Abstract

**Objectives:** To evaluate the colour stability of 3 recently developed resin based materials continuously exposed to various staining agents.

**Methods:** 144 disc-shaped specimens were made of each of the 3 tested composites (Essentia, Brillant, Inspiro). Half of them were of 1mm thickness, the other half 1.2mm thickness. The thicker group was then polished up to 4000 grit and reduced to 1mm thickness, too. All specimens after 24 h dry storage in an incubator (INP-500, Memmert), received an initial colour measurement by means of a calibrated reflectance spectrophotometer (SpectroShade, MHT, Niederhasli, Switzerland). Specimens were then divided into 6 groups (n=6) and immersed in 5 staining solutions or artificial saliva (control). All specimens were kept in an incubator at 37°C for 28 days. Staining solutions (red wine, curry mixed water, curry mixed oil, tea and coffee) were changed every 7th day to avoid bacteria or yeast contamination. After 28 days of storage spectrophotometric measurements were repeated and L* a* b* scores once more recorded to determine the colour (ΔE00) changes.

**Results:** All tested materials showed significant color changes after 28 days staining immersion. When considered over a black background ΔE00 of polished samples varied from 1.7 (Brillant/distilled water) to 24.1 (Brillant/wine). When considered over a white background ΔE00 of polished samples varied from 1.1 (Essentia/distilled water) to 32.5 (Inspiro/wine). When considered over a black background ΔE00 of unpolished samples varied from 1.1 (Essentia, Inspiro/distilled water) to 25.8 (Essentia/wine). When considered over a white background ΔE00 of unpolished samples varied from 1.4(Inspiro/distilled water) to 33.1 (Inspiro/wine).

**Conclusions:** Staining of restorative materials seems to be dependent on the composition of the product itself. Unpolished samples demonstrated to be more prone to staining than the polished ones.

Introduction

Resin composites are widely used worldwide due to their capacity of easily reproducing tooth like appearance [1-3]. Their use allows for a minimal invasive dentistry which imply lower cost if compared to the more invasive prosthetic approach based on ceramic crowns thus it is preferred by the majority of patients. Furthermore adhesive dentistry is less time consuming and do not require dental technician intervention.

Anyway, some disadvantages are evident when comparing resin composites to ceramics: gloss retention is lower over time and they have a much higher staining susceptibility [4,5]. Specifically, resin composite staining potential is a hot topic in today’s research [6-15] because it can furnish precious long-term data on restoration’s behavior to the practitioners.

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So far, no consensus was found if polishing was detrimental or advantageous for composite staining resistance and how results present in literature can be compared. Furthermore the presence of polished and unpolished part of a restoration is a common clinical situation and it is of interest to investigate how the different surfaces will react to staining agents. Class II, III and IV restored by means of resin composites have always the contact surface unpolished while the rest of the mass is mainly polished.

The aim of this study was to evaluate, in vitro, the staining potential of recently developed resin composites submitted to different food coloring liquids with or without surface polishing. The obtained data could be predictive of "in vivo" medium term clinical behavior.

The first hypothesis tested was that the materials included into the study do not significantly change their colour after 4 weeks immersion in the staining solutions.

The second hypothesis was that resin composite polishing does not significantly influence their staining susceptibility.

**Materials and Methods**

A total of 72 disc-shaped specimens were made of each of the 3 tested composites (Essentia, Brilliant, Inspiro). Their technical data are summarized in Table 1. All samples were light cured for 20 s at a distance of 1 mm with a LED curing device (Valo, Ultradent, South Jordan, USA) used in “standard mode” with a power density of >1000 mW/cm² (checked by LED Demetron radiometer 910726, Kerr Corporation Middleton, USA). Half of them were of 1 mm thickness, the other half 1.2 mm thickness. The thicker group was then polished with 500-, 1200-, 2400- and 4000-grit SiC abrasive paper and reduced to 1 mm thickness, too. Polishing was performed for 60s for each grit of abrasive paper under continuous water cooling at a constant force of 2 N, according to the methodology proposed by Ardu et al. [16] and as carried out in previous studies [17,18]. After 24 h dry storage in an incubator (INP-500, Memmert), all specimens received an initial colour measurement by means of a calibrated reflectance spectrophotometer (SpectroShade, MHT, Niederhasli, Switzerland). Specimens were then divided in 6 groups (n=6) and immersed in 5 staining solutions or artificial saliva (control). All specimens were kept in an incubator at 37°C for 28 days. Staining solutions (red wine, curry mixed water, curry mixed oil, tea and coffee) were changed every 7th day to avoid bacteria or yeast contamination. The details of staining solutions are summarized in Table 2. After 28 days of storage samples were

<table>
<thead>
<tr>
<th>Composite</th>
<th>Composition</th>
<th>Manufacturer</th>
<th>Lot and expiring date</th>
<th>Filler % by weight</th>
<th>Filler % by volume</th>
<th>Water sorption μm/mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essentia (dentin)</td>
<td>MD dentin (Universal restorative radiopaque) UDMA, Bis-MEPP, Silicon Dioxide, Fluoro-alumino-silicate glass</td>
<td>GC Corporation, Tokyo Japan</td>
<td>Lot: 1511201 2018-11</td>
<td>76</td>
<td>63</td>
<td>Not available</td>
</tr>
<tr>
<td>Brilliant Everglow (body)</td>
<td>A2/B2 body (Submicron hybrid universal) Aluminum Barium Silicate, Zinc oxide, Bis GMA based resins</td>
<td>Coltene-Whaledent, Altstätten, Switzerland</td>
<td>Lot: G27377 2017-06</td>
<td>79</td>
<td>64</td>
<td>15.1</td>
</tr>
<tr>
<td>Inspiro SN (enamel)</td>
<td>Enamel Skin Neutral (Nano-hybrid) Dental glass, silicon dioxide, Bis GMA based dental resins</td>
<td>Edelweiss-Whaledent DR, Zug, Switzerland</td>
<td>Lot: 750602 2018-11</td>
<td>82</td>
<td>65</td>
<td>20.0</td>
</tr>
</tbody>
</table>
cleaned for 60 s with a high-pressure-hot water airbrush (0.4 MPa, 135°C, Minivapor 93, Effegi Brega s.r.l., 29010 Sarmato, PC- Italy) and air-dried. Spectrophotometric measurements were repeated and L*a*b* scores once more recorded to determine the colour changes according to the classical ΔE00 formula.

All the details of the methodology employed in this study were widely explained in a precedent publication [16].

Statistical analysis was performed by means of Anova after testing data by means of Kolmogorov-Smirnov test in order to investigate the effect of the staining solutions (first goal of the paper). Polished and unpolished values of each resin composite were analyzed by means of Fisher’s LSD post-hoc test to check if all composites performed in the same way when faced to different staining solution or if their composition could influence their behavior.

Finally all staining values were pooled together per composite and divided in polished or unpolished samples and the ΔE00 values were submitted to Fisher’s LSD post-hoc test in order to test if polishing had an influence on staining results (second goal of the paper).

### Results

The results are summarized in Table 3.

All tested materials showed significant colour changes (p<0.01) after 28 days staining immersion.

When considered over a black background ΔE00 of polished samples varied from 1.7 (Brillant/distilled water) to 24.1 (Brillant/wine).

When considered over a white background ΔE00 of polished samples varied from 1.1 (Essentia/distilled water) to 32.5 (Inspiro/wine).

When considered over a black background ΔE00 of unpolished samples varied from 1.1 (Essentia, Inspiro/distilled water) to 25.8 (Essentia/wine).

When considered over a white background ΔE00 of unpolished samples varied from 1.4 (Inspiro/distilled water) to 33.1 (Inspiro/wine).

When all staining solutions’ means of polished samples were pooled together and analyzed over a black background, mean ΔE00 values varied from 11.7 (Essentia) to 16.3 (Inspiro) while over a white background were 12.6 (Essentia) to 21.9 (Inspiro).

When all staining solutions’ means of unpolished samples were pooled together and analyzed over a black background, mean ΔE00 values varied from 17.7 (Essentia) to 21.5 (Inspiro) while over a white background were 16.3 (Essentia) to 23.8 (Inspiro).

Finally, the Fisher’s LSD post-hoc test found that polishing had an influence on staining results by lowering their staining susceptibility.
Discussion

Different factors do influence staining of resin based materials: insufficient polymerization time, surface roughness and diet [19-50]. We aimed to investigate this latter in this in vitro study. Specifically we selected some of the most staining beverages such as tea, coffee, red wine and curry mixed to water or oil. Specifically we decided to investigate a spice like curry, which is widely used in eastern countries, and have an evident staining potential. We even decided to mix it alternatively with water or oil (according to different food recipes) in order to see if some differences could be seen. On the other hand, we maintained, according to previous studies [40,51] artificial saliva (Glandosan®, Helvepharm AG, Frauenfeld, Switzerland) as a control.

The second aim of the study was to investigate if surface polishing could have an influence on staining potential of the tested resins. Literature [41-43] is, in fact, not univocal on this point. The choice of 28 days of immersion in the staining solutions was done in order to be consistent with the most recent literature reviews [45,46] representing around 2.5 years of clinical service. The spectrophotometric measurements with a black and a white background were done in order to simulate different clinical conditions such as class IV restorations and class III with no tooth substance is remaining (black background), or class I,II,III with some remaining tooth substance and veneers (white background) [52].

In this study, red wine had the most staining potential, followed by coffee (when considered over a white background) or curry mixed with water (when considered over a black background) and tea. The low pH of 4.5 of the red wine used in this study and its relatively high level of tannins may serve as an explanation for its high staining capacity, especially if compared to the coffee brewed in “lungo” mode. These results are in line with the precedent study done on unpolished samples [40]. It is of interest to underline the quite high staining potential of curry only when mixed with water. Whenever was mixed with oil, in fact, its staining potential was sensibly lowered. This can be due to his insolubility in oil thus oil can have acted as a staining protector by covering resin composite surface not allowing a direct contact by curcuma particles with the surface.

Generally Essentia showed the best results in the study followed by Brillant and Inspiro, independent of the background. Not much is said by manufacturers on their exact composition which enhance difficulties in results interpretation. Even if filler percentage in volume and weight is, substantially, the same in the 3 tested materials, differences exist in their basic chemical composition. Essentia is based on UDMA chemistry, which is a hydrophobic monomer, this fact, can be one of the key factor of his good performance.

Table 3: Medians \( \Delta E \) and groupings according to the Fisher’s LSD test applied on \( \Delta E_{00} \) values (groups with the same letter are not significantly different (p<0.05)).

<table>
<thead>
<tr>
<th>Background</th>
<th>Staining</th>
<th>Medians ( \Delta E_{00} ) - Polished</th>
<th>Medians ( \Delta E_{00} ) - Unpolished</th>
<th>Grouping Polished</th>
<th>Grouping Unpolished</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Essentia</td>
<td>Brilliant</td>
<td>Inspiro</td>
<td>Essentia</td>
</tr>
<tr>
<td>Black</td>
<td>Control</td>
<td>2.4</td>
<td>1.7</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Black</td>
<td>Tea</td>
<td>3.0</td>
<td>4.1</td>
<td>7.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Black</td>
<td>Coffee</td>
<td>14.7</td>
<td>17.8</td>
<td>22.6</td>
<td>22.3</td>
</tr>
<tr>
<td>Black</td>
<td>Red Wine</td>
<td>20.9</td>
<td>24.1</td>
<td>23.1</td>
<td>25.8</td>
</tr>
<tr>
<td>Black</td>
<td>Curry w/Water</td>
<td>16.7</td>
<td>16.1</td>
<td>22.0</td>
<td>20.3</td>
</tr>
<tr>
<td>Black</td>
<td>Curry w/Oil</td>
<td>11.4</td>
<td>8.8</td>
<td>14.9</td>
<td>16.1</td>
</tr>
<tr>
<td>Black</td>
<td>All together</td>
<td>11.7</td>
<td>12.6</td>
<td>16.3</td>
<td>17.7</td>
</tr>
<tr>
<td>White</td>
<td>Control</td>
<td>1.1</td>
<td>1.5</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>White</td>
<td>Tea</td>
<td>5.1</td>
<td>5.5</td>
<td>11.2</td>
<td>5.7</td>
</tr>
<tr>
<td>White</td>
<td>Coffee</td>
<td>19.9</td>
<td>22.9</td>
<td>30.6</td>
<td>22.7</td>
</tr>
<tr>
<td>White</td>
<td>Red Wine</td>
<td>28.7</td>
<td>30.4</td>
<td>32.5</td>
<td>29.9</td>
</tr>
<tr>
<td>White</td>
<td>Curry w/Water</td>
<td>16.3</td>
<td>17.7</td>
<td>25.5</td>
<td>19.0</td>
</tr>
<tr>
<td>White</td>
<td>Curry w/Oil</td>
<td>9.8</td>
<td>11.5</td>
<td>19.0</td>
<td>13.5</td>
</tr>
<tr>
<td>White</td>
<td>All together</td>
<td>12.6</td>
<td>14.7</td>
<td>21.9</td>
<td>16.3</td>
</tr>
</tbody>
</table>

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On the other hand even a small percentage of TegDMA higher in Inspiro than in Essentia (Brillant doesn’t contain it) could explain his higher staining values when faced with high polarity molecules as tea and curry mixtures. Moreover, the results of Inspiro might be the consequence of its relatively high transluency, which may accentuate the perceptibility of staining. In general, the influence of the background on the ranking of the materials tested was low. When small differences were present, they were explainable by the different degree of transparence of the material. Generally all values obtained on white background were always higher than the ones obtained on black background.

It is important to state that the staining susceptibility of composite unpolished surfaces were around 30% higher, showing a higher discoloration potential of samples without polishing in comparison to samples with polishing. This is easily explainable by the possible effect of the free radicals present onto the surface which could react with staining molecules of the tested solutions. The small colour variations obtained with artificial saliva could be due to a natural ageing of the materials and can be related to the relatively low pH of our Glandosan solution (5.5), different artificial saliva composition could lead to dissimilar results and it could worth to test it.

**Conclusion**

Both hypotheses of the study were rejected. All resin composites tested showed significant changes in colour after 4 weeks of immersion in staining solutions. Polishing significantly decreases staining susceptibility of the resin composites. Under the conditions of this in vitro experiment, Essentia best performed in terms of resistance to staining. Clinical studies should confirm these observations in vivo.

**Conflict of interest**

The Authors of the manuscript “Staining susceptibility of recently developed resin composite materials” declare they have no conflict of interest and disclose all relationships or interests that could have direct or potential influence or impart bias on the work.

**References**


