Morphologic Texture Characterization Allied to Cigarette Smoke Increase Pigmentation in Composite Resin Restorations

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ABSTRACT

Statement of the Problem: The staining effect of tobacco smoke on resin color is clinically observed. However, there is no evidence determining whether this staining is increased on texturized surfaces or if the color change is superficial and can be removed by repolishing procedures.

Objective: To evaluate the effect of tobacco smoke on the color of a composite with smooth or texturized surfaces, before and after repolishing.

Materials and Methods: Forty composite specimens were allocated into four groups ($N = 10$): Smooth surface not exposed (G1) and exposed to tobacco smoke (G2), texturized surface not exposed (G3), and exposed to tobacco smoke (G4). During 21 days, G2 and G4 were daily exposed to the smoke from 20 cigarettes. Color measurements were carried out at baseline, after 21 days, and after repolishing. Variables L^* (luminosity), b^* (blue-yellow), and ΔE (total color change) were statistically analyzed (repeated measures analysis of variance/Tukey).

Results: Texturized and smooth specimens presented similar luminosity at baseline. Tobacco smoke significantly reduced L^* in G2 and G4, and increased b^* in G4. After repolishing, L^* increased and b^* reduced in stained groups, but values continued to be different from baseline ones. Repolishing significantly reduced ΔE, but values from stained groups were still greater than that from unstained groups.

Conclusion: Tobacco smoke changes the color of composite, and surface texture can increase the staining. Repolishing reduces superficial staining, but this procedure may not return the composite to baseline color.

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DOI 10.1111/j.1708-8240.2010.00347.x

CLINICAL RELEVANCE

Smokers that will receive anterior composite restorations should be warned about the negative cosmetic effect of the smoking habit on the color of restorations.

(*J Esthet Restor Dent* 22:252–261, 2010)

INTRODUCTION

Composite resins have been largely utilized for esthetic dentistry purposes.[1,2] These materials allow the use of minimally invasive cavity preparations or even the absence of any cavity preparation, resulting in the maximum preservation of sound tooth structure.[3] Besides that, composite resin restorations might be repaired,[4] present good longevity, and acceptable esthetic properties.[5]

With the improvement of mechanical and optical properties of esthetic restorative materials, more attention has been paid to the final result of direct composite restorations in the anterior teeth. In the search for performing invisible direct restorations, not only should the color of the composite be properly selected but also surfaces must be texturized to replicate the morphologic natural characteristics of the teeth. Superficial texture makes an average composite restoration become life-like and should be performed in accordance with the intrinsic characteristics of the natural dentition in each clinical situation.[1] Macro and micro superficial characterization can be made with 30-blade burs, median or fine diamond burs, and abrasive rubber points.[1,6,7] After the superficial characterization, restorations should be polished in order to reproduce the luster of the teeth and to smoothen the superficial texture, without removing it completely. Morphologic texture characterization can give the restoration a natural look but might also allow a higher concentration of pigments over surfaces, as the increased surface roughness of composites seems to be related to higher surface discoloration.[8,9] Exogenous sources of colorants may result from the patient's diet or from the smoking habit.[6] Since superficial textures generate irregularities on composite surfaces, it is worthwhile to determine whether this characterization facilitates superficial staining or not.

According to the World Health Organization, almost 1.3 billion people around the world have the smoking habit. The majority of smokers seem to initiate tobacco consumption before the adult age.[10,11] The smoking habit and the period of exposure to this risk factor are associated with a number of important health outcomes, increasing the patient's morbidity and mortality.[11] Tobacco consumption is responsible for alterations in oral health such as oral cancer, periodontal disease, delay in the healing process, and minor implant osseointegration, which is related to an impaired revascularization of bone and soft tissues.[12–16] Nevertheless, dental patients that smoke do not seem to be sufficiently aware of the oral health effects of smoking; and most individuals only recognize tooth staining as a negative outcome.[17] In research about self-assurance with teeth appearance, smokers more often indicated perceiving discoloration and were more likely to be dissatisfied with their own tooth color compared with nonsmokers.[18] This esthetic concern, which is highly valorized by the market and by the patients, can be an important strategy for future anti-smoking campaigns.[18]

A reduction in the superficial staining of esthetic restorative materials can be accomplished with repolishing procedures performed with abrasive instruments on restoration surfaces or through bleaching agents.[19,20] Some studies demonstrated that the repolishing

procedures caused perceptible color changes in esthetic restoratives stained with coffee, red wine, and tea, and mainly referred to the increase in the luminosity and to the decrease in the yellowish appearance.[19,21] Nonetheless, it is still unknown if repolishing procedures can provide significant color changes on composite materials stained by tobacco smoke with elevated tar content. For this reason, the aim of the present study was to evaluate the effect of tobacco smoke with elevated content of tar on the color parameters of a composite resin presenting smooth or texturized surfaces, before and after repolishing procedures. The null hypotheses tested were that the exposure of smooth and texturized composite resin surfaces to tobacco smoke with elevated tar content do not result in significant superficial staining and that repolishing does not reduce this superficial staining.

MATERIALS AND METHODS

Forty specimens were made from the nanofilled composite resin (Filtek Supreme XT, shade A2, 3M ESPE, St. Paul, MN, USA). A Teflon mold with a central orifice of 9 mm in diameter and with 2-mm thickness was filled with a single increment of the composite. A polyester strip was placed over the mold, and specimens were light-cured for 40 seconds with a quartz-tungsten-halogen light-curing unit (OptiPlus, Gnatus, Ribeirão Preto, Brazil), with a light power density of 500 mw/cm^2. Specimens were stored in artificial saliva for 24 hours at 37°C to simulate clinical conditions.

After this period, specimens were randomly allocated into four groups ($N = 10$) as follows: (1) group 1: smooth surface not exposed to tobacco smoke, (2) group 2: smooth surface exposed to tobacco smoke, (3) group 3: texturized surface not exposed to tobacco smoke, and (4) group 4: texturized surface exposed to tobacco smoke. In G3 and G4, the morphologic surface texture characterization was performed using a superfine diamond bur (#1190F, KG Sorensen, Barueri, SP, Brazil), operated in a high speed handpiece, with constant water cooling. Specimens were slightly roughened by passing the superfine diamond bur once over the entire surface. All specimens were then polished with fine and ultra-fine aluminum oxide abrasive disks (Sof-Lex Pop-On, 3M ESPE), with intermittent movements lasting 10 seconds each, without removing the surface roughness from G3 and G4. The polished surfaces of all specimens were examined using a stereoscope microscope (25×) to confirm the presence of initial superficial roughness in specimens from G3 and G4, and the smoothed surface in specimens from G1 and G2. Then, specimens were individually stored in artificial saliva at 37°C. The composition of the artificial saliva was: sodium bicarbonate 2,190 mg, monobasic potassium phosphate 2,170 mg, magnesium chloride 125 mg, calcium chloride 441 mg, potassium chloride 82 mg, sodium fluoride 4.5 mg, sodium benzoate 5,000 mg, sorbitol 24 g, carboxymethyl cellulose 8 g, and distilled water 1,000 mL.

For 21 days, specimens from G2 and G4 were daily exposed to tobacco smoke (10 cigarettes per 8 minutes, twice a day). Cigarettes used presented an elevated content of tar (10 mg; Hollywood Original Blend, Souza Cruz SA, São Paulo, Brazil). The method used for the exposure of composite specimens to tobacco smoke followed an adaptation of the one described by Le Mesurier and colleagues.[22] The exposure to tobacco was conducted in a hermetically closed acrylic device. This apparatus contained two chambers connected by orifices closed with cigarette filter papers. Lit cigarettes were placed in the first chamber that received external ventilation, from an air pump, to provide constant airflow. The smoke-filled air in the first chamber was drawn through the opening into the second chamber, where composite specimens were placed. To reach the second

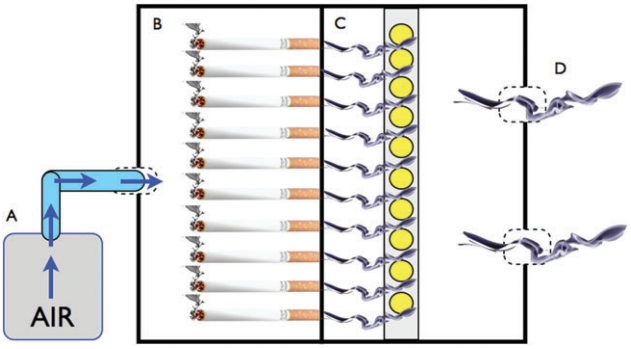

Figure 1. Schematic presentation of the method used for the exposure to tobacco smoke. A, *external source of air stream.* B, *first chamber where lit cigarettes were placed.* C, *second chamber with 10 composite specimens in position.* D, *orifice to release the air stream.*

chamber, smoke had to overcome the cigarette filter barrier. The second chamber had another orifice to release the air stream (Figure 1). Specimens were immersed in the artificial saliva (37°C) after each cycle of smoke exposure. After the period of 21 days, all specimens were repolished using fine and ultra-fine aluminum oxide abrasive disks.

Color measurements were performed according to the (CIE) $L^*a^*b^*$ color space.[23] The coordinate values L^* (lightness; 0 = black/100 = white), a^* (green [negative]/red [positive]), and b^* (blue [negative]/yellow [positive]) were measured at baseline, after 21 days, and after repolishing procedures. The total color variation (ΔE) was calculated before and after staining and before and after polishing according to the following formula:

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

A value of color difference (ΔE) of 5.5 was considered to be a clinically unacceptable color match.[24] Before each measurement, specimens were rinsed with water for 1 minute and dried with absorbent paper. To perform the color readings, each specimen was positioned inside the central orifice of the white Teflon mold. A white Teflon cover with a central orifice was placed over the mold to allow the tip of the spectrophotometer to be inserted (Easyshade, Vita, Bad Säckingen, Germany). Therefore, the distal end of the light guide of the hand-held spectrometer remained in contact with the specimen in a fixed position, controlling the influence of the external light and preventing the dissipation of the light from the spectrophotometer.

L^*, b^* ΔE values were analyzed with repeated measures analysis of variance. All possible interactions were included in the model. Multiple pairwise comparisons were done with Tukey post-hoc test. Statistical analyses were carried out in the SAS 9.1 statistical package (SAS Institute, Cary, NC, USA) with a 95% confidence level.

RESULTS

The statistical analysis of luminosity values (L^*) indicated a significant interaction between main factors (group × period of color measurement) ($p = 0.0001$). In groups exposed to tobacco smoke (G2 and G4), the luminosity decreased from the first to the second measurements (21 days after smoke exposure) and increased after repolishing procedures (Figure 2). Nevertheless, in both groups, the luminosity after repolishing was significantly lower than the baseline value. In G3, the luminosity showed a statistically significant decrease after the 21 days of storage in artificial saliva, but after repolishing, L^* values were statistically similar to the baseline ones. In G1, similar L^* values were detected at the three measurements.

Figure 3 represents b^* values obtained at the three periods of color measurement. Increased b^* values indicate a yellowish appearance. A significant interaction between groups and periods was also observed ($p = 0.0001$). The

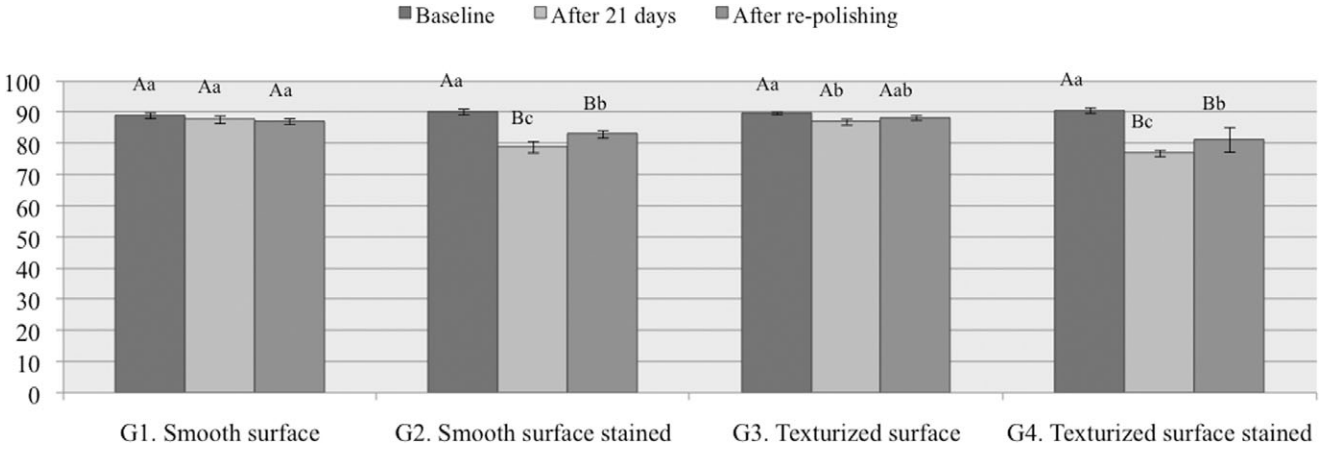

Figure 2. L* *values according to the experimental groups (*N = *10) and periods of color measurements. Dissimilar letters indicate statistically significant differences (repeated measures analysis of variance/Tukey,* $\alpha = 5\%$*). Capital letters compare groups within each period and lower case letters compare periods within each group.*

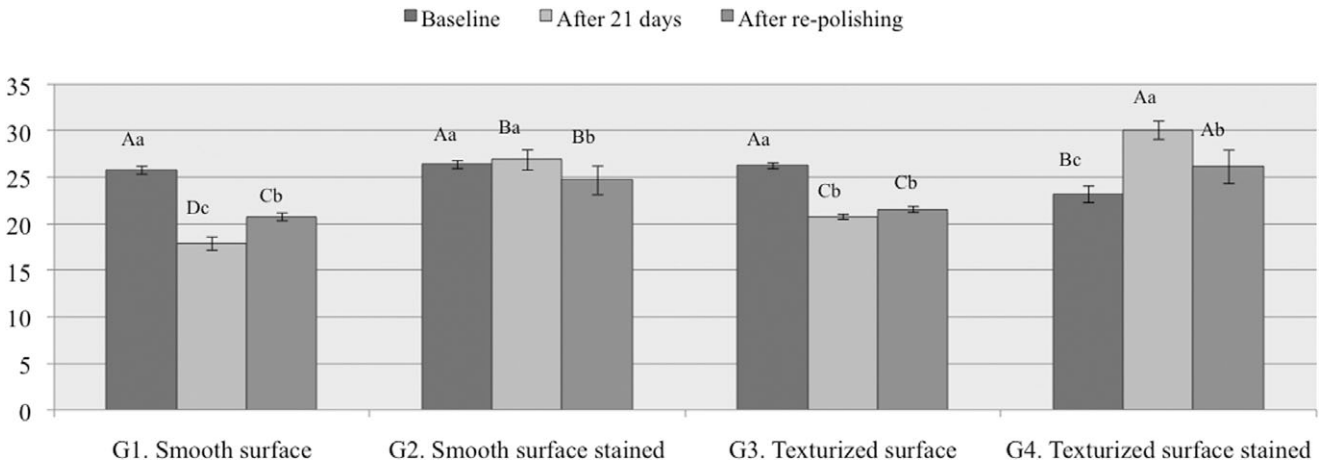

Figure 3. b* *values according to the experimental groups (*N = *10) and periods of color measurements. Dissimilar letters indicate statistically significant differences (repeated measures analysis of variance/Tukey,* $\alpha = 5\%$*). Capital letters compare groups within each period and lower case letters compare periods within each group.*

yellowish appearance increased in both groups exposed to tobacco smoke; nevertheless, the mean *b** value of G4 was significantly greater. After repolishing, the yellowish appearance from G2 and G4 decreased, but the texturized composite continued to present a significantly greater *b** value. In groups not exposed to the tobacco smoke, *b** values decreased after 21 days of storage in artificial saliva. After repolishing, *b** values from G3 have not changed, whereas the ones from G1 have increased significantly.

Table 1 presents the mean and SD of the total color change during the period of the study. A significant statistical interaction between main variables was detected ($p = 0.005$). Groups exposed to tobacco smoke presented significantly greater total color change

TABLE 1. MEAN AND STANDARD DEVIATION (SD) OF THE TOTAL COLOR CHANGE (ΔE) CALCULATED FROM THE THREE PERIODS OF COLOR MEASUREMENT: $\Delta E1$ ($\Delta E_{\text{after 21 days–baseline}}$) AND $\Delta E2$ ($\Delta E_{\text{after repolishing–baseline}}$).

Groups	$\Delta E1_{\text{(after 21 days–baseline)}}$	$\Delta E2_{\text{(after repolishing–baseline)}}$
G1. Smooth surface	8.2 (0.6) Ca	5.7 (0.5) Cb
G2. Smooth surface stained	12.1 (1.7) Ba	8.2 (1.0) Bb
G3. Texturized surface	6.3 (0.4) Da	5.0 (0.3) Cb
G4. Texturized surface stained	16.1 (0.9) Aa	11.2 (3.3) Ab

Means followed by dissimilar letters indicate statistically significant differences (repeated measures analysis of variance/Tukey, $\alpha = 5\%$). Capital letters compare groups within each delta and lower case letters compare delta values within each group.

after the second measurement ($\Delta E1 = \Delta E_{\text{after 21 days–baseline}}$), compared with the unstained ones. After repolishing, mean values from the four groups decreased, but G2 and G4 still had significantly greater values compared to the groups not exposed to tobacco smoke in the $\Delta E2$ ($\Delta E_{\text{after repolishing–baseline}}$) interval.

DISCUSSION

According to the results of the present study, texturized surfaces presented greater color change and increased yellowish appearance when exposed to tobacco smoke compared with nontexturized surfaces. These findings suggest that irregular surfaces can be easily pigmented because staining agents accumulate in the macroscopic and microscopic superficial defects. These results are in accordance with the ones of a previous work, which indicated that diamond finishing points produced rougher surfaces on different types of composites; and that a greater dye concentration was noted on composite surfaces finished with such instruments, compared with carbide burs and rubber points.[8] In another study, authors investigated the staining resistance of different composite materials and found that the discoloration provided by coffee solution increased as the average roughness from most composites increased.[25]

Although smooth surfaces might retain less pigmentation, both texturized and not texturized specimens presented a similar decrease in luminosity when exposed to tobacco smoke. Stained surfaces also presented higher color change and increased yellowish appearance compared with the unstained ones. Therefore, the first null hypothesis of the present study was rejected. The exposure of the composite resin to tobacco smoke with elevated tar content resulted in significant superficial staining, even though the change in luminosity was not accentuated by the presence of superficial textures. The effect of tobacco smoke on the color parameters of esthetic restorative materials was previously demonstrated[26] and is attributed to the brown pigments from tobacco leaves, present on the particulate phase of tobacco smoke known as tar. Therefore, one can speculate that the staining potential might be worsened with cigarettes with elevated content of tar, such as the ones used in this investigation. The thermal effect of the smoking habit might be another area of concern. During cigarette smoking, the oral environment might experience some degree of temperature change. The temperature measured into the chamber used in the methodology of this study ranged from 36 to 38.5°C. Thus, variations in the method have been considered in order to decrease the size of the original chamber and better reproduce the temperature that actually happens inside the mouths of smokers.

Previous work indicated that the surface texture of composite materials is greatly influenced by

temperature changes and that surfaces became more stained after being submitted to thermal variations.[27] The authors stated that, because of the differences in the thermal expansion coefficient between resin matrix and filler particles, thermal cycling might cause repetitive shrinkage and expansion, resulting in a difference in thermal volumetric changes between resin matrix and filler particles.[27] In the present study, the thermal variations from cigarette smoking together with hydrolytic degradation that occurs during storage in saliva might have provided changes on the surface of texturized and not texturized composites, consequently increasing the staining potential from tobacco smoke.

Alterations on the optic characteristics from composite surfaces not exposed to tobacco smoke were also detected in this study. Staining susceptibility of composite materials do not seem to be related to surface roughness alone,[6] and intrinsic factors may result in significant discoloration.[6,8,27] Intrinsic factors include loss of fillers, matrix, or silica coating of composites, which might happen following a period of storage in water or saliva.[27] The resin monomers also have an important role in the color stability of the composites, and a lower staining susceptibility might be related to a lower water absorption rate or a lower resin content.[8] UDMA based composites seem to present lower water sorption than Bis-GMA based composites, resulting in higher staining resistance.[8,27] Although the composite material used in the present study presents UDMA in its composition, in previous works, a similar nanofilled composite exhibited lower staining resistance compared with other composites.[6,27] There are some possible explanations for this finding: since the nanofilled material contains aggregated fillers, there might be porosity in the filler particle itself; and the hydrophilicity of some components from the resin matrix such as the TEGDMA and Bis-GMA monomers might increase the water uptake by the composite matrix, contributing to a higher stain accumulation.[6,27] It should be considered that only one type of composite was tested in this study, and other composites presenting different surface characteristics might show different results under similar conditions and should be further investigated.

The second null hypothesis of this investigation was also rejected because repolishing procedures using aluminum oxide abrasive disks reduced the total color variation and the yellowish appearance of groups exposed to tobacco smoke but did not change the luminosity in such groups. These findings are in accordance with the ones of another study in which the authors found that repolishing procedures with aluminum oxide abrasive disks were partially effective in removing coffee and tea staining; and the total color variation reversed nearly to less than values at 1 day of staining.[19]

The comparison between ΔE-values obtained after staining and after repolishing on groups exposed to cigarette smoke also have highlighted a reduction in exogenous staining following repolishing (Table 1). Nevertheless, clinically unacceptable values (<5.5) can be found among the ΔE-values gathered from the initial measurement (baseline) and the period after repolishing.[24] This finding indicates that repolishing procedures were not able to remove superficial deposition of pigments originating from cigarette smoke, resulting in a significant color change on the composite resin. Further studies should be conducted to analyze the degree and depth of such staining and to indicate if there is a thermal effect or a chemical interaction between components from cigarette smoke and the resin matrix.

CONCLUSION

According to the limitations of the present *in vitro* investigation, it could be concluded that the presence of superficial textures might intensify the color change of composite resin. It was also found

that tobacco smoke could induce significant color change in the nanofilled composite resin and that composite surfaces should be frequently repolished to decrease tobacco staining.

DISCLOSURE AND ACKNOWLEDGEMENTS

The authors do not have any financial interest in the companies whose materials are included in this article. The authors would like to thank 3M ESPE and KG Sorensen for donating the products used in this study.

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This article is accompanied by commentary, "Morphologic Texture Characterization Allied to Cigarette Smoke Increase Pigmentation in Composite Resin Restorations," Marcia Daronch, DDS, PhD, DOI 10.1111/j.1708-8240.2010.00348.x