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Mass change of a sodium bicarbonate air-polished nanocomposite exposed to cigarette smoke, coffee, and red wine

Perda de massa de nanocompósito jateado com bicarbonato de sódio e exposto à fumaça de cigarro, café e vinho tinto

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Resumo

Introdução: As resinas compostas estão sujeitas à desafios na cavidade oral relacionados aos hábitos dos pacientes, que podem comprometer a integridade e longevidade das restaurações. As consequências da associação do consumo de bebidas e o uso de cigarros à profilaxia profissional precisam ser estudadas. **Objetivo:** O objetivo desse estudo foi avaliar como o jateamento com bicarbonato de sódio afeta a mudança de massa (sorção e solubilidade) de uma resina composta exposta à fumaça de cigarro, vinho tinto e café. **Material e método:** Oitenta corpos-de-prova de resina composta (FiltekZ350 XT - 3M/ESPE) foram preparados e distribuídos em 8 grupos (n=10): G1 (jateamento + água destilada), G2 (jateamento + café), G3 (jateamento + vinho tinto), G4 (jateamento + fumaça de cigarro), G5 (água destilada), G6 (café), G7 (vinho tinto) e G8 (fumaça de cigarro). Os corpos-de-prova de resina composta foram pesados em três tempos diferentes para obter M1 (massa inicial), M2 (massa após 30 dias de armazenamento nas soluções testadas e exposição ao agente) e M3 (após dessecação). Os valores de sorção e solubilidade foram calculados e analisados usando ANOVA 2-fatores e teste Tukey (5%). **Resultado:** Os grupos experimentais tiveram maior sorção e solubilidade comparado ao grupo controle, independentemente do uso do jateamento. Não houve diferença estatística na sorção para o fator jateamento. Porém, a solubilidade foi maior nos grupos jateados. **Conclusão:** O jateamento com bicarbonato de sódio foi capaz de intensificar a solubilidade da resina testada, embora não tenha aumentado significativamente os valores de sorção.

Descritores: Resinas compostas; bebidas; solubilidade.

Abstract

Introduction: Composite resins are subject to challenges in the oral cavity that are related to patients' habits, which can compromise the restorations' integrity and longevity. Therefore, it is necessary to study how consuming beverages and smoking cigarettes affects professional prophylaxis. **Objective:** The aim of this study was to evaluate how the sodium bicarbonate air-polishing affects the mass change (sorption and solubility) of a composite resin exposed to cigarette smoke, red wine, or coffee solution. **Material and method:** Eighty composite resin samples (FiltekZ350 XT - 3M/ESPE) were prepared and distributed into 8 groups (n=10): G1 (air-polishing + distilled water), G2 (air-polishing + coffee), G3 (air-polishing + red wine), G4 (air-polishing + cigarette smoke), G5 (distilled water), G6 (coffee), G7 (red wine), or G8 (cigarette smoke). The composite resin samples were weighed in triplicate to obtain M1 (initial mass), M2 (mass after 30 days of storage in the tested solutions), and M3 (after desiccation) values. The sorption and solubility values were calculated and analyzed using 2-way ANOVA and Tukey's test (5%). **Result:** The experimental groups had higher sorption and solubility values than the control groups, regardless of whether air-polishing was used. There was no statistically significant difference in the sorption between the air-polished and non-air-polished groups; however, the solubility was higher in the air-polished groups. **Conclusion:** Air-polishing using sodium bicarbonate powder was able to intensify the solubility process of the tested resins but did not significantly increase the sorption values.

Descriptors: Composite resins; beverages; solubility.

INTRODUCTION

Dental composite resin restorations are exposed to a wet environment in the oral cavity and most of the monomers used in dental resin materials can absorb water from the surroundings[1]. The interaction of composite resin with water leads to water uptake into the composite resin through a diffusion process. Water permeates the resin network due to its porosity and intermolecular spaces and this is intensified by the hydrophilicity of the resin matrix and the composition of the resin and the contents of the fillers[1]. The water sorption followed by the solubility of resin components from the restorative material are precursors to a variety of chemical and physical degradation processes[2].

In addition, these restorations are also subjected to many other challenges, such as professional oral prophylaxis and the patient's daily habits[3]. These habits include the consumption of some beverages that have low pH, such as isotonic drinks, coffee, and wines, as well as drinks with high temperature that might affect the composite polymer matrix behavior[4,5]. Smoking also subjects the dental restorations to harmful substances[6-8].

The routine oral prophylaxis performed in the dental office helps to preserve and to increase the longevity of the restorations[9]. Among the available dental prophylaxis methods, sodium bicarbonate air-polishing powder is one of the most commonly used[10]. Its use on composite resin materials is considered a safe procedure in terms of the surface integrity of the material[11,12]. However, the increase in surface roughness[12], in marginal defects on the composite-resin interface[13], and changes in surface composition[11] or in optical properties of the composite materials have been described after its exposure to sodium bicarbonate air-polishing[14,15].

Dental prophylaxis using air-polishing powders performed over the composite resin materials might increase the deleterious action of other substances [i.e., sodium bicarbonate ($NaHCO_3$) air-powder polishing associated with mouthrinses decreases the translucency of the microfilled resin][14]. The increase in the surface roughness of the composite resin by action of the sodium bicarbonate air-polishing could also intensify the staining of the resin-based material exposed to the coffee solution[15].

The lifestyle of the patient can include habits such as tobacco smoke exposure. Exposure of the composite resin to cigarette smoke increases the change in color[7,8], the superficial roughness, and the water sorption of the resin-based materials[8,16].

Drinks commonly present in an adult's diet, such as coffee and red wine, have shown some deleterious effects on the composite resin materials. The pigments present in these solutions could compromise the color stability of the composite materials[4-7]. In addition, the beverage's composition, alcohol content, pH values, and the temperature at which the drink solution reaches the resin material could damage the material's surface area in terms of surface roughness, polymer matrix degradation, and mass changes (water sorption and solubility)[4,15].

Since the exposure of the resin-based materials to different challenges, such as sodium bicarbonate air-polishing, as well as to cigarette smoke contact or immersion in drink solutions, might further compromise the structural integrity of the composite resin, the aim of this study was to measure the mass change (water sorption and solubility) of a nanocomposite exposed to the sodium bicarbonate air-polishing followed by immersion in coffee or red wine solution or submitted to cigarette smoke action. The null hypotheses of this study are that the sodium bicarbonate air-polishing is unable to intensify the sorption and the solubility of a nanocomposite exposed to cigarette smoke or immersed in coffee or red wine drink.

MATERIAL AND METHOD

Samples' Preparation

Eighty composite resin specimens (FiltekZ350 XT - 3M/ESPE, Saint Paul, Minnesota, EUA) were prepared using a metallic matrix (6 mm diameter, 1.5 mm height). The matrix was filled with a single increment of the composite, a polyester strip and a weight of 500 g were positioned on the matrix, and left for 30 s, for the flow of material excess. The samples were photoactivated for 40 s using an LED (Light Emitting Diode, Radii Cal –SDI, Bayswater, Victoria, Australia; 1,200 mW/cm^2). Next, the samples were sonicated in distilled water for 2 min and then randomized, numbered, and individually stored in a desiccator containing silica gel in an oven at 37 °C. The samples were allocated into eight groups (n = 10) according to the following treatments:

G1- Sodium bicarbonate air-polishing + distilled water;
G2- Sodium bicarbonate air-polishing + coffee;
G3- Sodium bicarbonate air-polishing + red wine;
G4- Sodium bicarbonate air-polishing + cigarette smoke;
G5- Distilled water;
G6- Coffee;
G7- Red wine;
G8- Cigarette smoke.

Sodium Bicarbonate Air-polishing Procedure

Half of the samples were submitted to an air-polishing procedure for 30 s, at a distance of 15 mm from the specimen to the tip of the device used for prophylaxis (Profi Ceramic II, Dabi Atlante, Ribeirão Preto, SP, Brazil), with a pressure of 60 psi, using sodium bicarbonate powder containing the following composition: ($NaHCO_3$ - 99.35%) / water insoluble matter: 0.25 maximum / 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 and P_2O_3) 0.02%. After the air-polishing procedure, the samples were sonicated in distilled water for 2 min to remove residual powder particles from the resin surface.

Exposure to Cigarette Smoke, Coffee, and Red Wine

The samples were exposed to three different staining agents: cigarette smoke (Marlboro, Philip Morris International, New York, NY, EUA; 10 mg of tar), coffee (Maratá Traditional, Food Industries Maratá Ltda., Itaporanga D'Ajuda, Sergipe, Brazil), and red wine (Santa Ana Seleccion, Mendoza, Mendoza, Argentina, 2011 harvest, alcohol gradient of 12.5%).

The method of simulation of the frequent consumption of cigarettes used was a modified version of the method described by Le Mesurier et al.[17] We used an acrylic box composed of two chambers interconnected by holes. In the first chamber, the cigarettes were kept lit using a blowtorch, and the air was pumped, forming a chain that carried the smoke through the filter of the cigarette to the second chamber, in which the samples were kept. Also, in the second chamber, there was another hole to vent the pumped air. The samples were exposed to 20 cigarettes per day (10 cigarettes for 8 min, twice a day) for 30 days[18]. In the intervals between cigarette exposures, the samples were kept in distilled water at 37 °C. The samples were exposed to 2 ml of coffee or red wine solution for 3 min, twice per day, during 30 days. When the samples were not exposed to test solutions, they were kept immersed in distilled water at 37 °C.

Evaluation of Sorption and Solubility

The samples were stored in a desiccator containing silica gel in the stove at 37 °C for 24 h. For the daily weighing, the desiccator was removed from the stove and stored at 23 °C for 1 h, and a precision analytical balance was used (Shimadzu AUW220D, Kyoto, Japan) to calculate the change of mass. The samples were weighed daily until a constant mass (M1), when the difference between the weight of each sample was lower than 0.1 mg in 24 h. After obtaining M1, the samples were submitted to three exposure protocols according to the description above, except for the control group that was kept in distilled water for 30 days. After 30 days, the samples were removed from water/solutions, the excess of humidity was removed using absorbent paper, and they were weighed to obtain M2. Then, the samples were returned to a desiccator and were weighed daily until a new constant mass, M3. The sorption and solubility values (μg/cm^3) were calculated using the following formulas:

$$\text{Sorption} = \frac{M2 - M3}{V} \qquad (1)$$

and

$$\text{Solubility} = \frac{M1 - M3}{V} \qquad (2)$$

where V is the volume of samples in mm^3.

Statistical Analysis

Initially, the exploratory analysis of sorption and solubility data was performed to verify the parameters of the analysis of variance (ANOVA). The inferential statistical analysis was performed by two-way ANOVA, considering staining and blasting as the main factors. The Tukey test was used for multiple comparisons between means. All analyzes were performed in the statistical program SAS, version 9.1, with a significance level of 5%.

RESULT

According to sorption data analysis, no significant interaction between the main factors ($p = 0.93$) and differences between the levels of the blasting factor ($p = 0.06$) was observed. When the staining level was analyzed, only differences between the control group and experimental groups were observed for the three types of pigments regardless of the air-polishing procedure ($p < 0.001$) (Table 1).

The statistical analysis of solubility data indicated a significant interaction between the main factors ($p = 0.001$). Differences between sandblasting level in the presence of staining by coffee and cigarette smoke were observed. In the air-polished groups, comparing pigments, cigarette smoke and coffee presented similar values to each other and higher values than red wine and control groups. Regarding groups without air-polishing, the experimental groups presented similar values to each other and valued higher than the control group (Table 2).

Table 1. Mean (standard deviation) of the sorption of the composite resin

	Staining	Coffee	Red Wine	Cigarette smoke
	Water			
Air-polishing	0.02115 (0.00327) Ab	0.03128 (0.00133) Aa	0.03229 (0.00326) Aa	0.03152 (0.00265) Aa
Without air-polishing	0.02104 (0.00418) Ab	0.03112 (0.00113) Aa	0.03131 (0.00182) Aa	0.03078 (0.00105) Aa

Means followed by distinct letters represent statistical significance between the groups (2-way ANOVA/Tukey, alpha = 5%). Upper case letters compare pigments within the variable air-polishing and lower case letters compare air-polishing within each pigment.

Table 2. Mean (standard deviation) of the solubility of the composite resin

	Staining	Coffee	Red Wine	Cigarette smoke
	Water			
Air-polishing	0.00162 (0.00100) Ac	0.07438 (0.01992) Aa	0.03504 (0.04345) Ab	0.09512 (0.05926) Aa
Without Air-polishing	0.00094 (0.00076) Ab	0.00660 (0.00286) Ba	0.01883 (0.01176) Aa	0.02134 (0.01026) Ba

Means followed by distinct letters represent statistical significance (2-way ANOVA/Tukey, alpha = 5%). Capital letters compare levels of the polishing factor in each pigment and lower case letters compares pigments within the variable air-polishing.

DISCUSSION

In this study, the sorption and solubility properties were evaluated because they represent phenomena that occur in the resin composite structure as part of its interaction with the oral environment[19]. Of the null hypotheses of this study, only that for sorption was accepted; the sandblasting using sodium bicarbonate powder was unable to intensify the water sorption of composite resin immersed in water or coffee and red wine solutions or exposed to cigarette smoke, regardless the use of sandblasting. Although other studies have reported increased surface roughness[12] or the presence of small changes in the surface composition of the material submitted to sandblasting evaluated by scanning electron microscopy[11], these changes did not result in any structural ruptures of the material surface that would represent volumetric losses or material integrity violations material[11,12].

The exposure of nanocomposite to aqueous solutions of low pH, such as coffee and red wine, as well as exposure to cigarette smoke, was able to increase the water sorption of the experimental groups relative to the control group, which was immersed only in distilled water, regardless of the sandblasting procedure. This result is corroborated by the study by Zhang, Xu[19], which evaluated the water sorption and solubility and flexural properties of two composite resins immersed in three different solutions, and reporting that the properties were altered when immersed in these solutions.

Regarding the increase in water sorption in samples exposed to cigarette smoke, these results are in accordance with the results presented by Takeuchi et al.[20] and Mathias et al.[16] who stated that the chemical elements present in cigarette smoke are incorporated into the structure and alter the surface of the resin. Additionally, Vitoria et al.[21] demonstrated that cigarette smoke enhances the diffusion dynamics of adhesive system liquids by reducing their physical properties.

The partial rejection of null hypotheses was due to the inability of the air-polishing procedure to increase the solubility of samples immersed in coffee; the air-polishing procedure only increased the solubility of composites exposed to red wine solution and cigarette smoke. These results suggest that the air-polishing procedure caused a superficial alteration on a composite that was able to expose the organic matrix, making it more susceptible to loss of its components when immersed in aqueous solutions or when exposed to cigarette smoke.

The absence of differences between the solubility of those groups air-polished versus those that were not could be due to the coffee has decanted on surface irregularities of resin, caused by air-polishing procedure and has not been eliminated, even with the desiccation cycles to which the samples were submitted. Santos et al.[22] also found that coffee could induce a significant loss of inorganic particles of a composite resin.

Higher values of solubility were found for groups exposed to coffee, red wine, and cigarette smoke compared to a control group immersed in distilled water. In agreement with these results, Zhang, Xu[19] found higher solubility values for composite immersed in 75% ethanol compared to groups immersed in water, indicating that contact with solutions containing ethanol results in higher solubility values of the composite. According to Ferracane[2], the storage of composite resin samples in aqueous media can reduce its mass and increase the materials degradation.

Regarding cigarette smoke, Bertoldo et al.[23] demonstrated that the microhardness of tooth enamel and staining is altered by exposure to cigarette smoke. Additionally, Takeuchi et al.[20] concluded in an *in situ* study that both enamel and composite resin had their color and microhardness altered by cigarette smoke. In this study, higher values of solubility were for composite resin exposed to cigarette smoke, regardless of the air-polishing procedure.

Anfe et al.[24] found that composites that presented the greatest mass changes in the water sorption and drying process presented significant cracks in their surface. It is important to note that the success of restorative treatment depends on the clinical performance of material and its longevity and resistance to challenges in the oral environment.

The present study evaluated the dynamics of liquids, represented by water sorption and solubility phenomena, and verified that the solubility is altered by air-polishing with sodium bicarbonate when carried out on the surface of a composite nanoparticulated composite. Additional clinical trials are necessary to determine whether the increase in solubility after the air-polishing procedure compromises the longevity of the restorative materials.

Moreover, the composite resin is usually exposed to multiple agents according to the patient's habits, such as red wine that has been associated with alterations in the resin surface due to its alcohol content[3]. The consumption of coffee has been described as a precursor of superficial changes[25], and cigarette smoke promotes alterations in the superficial microhardness of the composite and results in significant color changes[20].

CONCLUSION

Based on the results of this study, we conclude that:

- The air-polishing using sodium bicarbonate powder is unable to increase the water sorption of composite resin;
- The air-polishing procedure using sodium bicarbonate powder increases the solubility of composite resin stored in water and exposed to red wine and cigarette smoke;
- When the composite resin is air-polished, the solubility is higher when the composite is exposed to coffee and cigarette smoke than when they are immersed in water and red wine;
- The immersion in solutions such as coffee and red wine, as well as exposure to cigarette smoke, increase the water sorption and solubility of the nanoparticulated resin.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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