Evaluation of the Possibility of Removing Staining by Repolishing Composite Resins Submitted to Artificial Aging

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ABSTRACT

This in vitro research verified the possibility of eliminating staining caused by coffee and red wine in five composite resins, after being submitted to thermal cycling. Thirty-six specimens were prepared and immersed in water at 37°C for 24 hours. After polishing, specimen color was measured in a spectrophotometer Cintra 10 UV (Visible Spectrometer, GBC, Braeside, VIC, Australia). All specimens were submitted to thermal cycling at temperatures of 5 and 55°C with a dwell time of 1 minute, for 1,000 cycles in a 75% ethanol/water solution. After thermal cycling, the specimens were immersed in water at 37°C until 7 days had elapsed from the time the specimens were prepared. All specimens were then taken to the spectrophotometer for color measurement. The specimens were divided into three groups ($N = 12$): distilled water (control), coffee, and red wine. For the staining process to occur on only one surface, all the sides, except one, of the surfaces were isolated with white wax. The specimens were immersed in one of the solutions at 37°C for 14 days. The specimens were dried and taken to the spectrophotometer for color measurement. After this, the specimens were submitted to 20 µm wear three times, and the color was measured after each one of the wear procedures. Calculation of the color difference was made using CIEDE2000 formula. According to the methodology used in this research, it was concluded that the staining caused by coffee and red wine was superficial and one wear of 20 µm was sufficient to remove the discoloration.

CLINICAL SIGNIFICANCE

Discoloration is one of the main causes of esthetic restoration replacement. As demonstrated in this study, repolishing could be an alternative method for removing staining, once it is superficial. This procedure can avoid the substitution of functional restorations and prevent trauma to the sound tooth structure.

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INTRODUCTION

In esthetic dentistry, color, form, and surface texture are important factors characterizing a restoration. The success of an esthetic restoration depends on the correct choice of shade and the color stability of the material. Composite resin staining is a multifactorial phenomenon and can be caused by intrinsic and extrinsic factors.

Internal color changes depend on the composite photoinitiator system.[1–3] Intrinsic discoloration is

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permanent and is related to polymer quality, type, and quantity of inorganic filler and type of accelerator added to the photoinitiator system.[4]

Extrinsic factors include staining through the adsorption and/or absorption of colorants, as a result of external sources of contamination.[2] Extrinsic staining depends on the individual's diet, hygiene, and the chemical properties of the composite. Composition and volume of organic matrix, type and volume of filler particles, type of filler-matrix silanization, and polishing are relevant factors in the composite susceptibility to staining.[5,6] The resin composite affinity for colorants can be modulated by its degree of conversion. Composites with a low degree of conversion tend to present higher discoloration when submitted to dyestuff.[7]

Staining of a material can be evaluated visually or with instrumental techniques. Since instrumental measurement eliminates subjective interpretation of visual color comparison, spectrophotometers began to be used for color evaluation.[2] In the CIELab system, color differences can be expressed in units that can be related to visual perception and clinical significance.[2,8–10] The color difference formula proposes to provide a quantitative representation (ΔE) of color difference between a pair of colored samples under experimental conditions.[11] However, the CIELab system has a poor uniform color space, at least where small color differences are concerned. In CIEDE2000 (ΔE_{00}) the color difference formula was adopted as the new CIE (*Comission Internacionale de l'Eclairage*) equation of color difference.[12]

In the regular oral functioning of eating and drinking, restorative materials are exposed to thermal stress.[13] In theory, thermal cycling simulates in vivo aging of the restorative material submitted to repeated cyclic exposure of hot and cold temperatures.[14]

The durability of composite restorations under oral conditions is an object of great concern among clinicians and researchers. Thus, studies have sought to evaluate the behavior of restorative materials under conditions close to those in the oral cavity. The Food and Drug Administration recommends an ethanol-water solution as a food simulator and it can be considered clinically relevant.[15,16]

It was reported that the ethanol-water solution has a solubility parameter close to that of bisphenol A glycidyl methacrylate (BisGMA).[15–17] Therefore, the 75 vol % ethanol-water solution became the solvent of choice to simulate accelerated aging in dental restorations.[15,16] The sorption percentage of composites is higher in an ethanol solution than in water.[18]

Currently, replacement of restorations is the main reason for performing direct restorations. Discoloration of the material is one of the main reasons for replacing esthetic restorations.[19–24] Once the material has been stained, repair can be carried out in an attempt to avoid the premature replacement of a restoration that is still in function.[25] Depending on the depth of the stain in the composite, there is the possibility of polishing restoration to remove the superficial layer, and recover the initial color of the esthetic restoration.

Thus, the aim of this in vitro study was to verify the possibility of repolishing as a means of removing staining caused by coffee or red wine, of five commercially available composites, after they had been submitted to the artificial aging process.

MATERIALS AND METHODS

Specimen Preparation

In this study, five different commercially available composite resins were tested (Table 1). Thirty-six specimens were prepared in a Teflon mold, 10 mm in diameter and 1.5 mm thick. A glass microscope slide was placed on a flat surface with a polyester strip over it, and the Teflon mold was set on it. Composite resin was inserted in one increment and another polyester strip and glass microscope slide were set on it and pressed over the mold to obtain a flat surface. The composite was light polymerized with halogen light[26] (Degulux Soft-start,

TABLE 1. Materials tested

Composite	Composition	% Filler (weight)	% Filler (volume)	Bath	Shade
4 Seasons Ivoclar-Vivadent, Schaan, Liechtenstein	BisGMA UDMA TEGDMA	75–77%	55–58%	K22176 K27524	A1
Esthet X Dentsply, Caulk, Milford, DE, USA	BisGMA uretano modificado BisEMA TEGDMA	—	—	0706128 070616	A1
Filtek Supreme 3M ESPE, 3M ESPE, St. Paul, MN, USA	BisGMA UDMA TEGDMA BisEMA	78.5%	59.5%	8FE	A1
Grandio Voco, Cuxhaven, Germany	BisGMA TEGDMA	87%	71.4%	0837088	A1
Venus Heraeus Kulzer, Hanau, Germany	BisGMA TEGDMA	78%	61%	010121	A1

Degussa-Hülls AG, Hanau, Germany) for 20 seconds, according to the manufacturers' instructions. The light activation unit tip was 7 mm in diameter, while the diameter of the specimen was 10 mm. Thus, each surface was divided into two parts, so that the whole surface was homogeneously light polymerized. On both surfaces, the light activation points were opposed. The light intensity was 475 mW/cm^2 and was verified with a radiometer before each specimen was made. Light activation was performed with the unit tip touching the glass microscope slide (1 mm thick) to standardize the light activation distance.

The specimens were immersed in distilled water at 37°C for 24 hours. This storage is important to leach unreacted components in composites.[27] After this initial storage period, the specimens were polished under irrigation (Ecomet, Buehler, IL, USA) on both surfaces, with # 600 grit silicon carbide paper, until a thickness of 1.3 ± 0.01 mm was achieved. The thickness was controlled with a digital pachymeter (Mitutoyo Sul Americana, Suzano, Brazil). The specimen thickness is relevant for measuring the material color,[28,29] thus it is important to make this control. The specimens were polished with a device that allows the abrasion to occur parallel to the surface.

Color Measurement

After polishing, the color of the specimens was measured (M_1) with a spectrophotometer Cintra 10 UV (Visible Spectrometer, GBC, Braeside, VIC, Australia—FAPESP No.05159695-1) against a white background, illuminant D65 and by a second observer using CIELab color space. Reflection values were recorded in the visible spectra range (380–780 nm) in increments of 9.6 nm. Three color measurements of each specimen were made and a mean value was obtained.

Thermal Cycling

All specimens were submitted to thermal cycling (Nova Ética, Vargem Grande Paulista, Brazil) at temperatures of 5 and 55°C with a dwell time of 1 minute, for 1,000 cycles in a 75% ethanol/water solution. This solution was chosen in an attempt to increase composite aging, as it presents a solubility parameter similar to that of BisGMA.[15,17] After thermal cycling, all specimens were taken to the spectrophotometer for color measurement (M_2).

The specimens were immersed in water at 37°C until 7 days had elapsed from the time of specimen preparation. This precaution was taken to ensure the

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sorption in the composite was close to saturation, which occurs around the seventh day.[15,30]

Artificial Staining

The specimens were divided into three groups ($N = 12$): distilled water (control), coffee (Nescafé Original, Nestlé, SP, Brazil), and red wine (13% vol alcohol; Santa Carolina, Reservado, Cabernet Sauvignon, D.O. Valle Central, Chile, 2006). So that the staining process would occur on only one surface, all the sides and one of the surfaces were isolated with white wax (Kota Indústria e Comércio Ltda, São Paulo, Brazil). The coffee was prepared with 3 g of powder in 100 mL of distilled water, according to the manufacturer's instructions. The specimens were immersed in one of the solutions at 37°C for 14 days.[2,31] Ertas and colleagues[10] related that a 24-hour storage time simulates about 1 month of coffee consumption. Thus, the authors chose to simulate the staining that occurred in, approximately, 14 months of coffee consumption.

Repolishing

After the staining period, specimens were washed with distilled water for 10 seconds. The wax was removed and the surface that had been submitted to the staining process was brushed[2,32,33] with an electric brush (Braun Oral-B, Procter & Gamble do Brazil S.A., Manaus, Brazil) for 30 seconds under slight pressure. The specimens were dried with tissue paper and were taken to the spectrophotometer for color measurement (M_3).

After this, the specimens were submitted to 20 μm wear three times, and the color was measured (M_4, M_5, and M_6) after each one of the wear procedures. This procedure made using the same device used for polishing and was controlled with a digital pachymeter.

Calculation of the color difference was made using the CIEDE2000 formula:

$$\Delta E_{00} = \{[\Delta L'/(KLSL)]^2 + [\Delta C'/(K_C S_C)]^2 + [\Delta H'/(K_H S_H)]^2 + R_T[\Delta C'/(K_C S_C)] \times [\Delta H'/(K_C S_C)]\}^{1/2}$$

where, $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the differences in lightness, chroma, and hue between two specimens being compared. SL, SC, and SH are the weighing functions for the lightness, chroma, and hue components, respectively. KL, KC, and KH are the parametric factors to be adjusted according to different viewing parameters. In this study, KL, KC, and KH were set to 1.[34]

The ΔE_{00} values were obtained for the color difference between the initial color measurement (M1) and

- After thermal cycling (M2)
- After staining process (M3)
- After 20 μm wear (M4)
- After 40 μm wear (M5)
- After 60 μm wear (M6)

The lower the value, the lower the color difference between initial color of the composite and the color presented after one of the above procedures.

Statistical Analysis

The experimental hypothesis was that repolishing of stained specimens would remove discoloration and recover the initial composite color. The null hypothesis was that discoloration would be deeper than repolishing would remove.

For each material, ΔE_{00} means were subjected to statistical analysis by analysis of variance and Scheffé's test at level of significance of 5%. For comparison between the materials, Kruskal–Wallis and Mann–Whitney tests at a level of significance of 5% were applied.

RESULTS

The color difference was calculated using the CIEDE2000 formula. The groups submitted to staining with coffee and red wine were compared with the control group (distilled water). The control group was submitted to the wear procedures to make it possible to compare its specimens with the other specimens of the same thickness.

TABLE 2. ΔE_{00} values in different measuring times of the specimens stained with coffee

	4 Seasons	Esthet X	Grandio	Supreme	Venus
M3	3.36	3.12	2.97	5.32	3.93
M4	1.18	0.94	1.08	1.20	1.14
M5	1.38	1.02	1.09	1.24	1.17
M6	0.93	0.93	1.00	1.15	1.11

TABLE 3. ΔE_{00} values in different measuring times of the specimens stained with red wine

	4 Seasons	Esthet X	Grandio	Supreme	Venus
M3	4.10	8.64	4.39	6.07	6.27
M4	1.41	1.25	1.21	1.39	1.22
M5	1.78	1.28	1.25	1.74	1.24
M6	0.85	0.81	0.97	0.77	1.00

TABLE 4. Discoloration after thermal cycling

Composite	*N*	Subgroup for $\alpha = 0.05$	
		1	2
Supreme	36	11.178	
Esthet X	36	12.968	12.968
4 Seasons	36	13.107	13.107
Grandio	36		16.730
Venus	36		17.242
Sig.	36	0.825	0.121

Values in the same column do not present statistical difference.

Table 2 presents ΔE_{00} values in different measuring times of the specimens stained with coffee and Table 3 presents ΔE_{00} values of the specimens stained with red wine. The comparison between the composites of the discoloration after thermal cycling is presented in Table 4.

The comparison between of ΔE_{00} values of the composites stained with coffee and red wine is presented in Table 5.

TABLE 5. ΔE_{00} values of the composites stained with coffee and red wine

Solution	4 Seasons	Esthet X	Grandio	Supreme	Venus
Coffee	3.36^{b}	$3.12^{a,b}$	2.97^{c}	5.32^{e}	3.93^{c}
Red wine	$4.10^{b,c}$	8.64^{f}	4.39^{a}	6.07^{d}	6.27^{e}

Values with same upper letter do not present statistical difference.

DISCUSSION

The constant replacement of restorations has concerned clinicians and researches. The growing demand for esthetics has led to premature replacement of discolored restorations, as one of the main causes of composite restoration replacement in anterior teeth is material discoloration.[20,21,23,24]

Discoloration can be caused by intrinsic or extrinsic factors. Extrinsic factors are directly related to the patient's diet.[33,35] The impact of a beverage on composite properties can be related to quantity and frequency of ingesting it.[33,35,36] In this study, the authors tested coffee and red wine because they are frequently consumed beverages. Specimens were previously submitted to an artificial aging process.

Composite degradation in the oral environment, involves not only chemical degradation, but masticatory and abrasive forces as well. In vivo, composite resins can be intermittently or continuously exposed to chemical agents found in saliva, food, and beverages. The chemical environment is one aspect of the oral environment that could have an appreciable influence on the in vivo degradation of composite restoratives.[27] In the normal oral functioning of eating and drinking, restorative materials are also exposed to thermal stress.[13] All these stimuli predispose to composite degradation, mainly in organic matrix, which can reduce the composite mechanical properties[37,38] and increase its susceptibility to discoloration.[13,39]

In this study, thermal cycling was performed with a 75 vol % ethanol-water solution[15] in an attempt to vigorously age composite resin and to simulate the susceptibility to staining of a material that would be

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under oral conditions for a period. For this purpose, the composite was exposed to temperature cycling and simultaneously to an ethanol solution. This solution has been the solvent of choice to simulate accelerated aging of restorations, as it has a solubility parameter, which matches that of BisGMA.[17,27]

Thermal cycling caused discoloration in the tested composites. Filtek Supreme was the material that presented the least discoloration. Eshtet X and 4 Seasons did not present significant difference from Filtek Supreme. Esthet X and 4 Seasons did not present significant difference from Grandio and Venus. This result is in agreement with Lee and Lee,[40] who evaluated changes in optical parameters in eight composite resins. The authors found discoloration in all the material tested and the results were material dependent.

When there is a report that a composite presented discoloration, it means that the spectrophotometer detected this change in material. However, it does not mean that this color difference is perceptible to the human eye. There is a ΔE_{ab} limit value that indicates that the change in color is perceptible to the human eye. There is no consensus about this value; however, various authors[1,6,35,39,41–45] adopt 3.3 as the limit value for being clinically acceptable. That is, a color difference of over 3.3 indicates the discoloration is perceptible and clinically unacceptable.

In the present study, the CIEDE2000 (ΔE_{00}) color difference formula was adopted, which is recommended for the evaluation of composite color.[11,12] The purpose of the color difference formula is to provide a quantitative representation (ΔE) of color difference observed between a pair of colored samples under experimental conditions. The ΔE values reported in the literature, which would be clinically acceptable, concern the CIELab formula, from 1976 (ΔE_{ab}). Perez Mdel and colleagues[11] conducted a study that established that there was a significant correlation between ΔE_{ab} and ΔE_{00}. However, depending on the parameters studied, it is impossible to find only one relationship between the two formulas. Lee[34] reported the need to develop a study that relates color difference values from CIEDE2000, which correlate with the average visual responses of observers, in order to obtain a value that is clinically relevant. Thus, this study compared ΔE_{00} values but it is not possible to relate them clinically.

At the dental clinic, the presence of stained composite restorations is common. For this reason, this study attempted to observe the depth of staining in composite resins. There was the hypothesis that staining would occur in the most superficial layer of the composite.[46–48] Thus, repolishing would be a possibility for removing discoloration, and prevent premature replacement of the restoration. For this purpose, three wear procedures of 20 μm each, and color measurement after each one of the wear procedures was performed. The ΔE_{00} values reduced significantly after the first 20 μm wear procedure, and remained stable after two other wear procedures. This result confirms that staining occurs in a superficial layer, at less than 20 μm, and it is possible to remove this layer through repolishing.[2]

Evaluation of all the composites tested revealed that coffee produced less color change than red wine. This result is in agreement with previous studies.[10,39,49] In the present study, some materials (4 Seasons and Filtek Supreme) did not present difference in staining between the two solutions, while in others (Esthet X, Grandio, and Venus) red wine produced a significantly higher color difference than coffee.

The comparison of staining between the tested composites showed that materials behaved differently in the solutions. In coffee, Filtek Supreme was the material that presented the highest color difference, followed by Grandio and Venus, which showed no statistical difference between them. Esthet X and 4 Seasons presented the least color difference with ΔE_{00} values of 2.98 and 3.39, respectively, and no statistical difference between them.

In red wine, Esthet X presented the highest color change, followed by Venus and Filtek Supreme. Grandio was the material that presented the least color change. All composites showed significant differences between them.

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Most of the studies have tested commercially available composites to evaluate their different properties. However, due to extensive variety of formulations, it is difficult to identify the factors that most contribute to the change in the properties of a material.

CONCLUSIONS

According to the methodology used in this research, it was concluded that staining caused by coffee and red wine was superficial and a 20 μm wear was sufficient for removing the discoloration.

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