Spectrophotometric evaluation of color changes of esthetic brackets stored in potentially staining solutions

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ABSTRACT

The purpose of this study was to evaluate, in vitro, the chromatic behavior of esthetic brackets stored in potentially staining solutions. The sample were divided into four groups according to the commercial brand and stored in four different solutions (distilled water, cola soda, coffee and mouthrinse) at 37°C for 14 days. Possible color changes measured according to the CIE L*a*b* color system with a spectrophotometer at five intervals of time after storage. The statistical analysis was carried out using ANOVA to 1%, Tukey’s tests and decomposition of interactions with a significance level of 5%.The color changes were dependent on the solution, storage time and the brand of brackets. The largest color changes were observed in the G3, followed by G2/G4/G1. The esthetic brackets do not present satisfactory and stable chromatic behavior.

DESCRIPTORS

Color. Orthodontic brackets. Spectrophotometry.

INTRODUCTION

The increasing demand by the adult population for orthodontic treatment has led to the use of esthetic brackets. The plastic brackets, developed in 1969, still present several problems, such as limited torque control, excessive wear and structural fragility, water absorption, low bond strength, high friction with orthodontic wires, outstandingly high color instability, and structural deformation. Thereafter, the original composition was modified with the incorporation of glass fibers or ceramic particles into the polycarbonate polymer matrix, resulting in the so called “composite” brackets, as well as the development of new types of polymers. Nevertheless, these problems have not yet been completely resolved.

In an attempt to eliminate the problems with polymeric accessories, ceramic brackets were developed in 1986, used in two forms: monocristalline or polycrystalline. The polycrystalline is more widely used, more opaque and presents less optical clarity. However, there are still some limitations, such as staining, frictional resistance, friability, abrasion of antagonist teeth, and problems with removal.

The color changes in esthetic brackets are of a multifactorial origin. Discoloration of dental materials may be the result of intrinsic factors such as water absorption, incomplete polymerization of adhesives or resins, matrix composition of the material, content and size of reinforcement particles, brand, tone, or extrinsic factors such as ingestion of food dyes containing caffeine (coffee, tea, colas), mouthrinse use, saliva, nicotine, lipsticks, heat, time and polymerization intensity.

OBJECTIVE

Therefore, the objective of this study was to evaluate the color changes of esthetic brackets after storage in potentially staining solutions. The null hypothesis to
be tested was that the esthetic brackets did not change color after contact with dye solutions.

**MATERIAL AND METHODS**

**Brackets**

For this study, 160 esthetic brackets for central incisors on the right side were used, of the Roth type, slot 0.022” x 0.028”, of different brands (Table 1).

**Solutions**

Four different solutions were used: (1) distilled water; (2) cola soda (Coca-Cola®, produced by Spaipa, Marília, SP, Brazil); (3) soluble coffee (Nescafé®, produced by Nestlé of Brazil Ltda, Araras, SP, Brazil), prepared according to the manufacturer’s recommendations; (4) mouthrinse containing alcohol (Listerine® Tartar Control, produced by Altana Pharma Ltda, Jaguariúna, SP, Brazil, Custom Johnson & Johnson Industrial Ltda).

**Study groups**

Four groups were formed with 40 brackets for group and ten brackets for solution (Table 1).

**Storage**

Each bracket was stored in a polypropylene microtube with cover, enumerated, and stored at 37°C. All solutions and microtubes were regularly renewed after every 24 hours of storage. The total storage period was 14 days.

**Spectrophotometric analysis**

The color change readings were made using a reflectance spectrophotometer (Un-Visible Spectrophotometer UV-2450®, manufactured by Shimadzu, Kyoto, Japan) with wavelength range 380-780 nm and standard illumination D65®. To allow the standard positioning of the brackets during the reading, four individual polystyrene chloride (PVC) matrices, black color were fabricated, one for each brand of bracket, with a standard fitting and precise positioning of the bracket-matrix set for later reading the bracket color (Figure 1). Before the readings, each bracket was washed by ultrasonic for one minute, and properly dried on paper towels. The color change to be calculated by the CIE L*a*b* system, and the total color difference (ΔE*) was calculated by the following equation: ΔE* = [(ΔL*)² + (Δa*)² + (Δb*)²]½. The L* parameter corresponds to the value or degree of lightness or brightness and a*b* values of chroma, where +a* is red and -a* is green, +b* is yellow and -b* is blue.

**Data collection**

The color change reading was taken by means of the software attached to a computer with a previously established configuration, and the value of ΔE* was automatically obtained for each bracket in each experimental period, generating a mean ΔE* for each experimental time, bracket brand and solution. The experimental times were: T₀ (before the initial immersion), T₁ (1 day after the initial immersion), T₃ (3 days), T₇ (7 days), T₁₀ (10 days) and T₁₄ (14 days after immersion).

**Table 1**

<table>
<thead>
<tr>
<th>Group</th>
<th>Bracket</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Material</th>
<th>Lot number</th>
<th>Solutions</th>
<th>Brackets for solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Composite®</td>
<td>Morelli Orthodontics, Sorocaba, SP, Brazil</td>
<td>Plastic</td>
<td>Polycarbonate reinforced with glass fiber (30%)</td>
<td>1066487</td>
<td>Distilled water</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cola soda</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coffee</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mouthrinse</td>
<td>10</td>
</tr>
<tr>
<td>G2</td>
<td>Silkon Plus™</td>
<td>American Orthodontics, Sheboygan, WI, USA</td>
<td>Plastic</td>
<td>Polycarbonate with ceramic particles (30%)</td>
<td>0201</td>
<td>Distilled water</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cola soda</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coffee</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mouthrinse</td>
<td>10</td>
</tr>
<tr>
<td>G3</td>
<td>Invu™</td>
<td>TP Orthodontics, La Porte, IN, USA</td>
<td>Ceramic</td>
<td>Polycrystalline alumina, with polycarbonate base</td>
<td>1258C05</td>
<td>Distilled water</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cola soda</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coffee</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mouthrinse</td>
<td>10</td>
</tr>
<tr>
<td>G4</td>
<td>Transcend™ 6000</td>
<td>3M/Unitek, Monrovia, CA, USA</td>
<td>Ceramic</td>
<td>Polycrystalline alumina</td>
<td>0904005766</td>
<td>Distilled water</td>
<td>10</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>Coffee</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Mouthrinse</td>
<td>10</td>
</tr>
</tbody>
</table>
Measurement of pH change

The pH of the solutions was measured before and after 24 hours of initial immersion and storage in polypropylene microtubes (Table 2), using ion analyzer (Orion Research 720A, Orion, USA) coupled to a magnetic stirrer (NT 101, Nova Técnica, Piracicaba, SP, Brazil).

Statistical analysis

Statistical analysis was performed using the SAS System™ and Microsoft Excel® programs. According to the Kolmogorov-Smirnov test, data distribution was normal with p=0.0539. Next, an arcsine transformation was performed and the three-factor analysis of variance (brand, solution and time) was applied (Table 3). Since there were no significant differences between any of the sources of variation, the Tukey’s test was applied and the decomposition of the interactions brand*solution*time was performed. The level of significance was 1% for analysis of variance and 5% for the decompositions.

Results

The mean color change values and their standard deviations (sd) during the experiment are shown in Table 3. Tests were also performed for comparisons between brands, solutions and time (Tables 4 to 6).

Group 1

In the distilled water solution, when chronologically compared, ΔE* values were statistically significant. In the soda, the values from ΔE* showing a gradual increase over time, with statistically significant differences. Similarly, the brackets stored in coffee showed a gradual increase in the value of ΔE*, statistically significant. When stored in the mouthrinse, only the value of ΔE* was found to be statistically significant when compared with the other values. (Figure 2)

Group 2

In distilled water the values not showing statistically significant difference. In the soda, showed a gradual increase over time, with statistically significant difference. The brackets stored in coffee also showed a gradual increase in the value of ΔE* with over time, and were statistically significant. In the mouthrinse only the value of ΔE*, was found to be statistically significant when compared with the other values. (Figure 3)

Group 3

For distilled water, statistically significant difference was found only between the values of ΔE*. In the soda, showed a gradual increase over time, with no statistically significant difference, except between the values of ΔE* and ΔE*. For coffee, no statistically significant difference were found between the values of ΔE*, ΔE*, and ΔE*, despite showing a tendency towards a gradual increase in

Table 2

<table>
<thead>
<tr>
<th>Solution</th>
<th>Before immersion</th>
<th>24 hours after immersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>6.34</td>
<td>6.42</td>
</tr>
<tr>
<td>Cola soda</td>
<td>2.61</td>
<td>4.80</td>
</tr>
<tr>
<td>Coffee</td>
<td>4.93</td>
<td>4.81</td>
</tr>
<tr>
<td>Mouthrinse</td>
<td>4.33</td>
<td>4.20</td>
</tr>
</tbody>
</table>

Figure 1 - Bracket-matrix set. (a) posterior view; (b) demarcations to position; (c) brackets attached.
Table 4
Comparison of performance between groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of measures</th>
<th>Average</th>
<th>Tukey</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>200</td>
<td>0.12511</td>
<td>A</td>
</tr>
<tr>
<td>G2</td>
<td>200</td>
<td>0.13725</td>
<td>B</td>
</tr>
<tr>
<td>G3</td>
<td>200</td>
<td>0.22339</td>
<td>C</td>
</tr>
<tr>
<td>G4</td>
<td>200</td>
<td>0.12355</td>
<td>A</td>
</tr>
</tbody>
</table>

Table 5
Comparison of the potential of the staining solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Number of measures</th>
<th>Average</th>
<th>Tukey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>200</td>
<td>0.085010</td>
<td>A</td>
</tr>
<tr>
<td>Cola soda</td>
<td>200</td>
<td>0.165116</td>
<td>B</td>
</tr>
<tr>
<td>Coffee</td>
<td>200</td>
<td>0.223280</td>
<td>C</td>
</tr>
<tr>
<td>Mouthrinse</td>
<td>200</td>
<td>0.135907</td>
<td>D</td>
</tr>
</tbody>
</table>

Different letters represent statistically significant difference.

Table 3
Mean values of ΔE* and standard deviation of each group, according to the solution over time

<table>
<thead>
<tr>
<th>Group</th>
<th>ΔE* 1</th>
<th>ΔE* 3</th>
<th>ΔE* 7</th>
<th>ΔE* 10</th>
<th>ΔE* 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.445a</td>
<td>0.725b</td>
<td>0.408a</td>
<td>0.533ab</td>
<td>0.750b</td>
</tr>
<tr>
<td></td>
<td>(0.194437)</td>
<td>(0.33768)</td>
<td>(0.287626)</td>
<td>(0.300335)</td>
<td>(0.450876)</td>
</tr>
<tr>
<td>G2</td>
<td>0.810a</td>
<td>0.696a</td>
<td>0.772a</td>
<td>0.606a</td>
<td>0.750a</td>
</tr>
<tr>
<td></td>
<td>(0.44572)</td>
<td>(0.302515)</td>
<td>(0.371118)</td>
<td>(0.405112)</td>
<td>(0.450876)</td>
</tr>
<tr>
<td>G3</td>
<td>0.597a</td>
<td>1.295b</td>
<td>1.389b</td>
<td>0.606a</td>
<td>0.750a</td>
</tr>
<tr>
<td></td>
<td>(0.407923)</td>
<td>(0.387076)</td>
<td>(0.34812)</td>
<td>(0.286543)</td>
<td>(0.263363)</td>
</tr>
<tr>
<td>G4</td>
<td>0.552a</td>
<td>0.632a</td>
<td>0.779a</td>
<td>0.537a</td>
<td>0.740a</td>
</tr>
<tr>
<td></td>
<td>(0.314812)</td>
<td>(0.349374)</td>
<td>(0.571731)</td>
<td>(0.346187)</td>
<td>(0.338625)</td>
</tr>
</tbody>
</table>

Different letters represent statistically significant difference intragroups.
the value of $\Delta E^*$. In the mouthrinse, the values indicating that there was no statistically significant difference, except between the values of $\Delta E^*_3$ and $\Delta E^*_7$ (Figures 4 and 5).

**Group 4**

For the distilled water solution the values of $\Delta E^*$ were not statistically significant. In the soda, the values no showed statistically significant difference. In coffee, despite the trend towards gradual increase over time, there was no statistically significant difference between the values of $\Delta E^*_3$, and $\Delta E^*_7$. In the mouthrinse, only the value of $\Delta E^*_1$ was found to be statistically significant, despite the gradual reduction in the values of $\Delta E^*$ over time. (Figure 6)

Considering the solutions used and the period of time of the trial as an overall treatment for the studied brands, the mean values of $\Delta E^*$, in ascending order, were found for the G₁ and G₃, followed by G₂ and G₄ (Table 4). When comparing the means of the solutions, it was possible to prove that coffee caused the greatest color change, followed by soda, mouthrinse and distilled water (Table 5). When comparing the values of $\Delta E^*$ versus time, it was observed that higher color change values were recorded in $T^*_{14}$, indicating that the longer the storage period, the greater the trend towards change color (Table 6).

**DISCUSSION**

As esthetics is their main advantage over metal brackets, the stability and color match of esthetic brackets is a cause for concern. Some authors have attempted to correlate the numerical values of color changes with visual perception, by means of spectrophotometry of esthetic brackets and composite resin or prosthetic restorations. However, these thresholds of reference for the $\Delta E^*$ cannot be compared with those in this study because the results are dependent on the methodology, moreover, the brackets tested were different.

It has been shown that the brand, the solution and storage time influence the degree of color change of the materials, which can also be observed in this experiment (Tables 4 to 6), since all bracket brands tested underwent color change in all solutions over time. The storage period was taken with the purpose of exposing the brackets to extreme conditions to assess the degree of staining, since after this period, there is a trend towards saturation. Moreover, a period of 24 hours of artificial treatment is considered very short to investigate the color change of the composites. The choice of solutions was based on the literature and the products routinely used by orthodontic patients.

### Table 6

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of measures</th>
<th>Average</th>
<th>Tukey*</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>160</td>
<td>0.145502</td>
<td>A</td>
</tr>
<tr>
<td>T₃</td>
<td>160</td>
<td>0.137901</td>
<td>B</td>
</tr>
<tr>
<td>T₇</td>
<td>160</td>
<td>0.148316</td>
<td>A</td>
</tr>
<tr>
<td>T₁₀</td>
<td>160</td>
<td>0.159168</td>
<td>C</td>
</tr>
<tr>
<td>T₁₄</td>
<td>160</td>
<td>0.170695</td>
<td>D</td>
</tr>
</tbody>
</table>

*Different letters represent statistically significant difference.

**Figure 2 - Behavior of G₁**

**Figure 3 - Behavior of G₃**

**Figure 4 - Behavior of G₅**
Figure 5 - Behavior of G₃ over time (T₀ to T₁₄) in distilled water (a), soda (b), coffee (c) and mouthrinse (d).

Figure 6 - Behavior of G₄

Among the evaluated groups, color changes were observed in the G₁ and G₃ in distilled water, resulting from the loss of brightness (L*) caused by water absorption, since the value of L* was decreased in relation to baseline (T₀). Water absorption by dental materials can be explained by differences in composition, size, quantity and distribution of particles within the matrix. Water absorption into the G₂ and G₄ brackets was lower, with no statistically significant difference between them.

In the soda, only G₂ underwent no statistically significant change in color, although the mean ΔE* value over time was relatively high. In the pH measurement of the solutions, it was found that the soda had the lowest initial pH (Table 2), which possibly affected the surface integrity of the specimens, favoring color change probably due to the absorption of pigments from the solution by the brackets.

For all groups stored in coffee there was statistically significant difference, with higher ΔE* values, which shows the greatest potential of this staining solution (Table 5), in agreement with previous studies. This color change was due to the large amount of yellow pigments in the solution, by adsorption and absorption, which could be corroborated the increase in the values of the coordinate b*.

In mouthrinse, all groups suffered color change, and the highest ΔE* values were observed for G₁. According to a previous study, 12 hours of immersion is equivalent to a period of one year under clinical conditions, that corresponding at only one daily rinse with duration of two minutes, with great compatibility with the values found from T₁ to T₃. Some authors reported that alcohol tends to alter the surface properties of composites, increasing the area of adsorption of pigments. Since the color of the mouthrinse was blue, the coordinate values L* and b* decreased gradually, which contributed to the higher ΔE* values for the G₁, particularly in T₁, possibly due to some type of specific reaction with some constituent of the ceramic matrix, since no other group showed similar behavior. According to literature whether or not mouthrinses contain alcohol in their composition, they affect the microhardness of restorative materials. Other authors reported no effect, saying that the behavior of this solution is no different from that of distilled water that also was observed in this study.

Although the literature reports that the low pH and high concentration of alcohol tend to increase the potential for staining of certain products, this study showed that the factor most responsible for color changes in the brackets was the amount and type of pigment in the solution, which is in agreement with previous studies. It was also reported that changes in optical properties (opacity/translucency) of the polymeric matrix may be responsible for clinically observed color change.

Due to these complications, a number of variables (intrinsic and/or extrinsic) should be considered in the inference clinic. The complex interaction of factors in the oral environment such as temperature, humidity, biofilm, salivary pellicle, food, and beverage consumption can affect dental materials. Furthermore, the combination and the simultaneous effects of different foods or beverages, mouthwash, saliva, and brushing were not evaluated.

Although ceramic brackets present better performance chromatic than the polycarbonate type, this laboratory study showed that this superiority is not always true and the association between laboratory results and clinical experience should guide the choice of the best accessories.
This study also showed that solutions used in everyday life are able to cause color changes in esthetic brackets, which may help to clear the frequent concern regarding the necessary minimum time required for the solutions to cause color change. In this study, the experimental times used were overestimated when compared to the times prevalent in the patients’ life. Nevertheless, the influence of cosmetic color enhancements in patients who make excessive use of these solutions can have a strong correlation with the results shown.

**CONCLUSION**

The results presented led to the rejection of the null hypotheses, and all groups tested underwent color changes when immersed in the studied solutions. Therefore, the esthetic brackets do not present satisfactory and stable chromatic behavior.

**ACKNOWLEDGMENTS**

The authors thank Morelli Orthodontics for the donation of the Composite® brackets.

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**RESUMO**

Avaliação espectrofotométrica das alterações cromáticas de braquetes estéticos armazenados em soluções potencialmente corantes

O objetivo deste estudo foi avaliar, in vitro, o comportamento cromático de braquetes estéticos armazenados em soluções potencialmente corantes. As amostras foram divididas em quatro grupos de acordo com a marca comercial e imersas em quatro soluções diferentes (água destilada, refrigerante à base de cola, café e enxaguatório bucal) a 37ºC, por 14 dias. As possíveis alterações de cor foram medidas de acordo com o sistema CIE L*a*b* por meio de um espectrofotômetro em cinco intervalos de tempo após armazenamento. A análise estatística foi conduzida usando ANOVA a 1%, testes de Tukey e decomposição das interações com nível de significância de 5%. As alterações de cores ocorreram conforme solução, tempo de armazenamento e marca dos braquetes. As maiores variações cromáticas foram observadas no G₃, seguido por G₂, G₁/G₄. Os braquetes estéticos não apresentam comportamento cromático estável e satisfatório.

**DESCRITORES**

Cor. Braquetes ortodônticos. Espectrofotometria.

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**REFERENCES**


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