Research Article

Effect of cigarette smoke and whiskey on the color stability of dental composites

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Abstract: Purpose: To evaluate the effect of cigarette smoke and whiskey on the color stability of resin composites. **Methods:** Disk-shaped specimens (8 mm x 1 mm) were prepared with five composites in two different shades (n=10). After light-curing, the specimens were stored in dark containers with artificial saliva at 37ºC for 24 hours. Baseline color was measured by CIEL*a*b* using a colorimeter (Easy-Shade, VITA). Half of the specimens were subjected to a discoloration process in a cigarette smoking machine (SM) and the other half to an immersion in whiskey (WH) for 24 hours. Another color measurement was performed for discolored specimens. The samples subjected to smoking were immersed in whiskey (SM/WH) and those subjected to whiskey immersion were subjected to cigarette smoking (WH/SM) followed by another color measurement. Color changes (ΔE*) were calculated and submitted to repeated measures 4-way ANOVA and Tukey tests ($P < 0.05$). **Results:** The most significant color change was observed after WH/SM (ΔE*= 22.8-31.5) discoloration process, followed by SM (ΔE*= 7.0-18.0), SM/WH (ΔE*= 4.9-16.5) and WH (ΔE*= 2.0 to 9.5). Translucent shades were more susceptible to discoloration than enamel shades. All the groups, with the exception of two, showed a significantly high perceptible color change (ΔE*> 3.3). Based on the results, the color stability of dental composites was affected by the discoloration process and was material and shade dependent. (*Am J Dent* 2010;23:4-8).

Clinical significance: Resin composites are susceptible to discoloration by oral habits such as cigarette smoking and alcoholic beverage drinking. This *in vitro* study suggested that the association of both habits can exacerbate the color changes of composites, mainly when translucent shades are used.

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Introduction

In order to meet patients' esthetic demands, manufacturers are continually launching new resin composites on the market that are claimed to simulate optical properties of natural teeth.[1] Despite recent improvements, color stability of light-cured composites after long-term intraoral exposure still remains a concern[2] and is considered one of the major factors for replacement of direct tooth-colored restorations.[3-4]

Discoloration of resin-based materials appears to be related to multiple factors and may be caused by intrinsic and extrinsic factors. The intrinsic factors involve the discoloration of the resin material itself, such as the alteration the resin matrix by physico-chemical reactions causing deterioration.[5-6] Studies have demonstrated that color stability is also affected by intrinsic factors, such as the composition of the resin matrix, filler loading and particle size distribution,[7] type of photoinitiator[8] and percentage of remaining C=C bonds,[9] which is directed influenced by the duration of the light exposure and the type of curing device.[10]

External discoloration may be caused by plaque and colored pigment accumulation.[5,11] Dietary patterns, such as caffeine, tea, red wine, orange juice, some soft drinks and food colorants also have been shown to influence the color stability of restorative materials.[6-7,12-16] Some oral habits, such as cigarette smoking[17-18] and alcoholic beverage drinking[6] may exacerbate the external discoloration of resin-based materials. Frequently, cigarette smokers consume alcoholic drinks simultaneously,[19] making the associated effect of both habits even more detrimental for color stability of resin-based materials. The individual effects of these habits on the color stability of composites has been investigated[6,17-18] but never in combination.

In order to simulate the long-term intraoral color stability of composites, several *in vitro* studies have developed methods to expose the material to environmental factors, like visible light and UV radiation,[16,20] prolonged immersion in water[4,21-22] and artificial accelerated aging.[2,5,14,23-25]

Discoloration of resin-based materials is frequently measured by colorimetry, which is a branch of the science of color, based on the digital expression of the color perceived from the object.[6] The most commonly used method to assess chromatic differences is the Standard Commission Internationale de L'Eclairage (CIE L*a*b*) Color System, where L* represents the value of white (100) or black (0), and hue (color) and chroma (saturation level) are represented by the chromatic axes a* (positive values representing red and negative values representing green chroma) and b* (positive values representing yellow and negative values representing blue chroma).[12,24]

This *in vitro* study investigated isolated and associated effects of cigarette smoke and immersion in an alcoholic drink (whiskey) on the color stability of microhybrid, nanohybrid and nanofilled dental composites.

The hypotheses of this study were that (a) all the discoloration methods would result in similar color changes of the composites evaluated and (b) the color stability of both enamel and translucent shades would be affected by the discoloration methods.

Materials and Methods

Two shades of five different resin composites were tested in this study. The brand names, manufacturers, shades, codes and

Table 1. Commercial name and composition of the composites used in the study.

Material	Composition
Grandio[a]	Bis-GMA, TEGDMA, 87 wt% of spherical silicon dioxide 20-50 nm and glass ceramic fine particles
Charisma[b]	Bis-GMA, TEGDMA, 78% wt of barium glass filler and silicon dioxide of 20- 70 nm
Filtek Supreme XT[c]	Bis-GMA, Bis-EMA, UDMA, TEGDMA, 78.5 wt%, combination of aggregated zirconia/silica cluster filler with primary particle size of 5-20 nm, and nanoclusters 20-nm silica filler
Opallis[d]	Bis-GMA, Bis-EMA, TEGDMA, 79 wt%, combination of Al-Ba silicate glass and silicon dioxide nanofillers of 40 nm-3µm
4 Seasons[e]	Bis-GMA, TEGDMA, UDMA, 76 wt% of barium glass filler, ytterbium trifluoride, Ba-Al-fluorsilicate glass and high dispersed silica

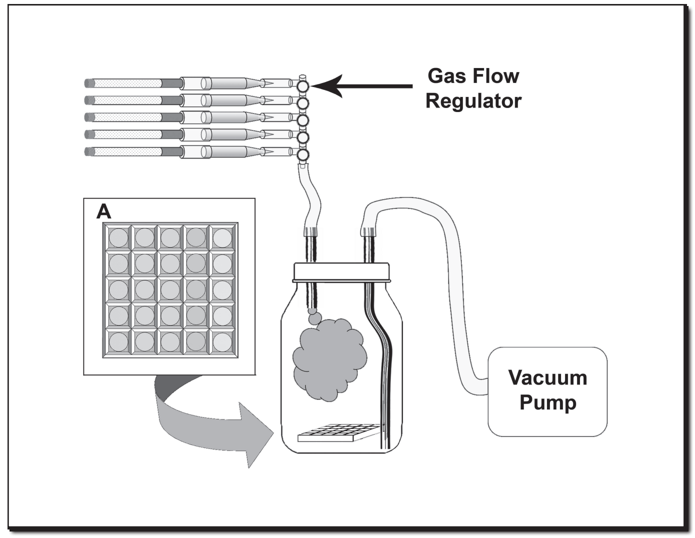


Fig. 1. Smoking machine used in the study, showing the acrylic box with nylon net in the bottom with the disc specimens inside the individual cells (A).

Table 2. ΔE* values (standard deviation) obtained by the resin composites in different shades after different staining methods.

Composite	Opacity	SM	SM/WH	WH	WH/SM
Grandio	Enamel	9.4 (0.6)^{CDb}	4.9 (0.5)^{Dc}	4.4 (1.8)^{BCDEc}	25.1 (2.0)^{BCa}
	Translucent	16.9 (1.6)^{Ab}	12.0 (2.1)^{Bc}	6.6 (1.3)^{ABCd}	31.5 (3.2)^{Aa}
Filtek Supreme XT	Enamel	9.7 (0.3)^{BCDb}	9.7 (1.6)^{BCb}	2.0 (0.5)^{DEc}	26.1 (1.3)^{Ba}
	Translucent	10.0 (1.2)^{BCb}	7.3 (1.2)^{CDbc}	5.4 (2.2)^{BCDc}	22.8 (1.5)^{Ca}
Charisma	Enamel	10.2 (1.1)^{BCb}	9.8 (0.9)^{BCb}	3.5 (0.8)^{CDEc}	26.4 (1.3)^{Ba}
	Translucent	18.1 (0.8)^{Ab}	16.5 (2.6)^{Ab}	9.5 (1.4)^{ABc}	31.4 (1.3)^{Aa}
Opallis	Enamel	9.0 (0.9)^{CDb}	7.7 (1.6)^{CDb}	2.9 (1.4)^{CDEc}	25.7 (1.4)^{Ba}
	Translucent	17.2 (3.8)^{Ab}	12.3 (2.5)^{Bc}	3.7 (1.6)^{CDEd}	26.2 (2.7)^{Ba}
4 Seasons	Enamel	7.0 (0.8)^{CDb}	7.2 (0.6)^{CDb}	5.5 (1.2)^{BCDb}	26.2 (1.9)^{Ba}
	Translucent	12.5 (1.7)^{Bb}	12.9 (1.7)^{Bb}	9.4 (2.3)^{ABc}	26.1 (2.0)^{Ba}

Groups connected by the same lower-case letter in a line or the same upper-case letter in a column are not statistically different ($P > 0.05$).

compositions are listed in Table 1.

Disk-shaped specimens, 8 mm in diameter and 1 mm in thickness, were prepared for each composite shade (n=10). Specimens were made by packing the composite in a Teflon mold ring placed on a glass slide and a Mylar strip. After the insertion of the composite, another Mylar strip and glass slide were pressed against the material. The composite was cured by a halogen light-curing unit (Optilux 501[f]) with a 450-500 mW/cm^2 light intensity, during the time recommended by each manufacturer. The specimens were stored in dark containers with artificial saliva at 37ºC ± 1ºC for 24 hours. The excess of artificial saliva was removed from the surface of each specimen with absorbent paper. The initial color value (baseline) of the specimens was measured in triplicate using a portable spectrophotometer, with a handpiece tip 6 mm in diameter (VITA Easyshade[g]). The color readings were performed according to the CIE L*a*b* system. The measurements were carried out placing the tip perpendicular to and in full contact with the specimens surface. The specimen was placed on a white background to prevent potential absorption effects on any of the color parameters measured.[20] The mean of the three measurements on each sample was used to represent the average values of the color parameters of each sample.

The specimens were separated in individual cells inside an acrylic box with nylon net in the bottom. Half of the specimens were subjected to a discoloration process in a cigarette smoking machine. The specimens were positioned at the bottom of a glass jar with a silicone tube penetrating the hole in the lid of the jar. Cigarette smoke was generated by automated smoking on a linear 5-port smoking machine (Fig. 1).[26] Once the device was assembled, a negative pressure (approximately 20 mm Hg; 1 mm Hg = 133 Pa) was applied and the cigarettes were smoked.[27] All cigarettes (Marlboro[h]) were smoked to a butt length of 10 mm before the filter tipping paper. The specimens were exposed to the mainstream cigarette smoke and the jar was kept saturated with the smoke for 10 minutes. This cycle was repeated four times, following the same standards.

The other half of the specimens was submitted to discoloration using an alcoholic drink. The acrylic box with nylon net in the bottom containing the specimens was immersed in 250 mL of whiskey (Johnnie Walker Red Label[i]) and kept in a closed container for 24 hours at 37°C.

The samples subjected to smoking discoloration were immersed in whiskey (SM/WH), and the samples subjected to alcoholic drink immersion were subjected to cigarette smoking (WH/SM) immediately after, following the same standards described previously. These conditions were considered associated treatments.

Color stability was assessed by determining the color differences (ΔE*) between CIE L* a*b* coordinates at baseline and after staining treatments. Mean (ΔE*) values of color change were calculated for each specimen group. Characteriza-

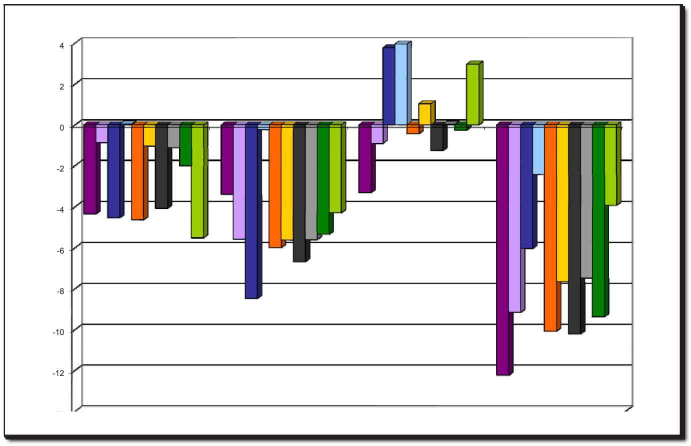


Fig. 2. Lightness changes (ΔL^*) of the tested composites submitted to different staining methods.

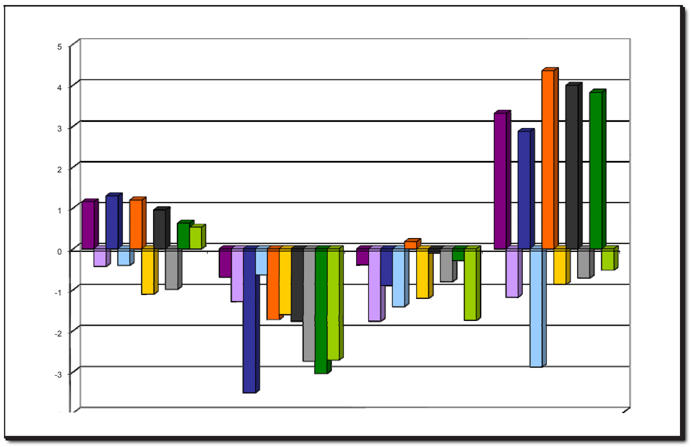


Fig. 3. Green-red changes (Δa^*) of the tested composites submitted to different staining methods.

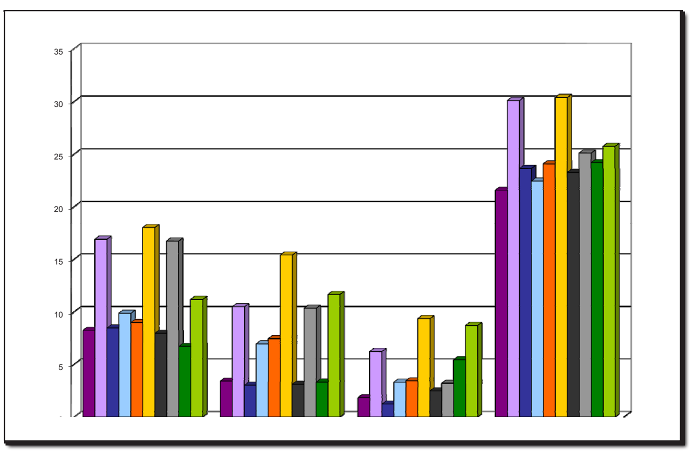
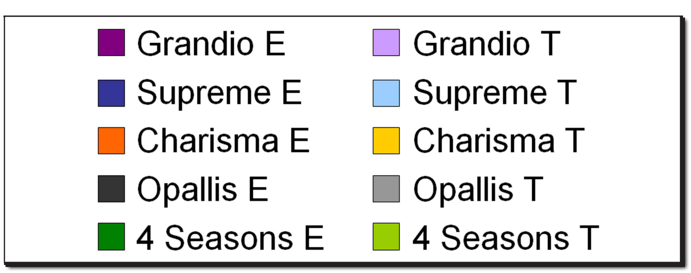


Fig. 4. Blue-yellow changes (Δb^*) of the tested composites submitted to different staining methods.



Legend for Figs. 2-4.

tion of color difference achieved by comparison of differences in individual coordinate parameters (ΔL^*, Δa^*, Δb^*) at baseline (0) and after each treatment (1) as follows:

$$\Delta L^* = L_1^* - L_0^*$$
$$\Delta a^* = a_1^* - a_0^*$$
$$\Delta b^* = b_1^* - b_0^*$$

Color differences were calculated using the formula:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

The ΔE^* data were submitted to repeated measures four-way ANOVA and Tukey test for multiple comparisons. In all cases, the level of statistically significant differences was $\alpha = 0.05$. Statistical analysis was performed using SPSS 15.0[j] and Statistica 7.0.[k]

Results

The results of the color changes (ΔE^*, ΔL^* and Δb^*) of tested materials are presented in Table 2 and Figs. 2-4. The ANOVA statistical analysis revealed that each of the effects was statistically significant ($P < 0.05$), but the effect of the interaction of opacity, associated staining treatment and isolated staining treatment was not statistically significant ($P = 0.90$).

The Tukey test was applied to perform multiple comparisons ($P < 0.05$), and it showed that the translucent shade of Charisma presented higher color change values (ΔE^*) after all treatments, the same occurring with the translucent shade of Grandio, with the exception of associated SM/WH treatment, with no statistically significant difference between both. After SM and WH staining, the translucent colors of Opallis and 4-Seasons showed similar discoloration when compared to the former composites, respectively ($P < 0.05$).

The WH/SM staining treatment increased the color changes (ΔE^*) significantly for all the composites. The other staining treatments also affected the color stability of the composites, in different intensities. The treatment that resulted in less color change was the immersion in the alcoholic drink.

Translucent shades of most of the composites revealed statistically significant differences in color changes when compared to enamel shades.

In this study, the ΔE^* values ranged from 2.0 (Filtek Supreme enamel, subjected to WH staining) to 31.5 (Grandio translucent, subjected to WH/SM staining).

Color changes of all materials comprised a decrease of the L^* value after all the staining methods, with the exception of the WH staining, which revealed some increase in lightness values. A moderate decrease in a^* values was found for most of the composites, mainly after WH and SM/WH staining treatments and for almost all of the translucent shades after SM and SM/WH treatments. All the composites showed a significant increase in the b^* values. These parameters demonstrate a tendency to discoloration to dark yellow for almost all the materials evaluated in the present study.

Discussion

In previous studies, it was concluded that ΔE^* values greater than or equal to 3.3 were considered visually perceptible[28,29] or clinically unacceptable.[5,30] However, Schulze *et al*[24] reported that values of ΔE^* in the range of 2-3 were just perceptible and that ΔE^* of 3.3 is the critical value for visual perception. In the present study, the ΔE* values varied from 2.0 to 31.5. The L*, a* and b* values found in the present study showed a tendency of the materials to become dark yellow or dark brown, the magnitude of which depended on the material and the staining treatment evaluated.

The immersion in whiskey demonstrated less color change when compared to the other staining treatments. However, when followed by smoking, whiskey immersion increased the discoloration significantly. Previous studies showed that alcohol causes softening of the resin composite surface plasticizing the resin matrix,[31,32] removing unreacted monomers, oligomers and linear polymers, making the material soft and prone to degradation.[11] Thus, the effect of the smoke was exacerbated due to the softening of the resin surface, causing an intense discoloration of all the composites evaluated. In contrast, when the composites were submitted to alcoholic drink immersion after the cigarette smoking treatment, the color change was reduced due to the attenuation effect of the whiskey immersion.

In this study, all the staining treatments that included cigarette smoke, either isolated or associated, resulted in a decrease of the L* values, which represents a reduction in lightness. Additionally, the increase of the b* values indicated that a severe yellow shift was found for all the composites, with the exception of Filtek Supreme enamel shade.

According to the manufacturer's information, the ingredients of cigarettes are tobacco (nicotine 1.1 mg and tar 15 mg), water, sugars (sucrose and/or invert sugar and/or high fructose corn syrup), propylene glycol, glycerol, licorice extract, diammonium phosphate, ammonium hydroxide, cocoa and cocoa products, carob bean and natural and artificial flavors. The cigarette smoke is composed of air, water, carbon monoxide (CO) and dioxide (CO_2) and tar, which represent more than 90% of the total amount of the smoke products. The other substances of the cigarette smoke are formed during the burning of tobacco or simply transferred from tobacco to smoke by the heating. Probably some of these components like sugars and cocoa could be responsible for the discoloration due to their dark shade and the ability to adhere to the surface of the composites. In a study carried out by Belli *et al*,[17] cigarette smoke was the most staining agent for laminate veneer materials.

According to Inokoshi *et al*[4] the resin component of resin-based materials is the source of discoloration and the higher volume fractions of this resin result in a greater appearance of discoloration. According to the manufacturers' information of Filtek Supreme and 4Seasons, the translucent shades contain a lower amount of filler particles than enamel shades. The translucent shades of 4Seasons present 75% of filler particles in its composition, while enamel and dentin shades contain 75.4% and 76% respectively. This difference is even more significant for Filtek Supreme where the percentage of filler particles is 72.5% for translucent shades and 78.5% for all the other shades. This fact could explain the higher discoloration of translucent shades, mainly after cigarette smoke and immersion in whiskey.

The substitution of part of TEGDMA for UDMA comonomer in BisGMA/TEGDMA resin matrix has been shown to reduce water uptake and stain susceptibility. Water uptake in BisGMA-based resins has been found to increase proportionally to TEGDMA concentration.[33] This leads to a change in stain susceptibility, which is expressed primarily by changes in L* values rather than a* and b* values.[15] In the current study, Filtek Supreme, a UDMA and BisGMA based composite, exhibited the lowest discoloration values probably because of the lower hydrophilicity of the monomers when compared to BisGMA and TEGDMA.

Within the limitations of this study, the null hypotheses of this investigation were rejected; it can be concluded that the most aggressive staining procedure was the association WH/SM, followed by SM, SM/WH and WH, respectively, and that translucent shades of the tested composites were more susceptible to discoloration than enamel shades.

Additional studies on the color stability of dental composites should be performed associating habits such as tooth brushing or mouthwash use to the effect of different staining agents in order to determine a realistic discoloration susceptibility of restorative materials.

a. VOCO GmbH, Cuxhaven, Germany.
b. Heraeus Kulzer GmbH & Co., Hanau, Germany.
c. 3M ESPE, St. Paul, MN, USA.
d. FGM Dental Products, Joinville, SC, Brazil.
e. Ivoclar Vivadent, Schaan, Liechtenstein.
f. Demetron Research Corp, Danbury, CT, USA.
g. VITA Zahnfabrik, Bad Säckingen, Germany.
h. Philip Morris, Richmond, VA, USA.
i. Johnnie Walker, Kilmarnock, Scotland, UK.
j. SPSS Inc., Chicago, IL, USA.
k. StatiSoft Inc., Tulsa, OK, USA.

Acknowledgement: To 3M ESPE, FGM Dental Products, Heraeus Kulzer GmbH & Co. and VOCO GmbH for supplying materials.

Disclosure statement: The authors have no conflict of interest.

Dr. Wasilewski and Dr. Kirsten is a postgraduate MDS student, Dr. Takahashi is a postgraduate PhD student, and Dr. Souza is Adjunct Professor School of Dentistry, Post-graduate Program, Pontifical Catholic University of Parana, Curitiba, Parana, Brazil.

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