The Effect of Drinks and Temperature on the Staining of Resin Composites Coated with Surface Sealants

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Abstract

Statement of problem: Surface staining of resin composite by dietary factors may be modified by the placement of a low-viscosity surface sealant aimed at reducing surface voids and defects occurring after light-curing and polishing.

Objectives: The aim of this study was to investigate the staining effect of various drinks and temperatures on the surface sealant (Fortify Plus™) sealed on a nano-filled resin composite (Supreme XTE™) after artificial aging at different temperatures.

Materials and Methods: Surface sealant was applied on one surface of forty resin composite discs (10×2 mm). Five discs each were immersed in test solutions of black cola, commercial dark grape juice, coffee and distilled water (negative control). Discs were either placed at 4°C (20 discs) or 37°C (20 discs) and the colour difference (ΔE) was calculated based on the colour coordinates at 0 (baseline), 7, 14 and 28 days of staining treatment. Two-factor with replication analysis was carried out with ANOVA.

Results: The results showed significant discolouration after 28 days immersion in coffee (P<0.001) and grape juice group (P<0.001). Surface sealant significantly affected colour changes in coffee and grape juice group (P=0.002). Higher temperatures in coffee and grape juice also significantly increased the effect of staining (P<0.001).

Conclusions: Surface sealant was able to reduce discolouration in the grape juice group only. A lower temperature of 4°C caused less staining in coffee and grape juice groups as compared to the 37°C corresponding test groups. Prolonged immersion time significantly increased discolouration in coffee and grape juice groups.

Keywords: Resin composite, Staining, Surface sealants, Temperature, Drinks

Introduction

Aesthetic requirements contribute a major aspect in determining the success of dental restorations. In most cases, aesthetics was considered more important than the functional aspects of restorations [1]. Poor aesthetics may result in patient dissatisfaction, treatment complications and even added expenses for replacement [2,3]. To preserve these aesthetic properties in resin composite restorations, surface sealants can be used [4].

Dental surface sealants, also known as Glazes, were first introduced some 30 years ago, and were mainly used for covering resin composite restorations [4]. Its composition consists of an unfilled, self-curing Bis-GMA (bisphenol- A- glycidylmethacrylate) resin matrix, which has less polymerisation shrinkage, linear expansion coefficient and water sorption than resin composite restorative materials [4,5]. Depending on the type of resin matrix, size of filler particles, manual mixing skills and the lack of accuracy in finishing instruments, resin composite restorations often
results in various surface defects [4]. These include microstructural cracks and surface irregularities due to the removal of surface particles. Micro-fractures can also occur along the enamel-adhesive interface due to light curing induced shrinkage [7]. This often results in poor aesthetics, discolorations, staining and potential plaque retentive sites in resin composite restorations [4,8]. Thus, surface sealants are placed to penetrate and fill in these voids, cracks and marginal openings to improve the surface texture, staining resistance and optical properties of resin composite restorations [4,6-10].

Intra-oral exposure to food dye, black cola, coffee, tea, chlorhexidine and even artificial saliva has a profound effect on staining susceptibility and physical properties in resin materials due to water sorption [8,11-12]. Staining of dental resin materials due to the patient’s dietary intake is often attributed to multiple factors. It is difficult to generalize the effect of diet as a whole on the staining susceptibility of dental resin materials. However, in support of this current study, a number of studies have shown that coffee, tea, grape juice and black cola had a significant staining effect on optical properties of resin-based restorative materials [11,12,13-17]. The temperature of oral cavity and dietary substrates are also associated with discoloration to resin-based materials [18]. Long-term immersion of resin composite in a high temperature solution can induce changes in the material properties, which ultimately may lead to discoloration [11,18]. This prolonged exposure to heat may degrade organic matrices to promote pigmentation [12]. Nevertheless; the effects of temperature on the staining susceptibility of surface sealants have never been explored. Therefore, in this current study, the role of temperature on the staining susceptibility of surface sealants will be investigated.

The aim of the current study is to investigate: (1) The effect of an unfilled low viscosity resin surface sealant (Fortify Plus™) on the staining susceptibility of nano-filled low viscosity resin composite restorative material when immersed in black cola, coffee and grape juice. (2) The effect of temperature on the staining susceptibility of the resin composite coated with surface sealants when immersed in black cola, coffee and grape juice.

The null hypothesis: (1) Presence of surface sealant significantly reduces the discolouration of resin composite restorative material when immersed in black cola, coffee and grape juice. (2) Increased temperature significantly increased the discolouration when immersed in black cola, coffee and grape juice.

Materials and Methods

Stainless steel washers 10 mm Ø×2mm height were placed on celluloid sheets and used as moulds. Filtek™ Supreme XTE (3M™ ESPE, St. Paul, Mn, USA) universal restorative resin composite (A2 shade) was dispensed into these washers carefully in order to avoid voids. A second celluloid sheet was placed over the washers and packed flat down using a 5 kg weight. Discs were then light cured by a 450 nm blue light (LE Demetron II, Sybron/Kerr; Middleton, USA. Output: 1200 mW/cm²) for 30 seconds on both sides. On one side of each specimen, an unfilled low viscosity resin based surface sealant (Fortify™ Plus, Bisco, Inc., Schaumburg, Illinois, USA) was applied with a micro-brush and light-cured for 10 seconds. The other side of each disc was left as the unsealed surface. All discs were then stored for 24 hours in a humidified incubator at 37.5°C and 95±5 % relative humidity.

The forty resin composite discs were randomly allocated to 6 test groups and 2 control groups; groups were black Cola®, (20 ml, pH 2.36, Coca Cola™, Amatil, Australia) stored in either 4°C (n=5) or 37°C (n=5), coffee (20 ml, pH 4.77, Nescafé Gold Dark 100% Arabica Beans, Nestlé Professional, Australia) at 4°C (n=5) or and 37°C (n=5), grape juice (20 ml, pH 3.24, Ariel Rouge® Premium De-alcoholised Wine, Organic Wine Pty Ltd, Australia), 4°C (n=5) or 37°C (n=5), control (20 ml, pH 6.62, distilled water) 4°C (n=5) or and 37°C (n=5). All specimens were stored in their respective solutions and temperatures in an environment where all sources of light were excluded for the length of the experiment. The resin composite discs were removed briefly from their respective staining solutions at days 7, 14 and 28, rinsed with deionized water (Milli-Q, Merck Millipore, Darmstadt, Germany) and pat dried with a cotton pad. Digital images of both the sealed and unsealed surfaces of each disc were obtained at days 0 (baseline), 7, 14 and 28 using a Nikon® D3000 camera under the same ambient controlled light environment (Figure 1). All photographs were analysed in Adobe Photoshop® 5.0 (Adobe Systems, Mountain View, CA) using a standardised internal feature of CIE L*a*b profile conversion and any colour difference (ΔE) was generated using the formulae:

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

Results were then analysed by 2-way ANOVA using GenStat® (14th Edition, VSN Int. Ltd., Hemel Hempstead, UK) and presented as mean±SD. An alpha value of 0.05 was considered to be statistically significant.

Results

A total of forty specimens were evaluated for colour alteration (ΔE). After 28 days of immersion, the maximum ΔE was observed in the sealed grape juice
group at 37°C (ΔE=58.42±3.97, Table 1 & Figure 1), and the minimum ΔE in the non-sealed black cola test group at 4°C (ΔE=0.9±0.9, Table 1 & Figure 1).

Effect of Surface Sealant

Two-way ANOVA showed significant interactions between the solution and the presence of surface sealant (P=0.002). The presence of surface sealants promoted a significantly higher discolouration in the sealed coffee group compared with the non-sealed coffee group (mean ΔE=3.02, 95% CI: 0.13–5.90). On the contrary, the surface sealant produced a lower ΔE observed in the sealed grape juice group as compared to the non-sealed grape juice group at 4°C (mean ΔE=-3.71, 95% CI: -6.59–-0.83). In other words, the surface sealants increased staining of the resin composite when soaked in coffee solutions but reduced staining in grape juice.

No significant effects were observed in the black cola or control test group (Figures 2 & 3).

Table 1: Mean ΔE values (±SD) of sealed and non-sealed specimens of all groups.

<table>
<thead>
<tr>
<th>Time (Days)</th>
<th>7</th>
<th>14</th>
<th>28</th>
<th>7</th>
<th>14</th>
<th>28</th>
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<td>Drink solutions</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>4°C</td>
<td>37°C</td>
<td>4°C</td>
<td>37°C</td>
<td>4°C</td>
<td>37°C</td>
</tr>
<tr>
<td>Coffee</td>
<td>16.3±3.1</td>
<td>26.6±2.4</td>
<td>27.3±7.5**</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Cola</td>
<td>2.5±1.1</td>
<td>1.6±1.2</td>
<td>2.3±1.0</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grape Juice</td>
<td>28.3±7.5</td>
<td>41.9±8.6</td>
<td>52.0±6.3***</td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distilled Water</td>
<td>1.3±0.3</td>
<td>1.8±1.1</td>
<td>1.3±1.5</td>
<td>2.4±0.7</td>
<td>2.7±1.9</td>
<td>3.1±1.2</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
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<tr>
<td>Sealed</td>
<td>4°C</td>
<td>37°C</td>
<td>4°C</td>
<td>37°C</td>
<td>4°C</td>
<td>37°C</td>
</tr>
<tr>
<td>Coffee</td>
<td>10.6±4.2</td>
<td>22.5±7.9</td>
<td>22.5±5.4*</td>
<td>30.9±6.0</td>
<td>36.2±4.3</td>
<td>37.3±5.6**</td>
</tr>
<tr>
<td>Black Cola</td>
<td>2.0±0.6</td>
<td>1.2±0.6</td>
<td>0.9±0.9</td>
<td>5.0±2.4</td>
<td>3.8±1.6</td>
<td>2.8±1.4</td>
</tr>
<tr>
<td>Grape Juice</td>
<td>33.1±11.8</td>
<td>50.3±4.8</td>
<td>53.1±5.0*</td>
<td>40.9±5.5</td>
<td>57.4±3.9</td>
<td>57.0±5.9**</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>2.6±1.7</td>
<td>3.5±1.4</td>
<td>2.3±1.4</td>
<td>2.4±0.7</td>
<td>3.4±1.0</td>
<td>4.1±2.3</td>
</tr>
</tbody>
</table>

**denotes P<0.01 when compared to its non-sealed counterpart, *** denotes P<0.001 when compared to baseline (day 0) in sealed group, * denotes a significant increase in ΔE as compared to baseline (day 0) in non-sealed groups, and + denotes a significant increase in discolouration as compared to 4°C.
Effect of Temperature
There were significant interactions between the storage solution and temperature for ΔE values compared to baseline (P<0.001). A warmer storage temperature of 37°C compared with 4°C induced higher ΔE values for all test solutions. Significant differences were observed in both the sealed and non-sealed coffee groups (mean ΔE=14.42, 95% CI: 10.97–17.87) and grape juice groups (mean ΔE=7.36, 95% CI: 3.91–10.81) compared to their corresponding 4°C groups (P<0.001, Figures 2 & 3). There were no significant differences in ΔE for both black cola and control groups at both temperatures.

Effect of Time
An effect of time on ΔE was evident in both the sealed and non-sealed coffee and grape juice groups. At both temperatures, there was a significant increase in ΔE in both coffee groups (mean ΔE=9.86, 95% CI: 6.48–13.24) and both grape juice groups (mean ΔE=20.79, 95% CI: 17.41–24.17) at 28 days of immersion, compared to baseline (P<0.001, Figures 1 & 2). There was no difference in discolouration amongst both the black cola groups and control groups over time (Figures 2 & 3).

Discussion
A previous 5 year clinical study has shown that unfilled resins placed on the surface of restorations were able to increase abrasion resistance and improve the marginal integrity of restorations, thus potentially reducing staining in resin composite restorations [4,6]. In addition, it has been shown that surface sealants
can improve the surface texture, staining resistance and optical properties of resin composites [4,6,9]. The surface sealants were thought to fill microstructural defects, decreasing the surface porosity and voids plus providing a more thoroughly cured surface [4,6,9,10].

The current study demonstrates that in both the 4°C and 37°C coffee test groups, resin composite discs sealed with a surface sealant showed higher levels of discoloration than its unssealed counterpart. The phenomenon was similar to those reported previously [1,2,19]. It may be due to the surface adsorption and absorption properties of surface sealant readily up-taking the astringent coffee pigments within the micro-pits and porosities present in the sealant material [19]. It is interesting to note that the greatest rate of discoloration for discs immersed in coffee was seen between baseline and day 7. Based on the results of this study, the discoloration in this test group appeared to plateau at approximately two weeks (Figure 1 & 2).

The greatest level of discoloration was observed in the grape juice test group at day 28 (P<0.001). This result is similar to findings in previous studies [18]. Dietschi et al. [21] showed that staining may be associated with the water sorption process. Water particles have the potential to act as carriers for staining agents in the sorption process [22], hence contributing to the staining adsorption that usually occurs within the first week [21]. Furthermore, the staining effect of grape juice may also be due to a combined effect of dark pigments of the solution and the low pH (pH=4.2). Dark pigments have been shown to cause drastic discoloration in other studies [15,18]. The acids present in grape juice are mainly tartaric, malic and citric acid [23]. These acids are different to the ortho-phosphoric acid present in black cola, thus may elicit different effects on resin composite disc surfaces comparatively [24]. It is also interesting to note that till the current date, the staining effect of flavonoid pigments present in grape juice and red wine have not been thoroughly explored and warrant further research. Furthermore, previous studies have shown that solutions such as grape juice (pH=3.24) can cause greater staining than lower pH black cola solutions (pH=2.36) [18]. However, this effect was not observed in the higher pH coffee solution (pH=4.77). The acidic nature of grape juice when combined with the presence of microleakage, dark pigments and flavonoid induced staining may further result in chemical degradation of the organic matrix of the resin composite discs. This may also contribute to the discoloration effect observed in the grape juice test groups, which may be absent in the coffee solution [16,18]. Similarly, other studies [11,12,13-17] also had concluded that diet constituents (including grape juice) have a significant staining effect on resin composite material. Further research is required to explore the staining effect of each individual staining agent.

Within the grape juice group it was also observed that 37°C results in a more intense colour change compared to the 4°C discs (P<0.001). Catelan et al. and Domingos et al. [11,18] have also demonstrated that long term high temperature exposure of resin composite discs in vitro can increase staining. It is thought that higher temperatures can degrade the organic matrix, induce microleakage, create microcracks and collect voids in the composite material, hence increasing the effect of staining [8]. The degree of discoloration in the grape juice discs also intensified over each interval in the 28 day period at both 4°C and 37°C (See Table 1). A significant association (P<0.001) was found between ΔE at each interval (7 days, 14 days, 21 days, 28 days). The greatest change in ΔE was between 0 and day 7, with a plateau after day 14 (Figure 1 & 2). These observations suggest that time may be an important consideration in staining of resin composite materials and may need to be factored in with future studies investigating staining of dental materials. Clinically, this also reinforces patient review protocols on all existing composite restorations, particularly in grape juice drinkers, as over time gradual discoloration may compromise the aesthetic value of existing restorations.

Interestingly, ΔE was significantly reduced on sealed discs compared with non-sealed discs within the grape juice test group, at both 4°C and 37°C. Although a reduction in grape juice discs were observed, there was little effect in black cola and the control groups. This phenomenon may be explained by the unique composition of grape juice, in contrast with black cola and coffee as previously mentioned. This may reveal that a certain component of the sealant is resistant to a unique discolouring agent present in the grape juice only. This serves as a basis for future investigations into grape juice constituents and their reduced affinity for unfilled, low viscosity surface sealants.

A decrease in ΔE was observed for the resin composite discs immersed in 4°C black cola in both the sealed and nonsealed groups (Table 1, Figure 1 & 2). This yellow to brown staining change is consistent with Catelan et al. [18] study which demonstrated that the caramel colour present in black cola was the primary cause, though when compared to other beverages such as coffee, had decreased levels of colourant resulting in decreased staining potential [15, 23]. Black cola has a low pH 2.36 due to the presence of orthophosphoric acid as well as the lime and lemon used in flavouring the beverage [24]. It has been shown that when enamel and dentine are exposed to a pH below 5.5 and 6.5 respectively, will result in mineral loss. This is also affected by the temperature of the solution and whether carbon dioxide is still present as carbonic acid is formed.
One of the limitations of this study revolves around the design of the resin composite discs. To improve the design, whole single resin composite discs should either have sealant placed or not placed so that specific sites can be examined for the effects of staining rather than one side of a same single disc. Another limitation is the clinical relevance of immersing resin composite discs in the same solution for 28 days. Although these laboratory test conditions assist in accelerating the staining effects of the solutions, clinical studies taking into account the presence of saliva and thermal cycling would provide further clinical information.

**Conclusion**

This current study demonstrates that surface sealants have a limited secondary role in preventing staining in certain beverages such as grape juice. A lower temperature reduces staining effect when resin composite discs were exposed to both coffee and grape juice for long periods of time. Solutions/drinks held in mouth for a longer period of time increases its temperature resulting in potentially higher staining than solutions/drinks that are consumed without holding in mouth. Time is also directly associated to increase in staining. Upon consumption of coloured beverages, it is advised to consume colder drinks in a shorter time frame to decrease the exposure of teeth and restorations with staining beverages. Clinically, in the mouth there will be saliva present, which may aid buffering of the acid and increase clearance of the fluids out of the oral cavity. The effects of saliva were not investigated in the current study; further research is required to explore these effects.

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**References**


