<tr>
<td></td>
<td>$\Delta E3$</td>
<td>5.13 Ca</td>
<td>3.19 Cb</td>
<td>2.26 Ccd</td>
<td>1.77 Cd</td>
<td>2.93 Bbc</td>
</tr>
<tr>
<td></td>
<td>$\Delta E4$</td>
<td>4.56 Dab</td>
<td>3.87 BCab</td>
<td>3.53 Bb</td>
<td>4.77 Ba</td>
<td>1.98 BCc</td>
</tr>
</tbody>
</table>

Means followed by the same capital letter in column do not differ ($P < 0.05$; Tukey).
Means followed by the same lowercase letter in the line do not differ ($P < 0.05$; Tukey).
Despite the versatility and good esthetic results of resinous materials, the absorption of staining agents is still the most prominent reason for chromatic alterations of these materials, and staining of restorations [23]. Among the liquid solutions tested in the present study, red wine (greater $\Delta E_1$ for Adoro and Sinfony), coffee (greater $\Delta E_1$ for Epricord and Cristobal), and orange juice (greater $\Delta E_1$ for Resilab) affected the color stability the most, with a statistically significant difference from the other solutions (Tables 5–9). According to some studies, coffee possesses a great capacity for staining, caused by absorption and adsorption of yellow pigments of low polarity, which possess a chemical affinity to the polymeric phase of the resinous material [19,24,25]. Similar to coffee, some studies demonstrate the great effect that red wine shows in pigmentation of resinous materials, due to the alcohol it contains [24,26]. Orange juice contains citric acid, which could influence the pigmentation of materials [27].

Several studies have also demonstrated a staining potential of tea, showing greater pigmentation than coffee [28] and grape juice [29], for example. The color alteration is a result of theaflavins present in tea leaves, which produce a yellowish-brown stain [16]. Therefore, this staining solution should be evaluated in further studies for a better understanding of its behavior.
Many times, dental surgeons perform superficial polishing of the material, trying to minimize staining and to remove extrinsic pigments from the surface of the restoration, thus increasing the longevity of the restoration. However, some studies affirm that bleaching agents could also be capable of removing intrinsic and extrinsic stains from restorations [8,9,30,31]. This was observed in the present study, in which the values of ΔE2, ΔE3, and ΔE4 indicated that the bleaching agent effectively decolored the surfaces of the materials (Tables 5–9). Nonetheless, to evaluate only the ΔE values could induce an error, since the color of these materials is affected by a combination of intrinsic and extrinsic factors, and the correlations in the results obtained by existing laboratory methods, such as the CIE L*a*b*, are poor [32], many times making it necessary to evaluate each coordinate.

Values of the L* coordinate (Figures 2–6) extend from 0 (black) to 100 (perfect white), describing the luminosity of the sample. It was observed that after the immersion in the staining solutions used, the bleaching agent produced an increase in the lightness of the resins analyzed, resembling the initial values. This indicates that removal of the pigments impregnated on the surfaces of the materials studied could have occurred.

However, this may not occur clinically, since the effects of the solutions tested could be modified by the action of bacterial biofilms and saliva. The laboratory tests, in which immersions of these restorative materials are performed in different solutions, are biased by disregarding these factors [9]. In addition, the bleaching agents could also provoke the detachment of charged particles from the surface of the resinous materials, since hydrogen peroxide can cause oxidation and reduction reactions [33,34]. This action could lead to an increase in the superficial roughness, facilitating even more staining of the material when it is again exposed to staining solutions [8,9,30]. Therefore, more in vitro studies that simulate the effects of these factors, and laboratory methods that possess a strong correlation between the laboratory tests and the results found in clinics, are necessary.

In the present study, a challenge was performed, which consisted of periods of exposure to solutions intercalated with periods of exposure to saliva, simulating oral conditions with high accuracy. The clinical implication of this study is that the greatest color alteration was observed in ΔE1, independent of color solution, indicating extrinsic pigmentation. The Resilab group exhibited greater values of ΔE1 when compared to the other resins. The 38% hydrogen peroxide-based bleaching agent effectively bleached the surfaces of the materials studied. Therefore, these findings are important to patients and can help scientists and professionals in their clinical practice.

5. Conclusions

Based on the results obtained, and considering the limitations of this study, it can be concluded that the 38% hydrogen peroxide-based bleaching agent produced a bleaching action of the surfaces of the materials studied, removing the previously impregnated pigments.

Author Contributions: In regards to the contributions of each author, all authors contributed equally to the work. M.C.G. and D.M.d.S. participated in the concepts and coordination of the study, performed the study design, and drafted the manuscript. E.V.d.d.S., J.B.M. and D.C. conceived the study, fabricated the samples, and participated in assays, as well helped draft the manuscript. F.P.d.C. performed the statistical analysis and participated in interpretation of data. All authors read and approved the final manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

References


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