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Original Article

Effect of air-polishing on properties of nanocomposite submitted to coffee, red wine and cigarette smoke

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ABSTRACT

Aim: The aim of this study was to evaluate the surface roughness and the color stability of nanocomposite exposed to the sodium bicarbonate air-polishing (SBAP) followed by red wine, coffee and cigarette smoke exposure. **Materials and Methods:** 64 nanocomposite specimens were prepared and allocated in 8 groups: G1 (SBAP + distilled water), G2 (SBAP + coffee), G3 (SBAP + red wine), G4 (SBAP + cigarette smoke), G5 (distilled water), G6 (coffee), G7 (red wine) and G8 (cigarette smoke). The surface roughness was evaluated in three periods: before and after SBAP and after exposuring to agents tested. The color was evaluated according to CIEL*a*b* parameters using reflection spectrophotometer in two moments: initial and 30 days after the exposure to staining agents. Data were subjected to three-way repeated measures ANOVA and Tukey's test (5%). **Results:** The results showed a higher surface roughness of the nanocomposite submitted only to the SBAP and those exposed to the SBAP followed by exposure to the coffee or wine solution. The previous application of SBAP followed by cigarette smoke exposure did not increase the roughness of nanocomposite. The SBAP procedure just increased the staining for cigarette smoke group. **Conclusion:** The SBAP increases resin surface roughness, which worsens when there is exposure to coffee and red wine solution. In addition, SBAP may also provide increased staining of nanocomposites exposed to cigarette smoke.

Keywords: Composite resins. Dental materials. Beverages. Smoke.

INTRODUCTION

The composite resins are widely used in restorative dentistry due to the evolution of aesthetic and mechanical properties, as well as the simplified clinical protocols compared to ceramic restorations[1–3]. The development of the chemical composition, inorganic particles distribution and size have provided better physical and mechanical properties, resulting in less surface roughness and better color stability against staining[1,4].

The nanoparticulate resin composite is composed of nanomer and nanoclusters and it is used on posterior and anterior teeth as universal resin composite by clinicians due to the characteristics that achieve good properties and better aesthetic[2,5]. The wear resistance of nanocomposites is related as comparable to or superior to that of microfill and microhybrid resin composites[1,5].

Overall, the surface quality of the restorative material influences the clinical performance and durability of restorations[5], since the maintenance of flat surface decreases early alterations of color and shine, besides of reducing the biofilm growth on surface restoration, which decreases risk of secondary caries lesions and periodontal inflammation[4–9]. The roughness present on resin surface can be detected by the tip of the patient's tongue since 0.3μm[10]. These irregularities are directly associated to the characteristics of the material, as well as the action of instruments used on it[4], besides several kinds of finishing and polishing procedures and follow-up sessions of aesthetic restorations, that include the use of air-polishing powders[3].

A regular and efficient practice in professional dental prophylaxis is the use of sodium bicarbonate air-polishing (SBAP)[1,11]. This system releases air jet, water and sodium bicarbonate particles that have the size by 250μm, and they may cause loss of resin surface smoothness, therefore they favor the staining and degradation of restorations[10,12]. On the other hand, studies have reported that the abrasiveness from air-polishing can be used as strategy to reduce dental and material surface staining[11,12], due to the ability of SBAP to remove waste substances containing dyes from food, drinks and cigarette smoke[13,14].

The advantages of air-polishing compared to the conventional rubber cup prophylaxis are the fast removal of tooth deposits, less hypersensitivity, lower operator fatigue and better access to pits and fissures[3,11,15]. Furthermore, the sodium bicarbonate particles are less abrasive than particles contained in commercially available polishing pastes or pumice[16].

In spite of the air-polishing has not been developed to direct use on aesthetic restorative materials and it be even condemned by some researchers[11,16], it is observed regularly its applications on clinical conditions. Besides, resin composite is a restorative material mightily influenced by oral environment conditions, as moisture, the contact with low pH substances, contact with alcohol or other solvents and even changes of temperature[17,18].These factors can be more harmful to the resin composite structure because it shows a more degraded or porous surface[6].

The resin extrinsic staining occurs due to adsorption of dyes by the composite resin matrix, leading to changes on its surface[17]. Therefore, the exposure of composite resin restorations to individuals habits such as the consumption of coffee, alcoholic beverages, such as red wine and the smoking are determinant for their color stability[19].

Therefore, it becomes important to evaluate the effects of SBAP on roughness surface and color stability of resin composite and if the air-polishing is able to intensify the resin surface roughness and staining, when associated to substances as coffee, red wine and cigarette smoke, agents often used by patients. Thus, the null hypothesis tested was the SBAP is not able to intensify the surface roughness and staining of nanocomposite not even when it is exposed to coffee, red wine and cigarette smoke.

MATERIALS AND METHODS

Specimen preparation

Sixty-four disc-shaped nanocomposite specimens (Filtek Z350 XT, 3M ESPE, St Paul, MN, EUA) were made on a metalic mold (6x1.5mm) in single increment and photo-cured using LED (Radii, SDI, 1200mW/cm^2, Bayswater, Victoria, Australia) through a polyester matrix strip, for 40 seconds. The light intensity of LED was measured before the photoactivation using a radiometer (RD-7, Ecel, Ribeirão Preto, São Paulo, Brazil). Then, the specimens were identified and stored in 3mL of distilled water at 37ºC for 24h. After this period, the specimens were planned and sanded with sandpapers with granulation of 2000, 1200 and 600 on metallographic polymeter (Aropol – 2V, Arotec, Cotia, São Paulo, Brazil), and they were submitted to ultrasonic bath with distilled water for 2 minutes. Posteriorly, the specimens were randomly allocated in 8 groups (n=8) according to the surface treatment and the exposure to agents (table 1).The roughness analysis was performed in three different periods: initial records, after sodium bicarbonate air-polishing and after the exposure to staining agents (experimental groups) or distilled water (control group). Moreover, the specimens were analyzed by spectrophotometer to measure color parameters, in two times: initial and after 30 days of exposure to staining agents.

Table 1. Groups according to the surface treatment and the staining agents.

Sodium Bicarbonate Air polishing	Exposure Agents	Groups
Yes	Distilled Water (control)	G1
	Coffee	G2
	Red wine	G3
	Cigarette smoke	G4
No	Distilled Water (control)	G5
	Coffee	G6
	Red wine	G7
	Cigarette smoke	G8

Surface roughness measurements

All the specimens were analyzed for surface roughness, for initial records (time 1) using a rugosimeter (Surftest 3000, Mitutoyo Sul, Americana, São Paulo, Brazil). The value considered was the arithmetic mean from peaks and valleys (Ra), recorded at 1.25mm and 0.1mm/s. The mean value obtained was the result of 3 measurements for each specimen made in different positions to cover the analyzed surface. After the initial evaluation (1), the roughness was again measured after sodium bicarbonate air-polishing (2) and after the exposure to the staining agents (3).

Color measurements

The color measurements were performed initially and after the period of exposure to the agent,using a reflection spectrophotometer (UV-2600; Shimadzu, Tokyo, Japan) and the software *UV Probe*, where reflectance spectra were obtained from the specimens. The spectral curves obtained from the reading of each test specimen were transported to the software *Color Analysis* for color evaluation following the parameters of the CIEL * a * b * system (*Commission Internationale de L'Eclairage*), with standardization of the illuminant D65. The coordinate values *L** (lightness; 0 = black/100 = white), *a** (green [negative]/red [positive]), and *b** (blue [negative]/yellow [positive]) were measured at baseline and after 30 days of exposure to staining agents. The L * (brightness), a * (green-red variation) and b * (blue-yellow variation) parameters were analyzed separately and the respective values were used to calculate the total color variation (ΔE), applying the formula : $\Delta E = \sqrt{(L-L0)^2 + (a-a0)^2 + (b-b0)^2}$.

Sodium bicarbonate air-polishing

The SBAP procedure was performed from G1 to G4 using a device for professional prophylaxis (Profi Ceramic II, Dabi Atlante, Ribeirão Preto, SP, Brazil) for 30 seconds, distance of 15mm of the specimen and pressure of 60psi. The sodium bicarbonate powder was composed by: $NaHCO_3$ (99.35%)/ chloride (Cl - 0.003%)/ phosphate (PO_4 - 0.001%)/ sulfate (SO_4 – 0.003%)/ ammonium (NH_4 – 0.001%)/ iron (Fe – 0.001%)/ potassium (K – 0.02%)/ precipitate (Ca/ Mg/ P_2O_3 – 0.02%). After the air-polishing, the specimens were submitted to ultrasonic bath with distilled water for 2 minutes to remove particles that may have impregnated on resin surface.

Exposure to staining agents

The composite resin specimens were immersed in red wine (Santa Ana Seleccion – 12.5% alcoholic gradient, Mendonza, Argentina) and in coffee solution (Maratá Traditional, Itaporanga D'Ajuda, Sergipe, Brazil) for 3 minutes, twice a day for 30 days. During this period the specimens that were not exposed to the staining agents were stored on distilled water at 37ºC, as well as the specimens of control group.

The cigarette used in the present study contained 10mg of tar (Malboro, Philip Morris International, Brazil) and the method used was a simulation of frequent cigarette smoking in an acrylic box contained 2 cameras interconnected by holes. The lit cigarettes were allocated in the first camera and the air was pumped up to the second camera, where the specimens were kept. The specimens were exposed to the smoke of 20 cigarettes for day (10 cigarettes for 8 minutes, twice a day), during 30 days. In the intervals between cigarettes exposures the specimens were stored in distilled water at 37ºC.

Statistical Analysis

Data were submitted to 3-Way Repeated Measures ANOVA and Tukey test for surface roughness and 2-Way Repeated ANOVA and Tukey test for ΔE data. The statistical procedures were performed using SAS 9.1 (SAS Institute, Cary, NC, USA) at a significance level of 5%. The power obtained with the sample size in this analysis was higher than 80%.

RESULTS

Surface roughness

The mean values and statistical comparisons for surface roughness analysis are shown in table 2. According to the analysis, there was statistical significance in the triple interaction between the main factors ($p < 0.0001$). When comparing the exposure agents in time *vs.* air-polishing levels, the differences were observed only in the time 3 both in the presence and in absence of the SBAP. In these experimental conditions, the control group presented mean values significantly different from experimental groups exposed to different agents, these values were higher in the presence of sodium bicarbonate air-polishing and lower in the absence of this one.

Regarding the differences of time in exposure agents *vs.* air-polishing levels, both in the presence and absence of air-polishing, higher means were found in the time 3 and lower means in the time 1, independent of exposure agent. However, in the absence of air-polishing and in the control group no differences between the times were found.

Table 2. Surface roughness means (Standard Deviations) according to the groups and different times.

Sodium bicarbonate air polishing	Exposure Agents	Time		
		1	2	3
Yes	Control	0.362(0.058) Ab	0.654 (0.418) Ab	1.074 (0.373) Aa
	Coffee	0.402(0.105) Ac	0.721 (0.373) Ab	0.896 (0.337) Ba
	Red wine	0.432(0.107) Ac	0.746 (0.174) Ab	0.907 (0.144) Ba
	Cigarette smoke	0.339(0.060) Ac	0.759 (0.150) Ab	0.888 (0.147) Ba
No	Control	0.376(0.070) Aa	0.358 (0.069) Aa*	0.350 (0.121) Ba*
	Coffee	0.369(0.087) Ab	0.382 (0.042) Ab*	0.565 (0.231) Aa*
	Red wine	0.376(0.068) Ab	0.384 (0.050) Ab*	0.591 (0.150) Aa*
	Cigarette smoke	0.384(0.065) Ab	0.391 (0.041) Ab*	0.871 (0.103) Aa

Means followed by different letters are statistical significance (3-way repeated measures ANOVA/ Tukey $p<0.0001$). Uppercase letters compare staining agents in time *vs*. air polishing levels. Lowercase letters compare times in air polishing *vs*. staining agents levels. Asterisks represent differences between the use of air polishing in staining agents *vs*. time levels.

Table 3. ΔE means (Standard Deviations) according to the groups.

	Staining			
	Control	Coffee	Red wine	Cigarette smoke
SBAP	4.66 (1.24) Ab	32.65 (3.19) Aa	30.13 (2.69) Aa	28.94 (1.1) Aa
No SBAP	5.74 (0.63) Ab	33.24 (3.88) Aa	31.50 (2.80) Aa	26.82 (1.21) Ba

Means followed by different letters are statistical significance (2-way repeated measures ANOVA/ Tukey test, p<0.0001). Uppercase letters compare the air polishing levels *vs*. each staining agents. Lowercase letters compare the surface *vs*. staining agents levels.

Lastly, the differences between the use of air-polishing in exposure agents *vs.* time were found only in the times 2 and 3, for all exposure agents tested, except for cigarette smoke group in the time 3.

Color analysis

The statistical analysis of the data obtained in the ΔE variable indicated a significant interaction between the main factors ($p<0.0001$). According to table 3, the only statistical difference between the use of SBAP or no SBAP was in cigarette groups, where the SBAP increased the staining. For other solutions (red wine and coffee) and in the control group, no difference was observed between using or not SBAP.

For SBAP groups, the exposure to colouring agents increased the staining if compared to control group, but there were no differences between the agents used. The same result could be seen in the groups without SBAP, where the staining values were higher in the groups exposed to pigment agents than in the control group, but without differences between them.

DISCUSSION

According to this study, the use of SBAP increased the composite resin surface roughness and also intensified the roughness when the resin was submitted to other substances as coffee and red wine. Moreover, the SBAP just increased staining for cigarette group. Thus, the null hypothesis of this study was partially rejected.

In agreement with other studies[3,20–23], the SBAP was able to increase the surface roughness even in a nanoparticulate composite.The abrasive jet action, which contains sodium bicarbonate particles, on the restorative material surface was demonstrated by comparison of the groups with and without SBAP at time 2 (after the SBAP jet application). The superficial abrasion of a composite resin leads to the loss of surface inorganic particles, increasing the roughness and it interferes in the reflective ability of the material[20]. Thereby, the SBAP is able to remove surface inorganic particles, due to the large particle size of sodium bicarbonate, exhibiting the organic matrix to degradation process, which increases the water sorption, solubility and hydrolysis[22]. This superficial degradation can result in microcracks that allow penetration of substances and dyes, further increasing the staining[20].

Besides the SBAP's abrasive effect on composite resin surface, other substances are able to alter the resin matrix, elevating the superficial roughness and thus the degradation of the material[24–26]. The exposure to coffee increased the resin surface roughness and staining if compared to control group, independently of the association to SBAP. This fact can be due to coffee's acid pH, around 5.0, as well as the presence of long-chain organic acids, that they can promote dissolution and corrosion on restorative materials[6].It is reported that the coffee also has high temperature, as used in this experiment, that it can promote degradation of the resin matrix, since areas of material exposed to high temperatures exhibited considerable increased of roughness and superficial staining[27].

The prior use of SBAP followed by immersion of the composite resin in coffee was able to significantly intensify surface roughness when compared to the roughness found in the resins only exposed to the coffee. This increasing can be due to the resin surface previously air polished has more pores and then, resulting in larger areas that remain in contact with coffee. Therefore, this greater contact can intensify the harmful effects of coffee on organic and inorganic matrix of resin, affecting its surface roughness.

The alcohol contained in the red wine can degrade chemically the resin composite surface, by softening of its organic matrix or by hydrolyzing the silane coupling agent, thus it being able to remove filler particles[8,28,29]. Although the inorganic particles protect the resins from deeper decomposition, the surface of material is more exposed and thus, compromised by the presence of microcracks in the interface between the inorganic particles and organic matrix[26]. This micromorphological change of resin surface can explain the surface roughness and the greater staining presented by the nanocomposite in this study, when immersed in red wine, twice a day during 30 days.

The SBAP applied prior to immersion in the red wine further increased the surface roughness of the material tested. It can be explained by the creation of porosities by the SBAP in the composite resin, increasing the surface area that remains in contact with the wine. This contact can intensify the deleterious potential of red wine on the resin, acting as a plasticizer of the polymer matrix[29].

In this study, the exposure to cigarette smoke was also able to increase the surface roughness and staining of composite resin, in agreement with other studies that have shown the smoke can influence on chemical and mechanical properties of resinous materials[13,17,25,30].The surface roughness showed by the composite resin exposed to cigarette smoke did not differ from other groups, regardless of the presence of SBAP. The roughness changes of resin exposed to smoke can be attributed to combustion process of organic matter present in tobacco, resulting in presence of carbon monoxide and carbon dioxide, among other harmful substances besides the increase of temperature[13,31]. Furthermore, an acidic pH solution can be produced by mixing water contained in saliva and cigarette components as carbon dioxide, promoting damage to resin surface integrity[32].These factors can compromise the organic matrix stability, causing superficial degradation of material.

However, there was no statistical difference between the roughness values of resin exposed to cigarette smoke submitted or not to SBAP. It can be explained by the excessive deposits of cigarette smoke components, that remained adhered to resinous surface[17,25]and it may have occluded the pores previously created by the SBAP, contributing for a more regular final surface of composite resin. It can be emphasized by the cigarette group have been the only group that showed increased staining after SBAP procedure.

The high roughness found in the SBAP group followed by exposure to cigarette smoke can result in sites that favor the deposition of particles containing brown pigments, as nicotine and tobacco-specific nitrosamines ranging from 0.1 to 1.0 μm in diameter, on resin surface, altering significantly the color of composite[13,30]. On the other hand, the previous use of SBAP did not alter the color of other groups tested. The remaining of the sodium bicarbonate could be able to prevent the detection of a staining, maybe due to the white coloration of the sodium bicarbonate powder.

The professional prophylaxis using SBAP was able to increase the roughness surface of the nanoparticulate resin tested and it worsen the action of other agents, as coffee and red wine. Although in the present study SBAP did not raise the surface roughness values for composite resin exposed to cigarette smoke, the SBAP was able to increase the staining potential of the cigarette smoke. This result may emphasize the recommendation to perform the re-polishing procedures in composite restorations after they are submitted to SBAP procedure[3].The SBAP can compromise the aesthetic and longevity of restorations, since the color stability also depends of the surface roughness and it can allow greater biofilm retention on these surfaces[9]. Considering that resins are in constant contact with several substances, pH and temperature variations in the oral environment, studies evaluating the effects of air-polishing in restorations for a long period should be performed.

Based on the results obtained in this study, it can be concluded that:

1. The sodium bicarbonate air-polishing is able to increase the nanoparticulate resin surface roughness;
2. The coffee, red wine and cigarette smoke increase the surface roughness and staining of the resin tested if compared to control group;
3. The previous use of SBAP intensifies the effects of immersion in coffee and red wine increasing the surface roughness of nanoparticulate resin;
4. The previous use of SBAP followed by cigarette smoke exposure does not affect the surface roughness of the material, when compared to the resin surface roughness exposed only to cigarette, but it increases the staining.

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