Surface roughness and color change of a composite: Influence of beverages and brushing

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This study evaluated the influence of beverages and brushing on the surface roughness (SR) and color change (ΔE) of a composite resin. For this, 120-disks (10 mm×2 mm) of composite resin (Filtek-Z250) were prepared and polished. Initials SR (Ra- μ m) and color (CIELab-system) were measured with rugosimeter and spectrophotometer; specimens were divided into four groups (red wine, soft drink, sugar cane spirit, or artificial saliva=control) and three subgroups (without brushing; brushed with Colgate or with Close-Up). Specimens were immersed in the beverage 5×/day, for 5', over 30 day, being two subgroups brushed (120 strokes/day). Color was measured at 15th day, 30th day and after repolishment; SR at 30th day. ΔE -values were statistically different after immersion in the beverages ($p<0.05$). Red wine promoted the highest alteration, followed by soft drink=sugar cane spirit and finally saliva. At 30th day, specimens exhibited ΔE higher than 15th day; after repolishing, ΔE was similar to 15th day. Beverages and brushing negatively influenced the SR. Therefore, ΔE and SR can be influenced by beverages and brushing.

Keywords: Color change, Surface roughness, Beverages, Brushing, Composite resin

INTRODUCTION

Resin composite restorations have begun to constitute a significant portion of dentists' routine practice due to patients' great demand for an esthetic appearance^{1,2}, and this is possible due to the rapid development of new restorative materials³, allowing their use in both anterior and posterior restorations^{4,5}. However, failure or success of any esthetic restoration depends on the color match and the color stability of the material³.

The structure of the resin composite and the characteristics of the particles have direct impact on the surface smoothness and the susceptibility to extrinsic staining^{6,7}. Intrinsic factors, such as the resin matrix of composites⁸ and incomplete polymerization⁹, have a considerable influence on color stability. This is usually attributed to chemical degeneration of the filler-resin bond and solubility of the resin matrix¹⁰. Besides the materials composition, the finishing and polishing procedures may also influence the composite surface quality and can therefore be related to the early discoloration of this material¹¹.

The roughening of the surface caused by wear and chemical degradation may also affect gloss and consequently increase the extrinsic staining¹². Also, the water sorption may cause softening of the resin matrix, degradation of resin, reduction of stain resistance¹³, and changes in translucency¹⁴. Moreover, external discoloration can be the result of dietary and smoking habits, bad oral hygiene and adsorption or absorption of water-soluble stains throughout the resin matrix¹⁵.

Biofilm-covered resin restorations are susceptible softening caused by organic acids produced in biofilm, producing surface texture alteration and, consequently, may be liable to pronounced surface staining¹⁶.

Previous studies^{17,18} concerning color stability have

shown that drinks (such as coffee, tea, red wine, and cola) and mouth rinses have varied degrees of staining effect on auto- and light-cured composite resin. The staining potential of these drinks and solutions vary according to their composition and properties¹⁹.

Once staining has occurred, brushing with toothpaste, repolishing, and bleaching procedures²⁰ can remove the stains partially or even totally. Polishing procedures, although remove material from the composite surface, can remedy highly stained composites¹⁷. Finishing the composite surface with a celluloid strip can produce the smoothest composite surface, but the celluloid strip finished composite surface discolors more than a polished one⁹. Therefore, it is recommended that composite resins should be finished and polished in the appropriate time, because early finishing and polishing result in greater staining susceptibility²¹.

While studies^{22,23} have shown that the surface roughness of composite resins have a direct influence on susceptibility to staining, others^{6,7} have reported no correlation between surface roughness and staining susceptibility. The surface roughness of the composite is usually dictated by size, hardness and quantity of load particles, which influence the mechanical properties of composites, the flexibility of organic matrix, hardness and size of the abrasive²⁴.

However, there is lack of studies to assess the influence of beverages in the color stability of composite resins associated to brushing. So, the objective of the present study was to evaluate the color stability of a composite resin immersed in different solutions, associated or not to brushing. The tested hypothesis was that the beverages, associated or not to brushing, would significantly increase the color change values compared to control group.

MATERIALS AND METHODS

The study factors were: 1) solutions in four levels (red wine, soft drink, sugar cane spirit and artificial saliva), 2) brushing in three levels: one control (without brushing=GA) and two experimental groups (brushed with Colgate=GB; brushed with Close-Up Xtra Whitening=GC). The experiment sample was composed by 120 specimens of composite resin, divided into 12 groups/subgroups (by combining the levels of factors solutions and brushing). Separately was analyzed the immersion period (15 days and 30 days) and re-polish. The quantitative variables of response were color alteration and surface roughness.

The composite resin (Z250-Table 1) was manipulated according to the manufacturer's instructions. A stainless steel matrix ($\phi=10$ mm; thickness=2 mm) was used for specimen preparation. The resin composite was inserted into the matrix cavity in a single increment and covered with an acetate strip. In order to compact the material and prevent void and bubble formation, a microscopic slide with a 500 g weight on it was placed over the resin composite/matrix ensemble, producing specimens with smooth, highly flat surfaces. After one minute, the weight was removed and the resin was light cured for 20 s through the glass slide, by means of the tip of a visible light-curing unit with 900 mW/cm² output (Jetlite 4000, J Morita USA Inc, Irvine, CA, USA).

The obtained specimens were kept in artificial saliva and stored in oven at 37°C ($\pm 1^\circ\text{C}$). After 24 h, the experimental units were submitted to finishing and polishing with Super-Snap discs (Shofu Inc, Kyoto, Japan), using medium and fine granulation. As a result, the specimens were polished with felt discs and diamond paste (KG Sorensen Ind/Com Ltd, Barueri, SP, Brazil) of 6 μm and 3 μm . At the end of these procedures, the specimens were washed with distilled water for 30 s, dried with paper towels and immersed in artificial saliva for more 24 h at 37°C.

Before the cycling/brushing, the original color of each specimen was analyzed with a spectrophotometer (Color guide 45/0, PCB 6807 BYK-Gardner GmbH, Geretsried, Germany). This handheld portable equipment is unique

as it measures color and gloss attributes simultaneously. The spectro-guide spectrophotometer, with color-guide 45/0 and 11 mm aperture and circumferential illumination, allows repeatable results and a convenient sample placement.

The standard of observation simulated by spectrophotometer follows the CIELab system, recommended by the CIE (Commission Internationale de l'Éclairage) and widely used nowadays. This consists of two axes a^* and b^* , which have right angles, representing the size of the shade or color. The third axis is the brightness L^* , that is perpendicular to the plane a^* and b^* . With this system, any color can be specified by the coordinates L^* , a^* and b^* .

After activating the spectrophotometer, 30 LED lamps, with 10 different colors, arranged in a circular shape, focus the light beam at 45° with the material surface. This beam is reflected back at 0° to the apparatus and thus, it captures and records the values L^* , a^* and b^* of each sample. The instrument transfer color data to Excel® within a second.

In relation to surface roughness, an initial measure was performed using a rugosimeter (Surfcorder SE1700, Kosaka Laboratory Ltd, Tokyo, Japan). The sensing tip of 2 μm diameter, exerting contact pressure of 0.7 mN, performed plotted at a speed of 0.5 mm/s, totaling 12 readings per specimen, 4 in the direction of brushing and 8 perpendicular to this direction. The sampling length or cut-off used was 0.08 mm. Measurements were made using the parameter that is based on vertical measurement ($Ra/\mu\text{m}$) of surface roughness. The average of 12 readings was used as the measure of each specimen, prior to the testing of brushing, considered the initial roughness (IR).

Then, the specimens of composite resin were divided into four groups: the control group was maintained in artificial saliva and the three experimental groups were submitted to cycling in selected drinks (red wine, soft drink and sugar cane spirit) (Table 2).

The specimens were kept immersed in artificial saliva at 37°C $\pm 1^\circ\text{C}$ during the interval between the cycles. The drinks were employed in the temperature of consumption, *i.e.*, soft drink $\pm 4^\circ\text{C}$, red wine $\pm 25^\circ\text{C}$

Table 1 Composite resin employed

Composite (Shade)	Composition of the resin matrix (Filler)	Average filler size	Filler %	Photo- polymerization time	Manufacturer	Lot
Filtek Z250 (A3)	Bis-GMA, UDMA, and Bis-EMA (zirconia/silica)	0.01–3.5 μm with an average particle size of 0.6 μm	82% weight (60% content)	20"	3M ESPE St. Paul- MN - 55144-1000 - USA	6BN

Bis-GMA: bisphenol-A-glycidyl-dimethacrylate; UDMA: urethane-dimethacrylate; Bis-EMA: bisphenol-A-polyethylene glycol-diether-dimethacrylate. *Information from the manufacturer's instructions.

and sugar cane spirit $\pm 25^{\circ}\text{C}$. The temperatures were measured with a digital thermometer.

The specimens were immersed in their solutions for five minutes in agitation²⁵⁾ (CT-155, Cientec, Piracicaba, SP, Brazil), five times a day, with intervals of 2 h. For the control group (specimens kept in artificial saliva), the specimens were kept at 37°C changing daily the

artificial saliva. These procedures were repeated for 30 days.

The abrasive wear was performed in an automatic toothbrushing machine (MSEt-Marcelo Nucci-ME, São Carlos, Brazil) that simulates the horizontal brushing technique. This instrument was structured with a motor that transferred reciprocating movement to ten

Table 2 Solutions employed

Solution (Brand)	Composition	Alcohol content	pH	Manufacturer	Lot
Saliva Artificial	KH_2PO_4 , K_2HPO_4 , KCl, NaCl, $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$, NaF, sorbitol, nipagin, nipasol, carboxymethylcellulose (CMC), water.	–	7.00	Laboratory of Biochemistry of FCFRP-USP	–
Sugar Cane Spirit (Ypióca Limão®)	Rum, water, sugar, lemon juice, essential oil of lemon	30% Vol.	3.53	Ypióca Agroindustrial Ltda. Fortaleza - CE - 60841-030 - Brazil	010
Red Wine (Vinho Chapinha®)	Dry red wine, INS 200, 224 and 330. Does not contain gluten	10.7% Vol.	3.19	Passarin Ind. e Com. De Bebidas Ltda. Jundiaí - SP - 13216-351 - Brazil	154/07
Soft Drink (Schweppes Citrus®)	Carbonated water, sugar, natural juices of Apple, Orange and grapefruit 5%, INS 211, 330, 414 and 445ii, natural flavor, artificial coloring tartrazine	–	2.75	Cia. de Bebidas Ipiranga. Ribeirão Preto - SP - 14055-630 - Brazil	P071007

Table 3 Toothpastes used

Dentifrice Brand	Composition	Manufacturer	Lot
Colgate®	1450 ppm of fluoride, calcium carbonate, sodium lauryl sulfate, sodium saccharin, tetrasodium pyrophosphate, sodium silicate, sorbitol, carboxymethylcellulose, methylparaben, propylparaben, flavor and water. Contains sodium monofluorophosphate	Colgate-Palmolive Indústria e Comércio Ltda. São Bernardo do Campo - SP - 09696-000 - Brazil	7141BR123M
Close Up Xtra Whitening®	1500 ppm of fluoride, calcium carbonate, water, sorbitol, silica, sodium lauryl sulfate, flavor, trisodium phosphate, titanium dioxide, cellulose gum, <i>perlite</i> , sodium saccharin, formaldehyde. Contains sodium monofluorophosphate	IGL Industrial Ltda. - Vinhedo - SP - 13280-000 - Brazil (Unilever)	8081

soft nylon bristle toothbrushing heads. This brushing was performed one hour after the end of cycling in the solution.

The device consisted of a stainless-steel base with ten independent appliances for positioning the specimens. The specimens were positioned alongside the bristles of the dental brush (Colgate Classic, Colgate-Palmolive Ind/Com Ltd, São Bernardo do Campo, SP, Brazil) and focused on them a load of 400 g.

A solution (slurry) obtained by the mixture of toothpaste (Table 3) and distilled water in the proportion of 1:2 in weight, respectively, were injected laterally to the specimens, between the restorative material and the dental brush, before starting the brushing movements.

One hundred and twenty movements of brushing/day were made (simulating three brushing with 40 movements per day), with speed of 4.5 movements/s⁽²⁶⁾ with magnitude of tour of 25 mm, at 37°C ($\pm 0.5^\circ\text{C}$). This procedure was performed by 30 days.

A new color measurement was performed in all specimens after the first 15 experimental days and at the end of the cycling. After the immersion period, specimens were stored in artificial saliva for 7 days, when their surfaces were re-polished and immediately assessed by color. This repolishment was performed with water sandpaper #1200, through the use of a fixed weight of 500 g for 30 s, thus providing a wear of approximately 100 μm . Color change was analyzed by ΔE values (CIELab system).

The surface roughness of the specimens was re-evaluated at the end of 30 days (FR). The response variable was the difference of final roughness minus the initial roughness (FR-IR).

Data were analyzed by two-way ANOVA (solutions; brushing). The time factor was examined individually for color change. Fisher's least significant difference (LSD) multiple-comparisons test was used using statistical software (Origin 8, OriginLab Corporation Northampton, MA, USA) at $\alpha=5\%$ significance level.

RESULTS

The data analysis showed that the solutions (independently of brushing) promoted a statistically significant alteration ($p<0.05$) in the color (ΔE) of the specimens, with red wine promoting the highest change, followed by soft drink and sugar cane spirit, which presented similar results between them and different from saliva (Table 4). For the brushing factor, it was found similar behavior for the subgroups, regardless of toothpaste.

The interaction of factors showed that the saliva promoted the lowest color change, but when specimens were brushed with Close-Up, there was significant change of property ($p<0.05$). For the solutions sugar cane spirit and soft drink, it was noted similar behavior among the specimens brushed and non-brushed, an exception for brushing with Colgate. In red wine, it was observed that the subgroup not brushed showed statistically ($p<0.05$) higher color change than the other and the toothpastes

influenced the intensity of the alteration, and the GB showed minor changes ($p<0.05$).

Regarding the comparison of time, it was observed that the saliva had the lowest alterations and statistically significant in relation to the other subgroups. The repolishment promoted a more intense color and statistically significant ($p<0.05$) in specimens of solutions sugar cane spirit, soft drink and artificial saliva in relation to 30 days of immersion. However, for red wine, the repolishment promoted a marked improvement in color and was statistically different in relation to the 15th and 30th day.

Averages and subgroups' standard deviations of ΔE^* , ΔL , Δa and Δb for 15 days, 30 days and after repolish are described in Tables 4 to 7.

In relation to brushing, it was observed that this factor increased surface roughness of the composite, regardless of toothpaste used, *i.e.*, the brushed specimens showed roughness values statistically higher when compared with the group without brushing. Analyzing the factor solutions, the specimens stored in artificial saliva (control) had the lowest values of surface roughness. These results are better highlighted in Table 8.

Observing the interaction brushing X solutions (Table 9), we can say that the specimens not brushed showed the lowest roughness values in all solutions, when compared with the other associations solution/brushing. It can also be seen in Table 9 that no solution alone could promote a significant increase in roughness, however, when combined with Colgate toothpaste, it can be seen that, especially the soft drink, promoted a significant change in surface texture.

DISCUSSION

With the improvement of restorative materials and the demand for aesthetic restorations, the composite resin has become the material of choice for anterior teeth restorations^{1,5}. But, despite the improvement of its physical and chemical properties, color stability is still a limitation on the longevity of the restoration²⁷.

There are in the literature a large number researchers^{28,29} reporting that the resin materials are susceptible to staining after immersion in solutions such as coffee, tea and other beverages. However, when referring to the association immersion in solutions/brushing, few studies have been carried out to demonstrate the changes in physical properties of composites.

In the present study, it was observed that the solutions affected the color of specimens, especially red wine (Table 4), which promoted a marked color change, probably because the red wine has a high concentration of pigments⁴, visibly higher than the other beverages used in this study. Besides the higher values achieved by the wine, the intensity of this color change would be clinically perceptible. The literature³⁰ reports that restorations are considered acceptable in relation to its color with a ΔE^*_{ab} value lower than 3.7. However, 50% of observers considered a restoration unacceptable when the values of

Table 4 ΔE^* average and standard deviation of the studied subgroups at different immersion times

Groups	Subgroups	15 days	30 days	Re-polish
Without brushing (GA)	Artificial Saliva	0.957 (0.28)	0.712 (0.30)	1.223 (0.39)
	Spirit	1.909 (0.37)	1.769 (0.52)	2.598 (0.62)
	Soft Drink	2.109 (0.61)	1.963 (0.54)	2.655 (0.53)
	Red Wine	3.185 (0.54)	6.727 (0.78)	2.562 (0.53)
Brushed with Colgate (GB)	Artificial Saliva	0.991 (0.36)	0.828 (0.41)	1.522 (0.51)
	Spirit	2.112 (0.65)	2.205 (0.71)	2.499 (0.63)
	Soft Drink	2.391 (0.81)	2.274 (0.74)	2.486 (0.97)
	Red Wine	3.243 (0.83)	5.233 (0.90)	2.157 (0.55)
Brushed with Close-up (GC)	Artificial Saliva	1.468 (0.59)	1.250 (0.67)	1.639 (0.72)
	Spirit	2.023 (0.65)	1.822 (0.60)	1.860 (0.91)
	Soft Drink	1.900 (0.49)	2.015 (0.33)	2.264 (0.56)
	Red Wine	3.239 (0.42)	6.281 (0.48)	2.295 (0.56)

Table 5 ΔL average and standard deviation of the studied subgroups at different immersion times

Groups	Subgroups	15 days	30 days	Re-polish
Without brushing (GA)	Artificial Saliva	0.734 (0.40)	0.447 (0.41)	1.173 (0.40)
	Spirit	1.132 (0.24)	0.728 (0.17)	2.051 (0.60)
	Soft Drink	1.077 (0.47)	0.823 (0.37)	1.782 (0.52)
	Red Wine	-2.51 (0.51)	-6.16 (0.78)	1.180 (0.47)
Brushed with Colgate (GB)	Artificial Saliva	0.779 (0.26)	0.645 (0.34)	0.729 (0.98)
	Spirit	0.963 (0.32)	1.055 (0.28)	1.654 (0.34)
	Soft Drink	1.135 (0.76)	1.083 (0.73)	1.527 (0.71)
	Red Wine	-2.54 (0.81)	-4.75 (1.01)	1.334 (0.95)
Brushed with Close-up (GC)	Artificial Saliva	1.120 (0.32)	0.833 (0.38)	1.102 (0.50)
	Spirit	1.028 (0.66)	0.932 (0.64)	0.875 (0.89)
	Soft Drink	1.088 (0.53)	1.067 (0.42)	1.025 (0.41)
	Red Wine	-2.74 (0.60)	-5.85 (0.50)	0.459 (0.66)

Table 6 $\Delta \alpha$ average and standard deviation of the studied subgroups at different immersion times

Groups	Subgroups	15 days	30 days	Re-polish
Without brushing (GA)	Artificial Saliva	0.19 (0.30)	0.16 (0.26)	0.04 (0.17)
	Spirit	0.35 (0.09)	0.40 (0.20)	0.23 (0.28)
	Soft Drink	0.22 (0.48)	0.33 (0.20)	0.30 (0.22)
	Red Wine	0.98 (0.23)	2.14 (0.29)	0.49 (0.18)
Brushed with Colgate (GB)	Artificial Saliva	0.01 (0.22)	0.11 (0.23)	-0.22 (0.48)
	Spirit	0.28 (0.10)	0.39 (0.15)	0.31 (0.21)
	Soft Drink	0.23 (0.44)	0.35 (0.35)	0.20 (0.31)
	Red Wine	0.69 (0.25)	1.69 (0.29)	0.47 (0.26)
Brushed with Close-up (GC)	Artificial Saliva	0.08 (0.21)	0.19 (0.20)	0.15 (0.27)
	Spirit	0.24 (0.23)	0.33 (0.38)	0.20 (0.39)
	Soft Drink	0.35 (0.26)	0.31 (0.31)	0.14 (0.32)
	Red Wine	0.70 (0.19)	1.50 (0.44)	0.12 (0.44)

Table 7 Δb average and standard deviation of the studied subgroups at different immersion times

Groups	Subgroups	15 days	30 days	Re-polish
Without brushing (GA)	Artificial Saliva	0.24 (0.39)	0.32 (0.24)	0.15 (0.28)
	Spirit	-1.47 (0.44)	-1.52 (0.60)	-1.51 (0.47)
	Soft Drink	-1.61 (0.82)	-1.69 (0.62)	-1.84 (0.66)
	Red Wine	-1.65 (0.43)	-1.62 (0.36)	-2.19 (0.45)
Brushed with Colgate (GB)	Artificial Saliva	-0.36 (0.55)	-0.11 (0.53)	-0.60 (0.78)
	Spirit	-1.86 (0.58)	-1.86 (0.75)	-1.79 (0.71)
	Soft Drink	-1.85 (0.98)	-1.73 (0.96)	-1.79 (1.01)
	Red Wine	-1.82 (0.60)	-1.27 (0.39)	-1.30 (0.65)
Brushed with Close-up (GC)	Artificial Saliva	-0.77 (0.74)	-0.74 (0.78)	-0.91 (0.95)
	Spirit	-1.59 (0.67)	-1.36 (0.62)	-1.41 (0.80)
	Soft Drink	-1.45 (0.39)	-1.62 (0.30)	-1.97 (0.51)
	Red Wine	-1.45 (0.49)	-1.61 (0.55)	-2.12 (0.58)

Table 8 IR and FR average and standard deviation of the studied subgroups

	Initial Surface Roughness (IR)			Final Surface Roughness (FR)		
	GA	GB	GC	GA	GB	GC
Artificial Saliva	0.14 (0.03)	0.14 (0.02)	0.14 (0.02)	0.13 (0.02)	0.25 (0.04)	0.30 (0.03)
Spirit	0.14 (0.03)	0.12 (0.02)	0.13 (0.02)	0.14 (0.02)	0.32 (0.04)	0.29 (0.03)
Soft Drink	0.13 (0.02)	0.11 (0.02)	0.13 (0.02)	0.15 (0.02)	0.35 (0.05)	0.29 (0.04)
Red Wine	0.13 (0.03)	0.13 (0.02)	0.15 (0.02)	0.15 (0.02)	0.33 (0.06)	0.30 (0.04)

Table 9 Surface roughness (R_a - μm) mean alteration and standard deviation of the studied subgroups after 30 day immersion

	Without Brushing (GA)	Brushed with Colgate (GB)	Brushed with Close-Up (GC)
Artificial Saliva	-0.01 (0.01) ^a	0.10 (0.04) ^c	0.16 (0.03) ^d
Spirit	0.00 (0.02) ^{ab}	0.20 (0.04) ^e	0.16 (0.02) ^d
Soft Drink	0.02 (0.02) ^b	0.24 (0.04) ^e	0.16 (0.03) ^d
Red Wine	0.02 (0.02) ^b	0.20 (0.06) ^e	0.15 (0.04) ^d

The same letter represents statistical similarity.

ΔE^*_{ab} was approximately 3.3³¹⁾. Study on the correlation of ΔE^*_{ab} values and human observer responses verified that a specific relationship exists between the magnitude and direction of the measurements and the average dental-observer responses³²⁾. However, regardless of the acceptability level, in this study, the red wine has reached higher levels as to the threshold perceptible/acceptable color differences, and the threshold of acceptability vary by the shades, and are $\Delta E^*=1.1$ units for red-varying shades and 2.1 for yellow-varying shades³³⁾.

The staining caused by sugar cane spirit and soft drink were lower than the red wine, though more intense than the control. This fact can probably be explained by the characteristics of solutions, which can

promote the chemical degradation of organic matrix to a greater or lesser intensity and therefore facilitate the material staining. The presence of alcohol in the studied solutions may have provided the softening of resin³⁴⁾ and consequently promote an irreversible degradation of the material³⁵⁾. In this research, the artificial saliva promoted a slight color change of specimens, slightly perceptible²⁹⁾, similar to those seen by Omata *et al.* (2006)³⁶⁾. According to these authors, the artificial saliva can promote staining by the presence of mucin in its composition, which is a yellow-shade substance. However, in this study, this justification does not apply for two reasons: the artificial saliva used did not have mucin in its composition and the variation of chromaticity of the blue-yellow axis

proved to be negative (Table 7), showing a tendency for the color blue and not for the yellow. So, two possibilities may be raised: the first is the deposition of minerals on the surface of the specimens forming a whitish film, the second would be the increase of brightness (Table 5) of the specimens immersed in artificial saliva.

Moreover, the discoloration of the material can be affected by the oral conditions and by the exposure time in the oral cavity³⁷⁾, as observed in the present study, which found that the higher the time of cycling, the more intense was the color change. These data are discordant of another study in the literature³⁸⁾, which observed that the composite resins evaluated presented higher staining between the first 24 h and 7 days. This discrepancy in relation to the time factor can be attributed to the difference between the methodologies, because, in that, the specimens were immersed in their solutions for the whole period of experiment and, in this one, it was tried to simulate a clinical situation³⁹⁾ and thus the specimens were immersed in their solutions for only 25 min daily.

The brushing, in general, was not able to minimize the color change of resin, suggesting that intrinsic staining occurs beyond the extrinsic, *i.e.*, the resin's affinity for stains is modulated by its conversion rate and physic-chemical characteristics with water sorption rate being of particular importance^{18,40)}. Other important factors that affect the color stability are the surface roughness, surface integrity and finishing and polishing techniques.

It was also observed in this study there was no difference in color stability between brushed and not brushed specimens, regardless of toothpaste used, showing that despite the greater roughness of the brushed specimens, did not result in color change. This fact can be justified because, although rough surfaces are discolored by adsorption of pigments, some studies^{6,41)} demonstrated no correlation between surface roughness and staining.

In fact, the surface roughness is related to a combination of factors such as size, hardness and the percentage of surface area occupied by filler particles⁴²⁾, the composition of the monomer⁴³⁾ the degree of conversion of the polymer matrix of resin matrix⁴⁴⁾ and the interaction matrix/particle, as well as the silane union stability⁴⁴⁾.

As a result of abrasion by brushing, as well as by the corrosive process (erosion), restorative materials can become rough and wear out^{43,45)}. The presence of irregularities can influence the appearance, lead to surface discoloration, bacterial biofilm retention and gingival irritation^{7,46)}, increasing the risk of caries and periodontal inflammation.

Based on the results of this study, the tested hypothesis was partially validated. Although in this study the brushing did not increase the intensity of staining, further studies are needed to establish a correlation between surface roughness and staining, as well as to assess whether the time has direct influence on the pigmentation of composite resins.

CONCLUSIONS

According to the results obtained in the present study and considering the *in vitro* study restrictions, it can be concluded that:

1. Color change of the composite resin was influenced only by the beverages; surface roughness was influenced by beverages and brushing,
2. Brushing did not affect the color, although it increased the surface roughness,
3. The repolishment was not sufficient to promote the return of the specimen's color to their initial values, but the discoloration of composite resin can be partially removed.

Disclosure Statement

The authors do not have any financial interest in the companies whose materials are included in this article.

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REFERENCES

- 1) Mjör IA, Moorhead JE, Dahl JE. Reasons for replacement of restorations in permanent teeth in general dental practice. *Int Dent J* 2000; 50: 361-366.
- 2) Al-Negrish AR. Composite resin restorations: a cross-sectional survey of placement and replacement in Jordan. *Int Dent J* 2002; 52: 461-468.
- 3) Abu-Bakr N, Han L, Okamoto A, Iwaku M. Color stability of compomer after immersion in various media. *J Esthet Dent* 2000; 12: 258-263.
- 4) Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. *Dent Mater J* 2006; 25: 371-376.
- 5) Hickel R, Heidemann D, Staehle HJ, Minnig P, Wilson NH. Direct composite restorations: extended use in anterior and posterior situations. *Clin Oral Investig* 2004; 8: 43-44.
- 6) Reis AF, Giannini M, Lovadino JR, Ambrosano GM. Effects of various finishing systems on the surface roughness and staining susceptibility of packable composite resins. *Dent Mater* 2003; 19: 12-18.
- 7) Shintani H, Satou J, Satou N, Hayashihara H, Inoue T. Effects of various finishing methods on staining and accumulation of *Streptococcus mutans* HS-6 on composite resins. *Dent Mater* 1985; 1: 225-227.
- 8) Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. *Dent Mater* 2004; 20: 530-534.
- 9) Janda R, Roulet JF, Kaminsky M, Steffn G, Latta M. Color stability of resin matrix restorative materials as a function of the method of light activation. *Eur J Oral Sci* 2004; 112: 280-285.
- 10) Iazzetti G, Burgess JO, Gardiner D, Ripps A. Color stability of fluoride-containing restorative materials. *Oper Dent* 2000; 25: 520-525.
- 11) Patel SB, Gordan VV, Barrett AA, Shen C. The effect of surface finishing and storage solutions on the color stability of resin-based composites. *J Am Dent Assoc* 2004; 135: 587-594.
- 12) van Groenigen G, Jongebloed W, Arends J. Composite degradation in vivo. *Dent Mater* 1986; 2: 225-227.

- 13) Shah MB, Ferracane JL, Kruzic JJ. R-curve behavior and toughening mechanisms of resin-based dental composites: effects of hydration and post-cure heat treatment. *Dent Mater* 2009; 25: 760-770.
- 14) Fontes ST, Fernández MR, de Moura CM, Meireles SS. Color stability of a nanofill composite: effect of different immersion media. *J Appl Oral Sci* 2009; 17: 388-391.
- 15) Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. *J Dent* 2005; 33: 389-398.
- 16) Asmussen E, Hansen EK. Surface discoloration of restorative resins in relation to surface softening and oral hygiene. *Scand J Dent Res* 1986; 94: 174-177.
- 17) Türkün LS, Türkün M. Effect of bleaching and repolishing procedures on coffee and tea stain removal from three anterior composite veneering materials. *J Esthet Restor Dent* 2004; 16: 290-301.
- 18) Manabe A, Kato Y, Finger WJ, Kanehira M, Komatsu M. Discoloration of coating resins exposed to staining solutions *in vitro*. *Dent Mater J* 2009; 28: 338-343.
- 19) Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. *J Prosthet Dent* 2005; 94: 118-124.
- 20) Celik C, Yüzügülü B, Erkut S, Yazici AR. Effect of bleaching on staining susceptibility of resin composite restorative materials. *J Esthet Restor Dent* 2009; 21: 407-414.
- 21) Kameyama A, Nakazawa T, Haruyama A, Hosaka M, Hirai Y. Influence of finishing/polishing procedures on the surface texture of two resin composites. *Open Dent J* 2008; 2: 56-60.
- 22) Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an *in vitro* study. *Dent Mater* 1994; 10: 353-362.
- 23) Sarac D, Sarac YS, Kulunk S, Ural C, Kulunk T. The effect of polishing techniques on the surface roughness and color change of composite resins. *J Prosthet Dent* 2006; 96: 33-40.
- 24) Yap AU, Lye KW, Sau CW. Surface characteristics of tooth-colored restoratives polished utilizing different polishing systems. *Oper Dent* 1997; 22: 260-265.
- 25) Brada VV, Faraoni JJ, Ramos RP, Palma-Dibb RG. Influence of different beverages on the microhardness and surface roughness of resin composites. *Oper Dent* 2005; 30: 213-219.
- 26) Heath JR, Wilson HJ. Forces and rates observed during *in vivo* toothbrushing. *Biomed Eng* 1974; 9: 61-64.
- 27) Schulze KA, Marshall SJ, Gansky SA, Marshall GW. Color stability and hardness in dental composites after accelerated aging. *Dent Mater* 2003; 19: 612-619.
- 28) Yazici AR, Celik C, Dayangaç B, Özgünaltay G. The effect of curing units and staining solutions on the color stability of resin composites. *Oper Dent* 2007; 32: 616-622.
- 29) Burrow MF, Makinson OF. Color change in light-cured resins exposed to daylight. *Quintessence Int* 1991; 22: 447-452.
- 30) Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. *J Dent Res* 1989; 68: 819-822.
- 31) Rao YM, Srilakshmi V, Vinayagam KK, Narayanan LL. An evaluation of the color stability of tooth-colored restorative materials after bleaching using CIELAB color technique. *Indian J Dent Res* 2009; 20: 60-64.
- 32) Jarad FD, Albadri SS, Mair LH. The use of objective digital matching to achieve an esthetic composite restoration. *J Clin Dent* 2008; 19: 9-13.
- 33) Douglas RD, Brewer JD. Acceptability of shade differences in metal ceramic crowns. *J Prosthet Dent* 1998; 79: 254-260.
- 34) Asmussen E, Peutzfeldt A. Two-step curing: influence on conversion and softening of a dental polymer. *Dent Mater* 2003; 19: 466-470.
- 35) Han L, Okamoto A, Fukushima M, Okiji T. Evaluation of flowable resin composite surfaces eroded by acidic and alcoholic drinks. *Dent Mater J* 2008; 27: 455-465.
- 36) Omata Y, Uno S, Nakaoki Y, Tanaka T, Sano H, Yoshida S, Sidhu SK. Staining of hybrid composites with coffee, oolong tea, or red wine. *Dent Mater J* 2006; 25: 125-131.
- 37) Buchalla W, Attin T, Hilgers RD, Hellwig E. The effect of water and light exposure on the color and translucency of a hybrid and a microfilled composite. *J Prosthet Dent* 2002; 87: 264-270.
- 38) Topcu FT, Sahinkesen G, Yamanel K, Erdemir U, Oktay EA, Ersahan S. Influence of different drinks on the colour stability of dental resin composites. *Eur J Dent* 2009; 3: 50-56.
- 39) Türkün LS, Türkün M, Ozata F. Two-year clinical evaluation of a packable resin-based composite. *J Am Dent Assoc* 2003; 134: 1205-1212.
- 40) de Gee AJ, ten Harkel-Hagenaar E, Davidson CL. Color dye for identification of incompletely cured composite resins. *J Prosthet Dent* 1984; 52: 626-631.
- 41) Smales RJ, Gerke DC. Clinical evaluation of light-cured anterior resin composites over periods of up to 4 years. *Am J Dent* 1992; 5: 208-212.
- 42) Jaarda MJ, Wang R, Lang BR. A regression analysis of filler particle content to predict composite wear. *J Prosthet Dent* 1997; 77: 57-67.
- 43) Tanoue N, Matsumura M, Atsuta M. Wear and surface roughness of current prosthetic composites after toothbrush/dentifrice abrasion. *J Prosthet Dent* 2000; 84: 93-97.
- 44) Kaway K, Iwami Y, Ebisu S. Effect of resin monomer composition on toothbrush wear resistance. *J Oral Rehabil* 1998; 25: 264-268.
- 45) Momoi Y, Hirotsaki K, Kohno A, McCabe JF. *In vitro* toothbrush-dentifrice abrasion of resin-modified glass ionomers. *Dent Mater* 1997; 13: 82-88.
- 46) Chan KC, Fuller JL, Hormati AA. The ability of foods to stain two composite resins. *J Prosthet Dent* 1980; 43: 542-545.