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Repolishing Resin Composites After Bleaching Treatments: Effects on Color Stability and Smoothness

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Clinical Relevance

When resin composites are submitted to bleaching procedures, immediate repolishing after the last gel application can improve color stability.

SUMMARY

This study aimed to evaluate the effect of repolishing after bleaching on color stability and smoothness of two resin composites aged in a high-staining beverage. Fifty-six disc-shaped specimens (8×2 mm) of each resin composite were fabricated (Filtek Z250, 3M ESPE, microhybrid, and Filtek Z350 XT, 3M ESPE, nanofilled) and then divided according to treatment: bleached or nonbleached. After treatment application, groups were subdivided according to the surface treatment: repolished or unrepolished. A new subdivision was performed according to aging conditions: immersion in red wine for 15 min/d or in artificial saliva for 24 h/d during 30 days. Color (CIE-*L*a*b system) and roughness (Ra) were assessed at baseline (P0), after bleaching procedures (P1), after surface treatment (P2), and after aging (P3). Color change (ΔE_{00}) was calculated through the CIEDE2000 formula. Statistical analysis was performed using repeated measures analysis of variance and the Tukey *post hoc* test. Bleached repolished groups presented lower color alteration than the bleached unrepolished groups from both resin composites when aged in red wine. Repolishing (P1 vs P2) promoted a slight decrease in roughness values of almost all groups. Nanofilled composite presented greater ΔE_{00} values than microhybrid composite when aged in red wine.**

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INTRODUCTION

Resin composites and bleaching agents have been widely used due to increasing demand for esthetics. Bleaching procedures are commonly employed for removing intrinsic and extrinsic stains from dental tissue, and those who seek fast results often choose in-office techniques. In addition, the presence of resin composite restorations in the areas that are exposed to bleaching agents is very common.

Color change of a resin composite is related to factors such as matrix type, filler type, and coloring agents,[1] and it intensifies when the material is in contact with staining agents or alcoholic and acidic media commonly present in one's diet, further degrading the organic matrix.[1-4] Roughness is another important factor that determines composite discoloration.[5-7] High-quality finishing and polishing improve both the longevity and the appearance of resin composites, whereas rough surfaces contribute to staining, plaque accumulation, recurrent caries, and gingival irritation[8] in addition to also causing discomfort and cleaning difficulties for the patients.[9]

Teeth and resin composite restorations are exposed to bleaching action during treatments. These restorations are commonly replaced after the treatment due to possible physical and mechanical alterations in their smoothness, hardness, and color stability.[10-12] According to Rodrigues and others,[13] a resin composite surface becomes more porous and rougher when it is submitted to bleaching procedures, which may facilitate discoloration.[14] Nevertheless, resin composite restorations can be maintained after bleaching in some situations, such as when the dental tissue and restorative material interface in the bleached teeth are not affected[15] and the bleached enamel color matches the restoration color.[16]

The consequences of bleaching on resin composites depend on both the bleaching agent and the composite compositions as well as on the frequency and duration of exposure to bleaching.[17] Yu and others[14] evaluated the effect of 15% carbamide peroxide on the staining susceptibility of resinous materials and observed that bleached specimens stained more easily when compared to nonbleached specimens. In a similar manner, Çelik and others[18] analyzed the influence of 20% carbamide peroxide on the color stability of resin composites and did not find greater discoloration in bleached specimens. Polydorou and others[19] did not verify alterations to the surface texture of polished and bleached specimens when studying the effect of 15% carbamide peroxide and 38% hydrogen peroxide on three different resin composites. Hubbezoglu[20] found statistically significant differences in the color stability of specimens bleached with 35% hydrogen peroxide. Yu and others[21] also studied the effect of bleaching agents on these material surfaces and suggested that it may be necessary to polish the restorations that were in contact with bleaching gel during the treatment.

To date, no research has shown if repolishing resin composite restorations after bleaching treatment has any significant importance. In this context, this study aimed to evaluate the effect of repolishing after bleaching on color stability and smoothness of two resin composites (microhybrid vs nanofilled) aged in a high-staining beverage. The tested hypotheses were that 1) repolishing after bleaching promotes the smoothness of resin composites and a decrease in the color change after aging, 2) bleaching resin composites promotes a color change and increases roughness, and 3) there is no difference between the resin composites after aging.

METHODS AND MATERIALS

Study Design

The characteristics of the materials used in this *in vitro* study are described in Table 1, and Figure 1 describes the study's time line.

The factors analyzed were resin composite (two levels: microhybrid or nanofilled composites), bleaching (two levels: bleached or nonbleached), surface treatment (two levels: repolished or unrepolished), aging media (two levels: red wine or artificial saliva), and study phase (four levels: P0, P1, P2, and P3). The same specimen within each experimental condition was analyzed in all phases (repeated measures approach): baseline (P0), after bleaching procedure (P1), after surface treatment (P2), and after aging (P3). Primary outcomes under investigation were color difference (ΔE_{00}) and roughness (Ra).

Specimen Preparation

The sample size was calculated using information from Sealed Envelope.[22] Means and standard deviations of ΔE_{00} needed to calculate the sample size were obtained from a pilot study. It was observed that $n = 7$ was the minimum sample size, considering a 5% significance level and 80% statistical power.

Thus, 56 specimens of each resin composite were fabricated for this study: Filtek Z250 (microhybrid) (3M ESPE, St Paul, MN, USA) and Filtek Z350 XT (nanofilled) (3M ESPE). A stainless-steel matrix with a central hole of 2-mm thickness and 8-mm diameter was positioned over a polyester strip on a glass plate. The resin composite was placed in one increment into the matrix and covered by another polyester strip and a glass plate. An axial load of 500*g* was applied during 20 seconds to promote

Table 1: *Materials and Manufacturers, Type/Color, and Composition of Composite Resins, Bleaching Gels, and Aging Solutions Used*

Material/Manufacturer	Type/Color	Composition[a]
Filtek Z250 (3M ESPE, St Paul, MN, USA)	Microhybrid/A2 Enamel	Matrix based on bis-GMA, bis-EMA, TEGDMA, UDMA; 60% silica/zirconia (0.6 μm) particles
Filtek Z350 XT (3M ESPE)	Nanoparticle/A2E	Matrix based on bis-GMA, bis-EMA, UDMA,TEGDMA; 63.3% silica/zirconia clusters; silica particles (20 nm); zirconia (4-11 nm) and silica/zirconia clusters (0.6-10 μm)
Total Blanc Office H35 (Nova DFL, Rio de Janeiro, Brazil)	—	35% hydrogen peroxide, thickener, plant extracts, amide, sequestering agent, glycol, dye and water
Artificial saliva (Dermapelle Farmácias de Manipulação, Santa Maria, Brazil)	—	Sodium chloride, potassium chloride, calcium chloride, magnesium chloride, potassium phosphate, methylparaben, carboxilometilcelulose, sodium fluoride, xylitol C, and deionized water
Salton Classic Cabernet Sauvignon (Vinícola Salton, Bento Gonçalves, Brazil)	—	Dry red wine fermented of cabernet sauvignon grapes; alcohol content of 13.0%

[a] *Manufacturer's information.*

smoothness and extrude the resin composite excess. The specimen was then photoactivated by an LED light source (Radii, SDI, Bayswater, Australia) with approximately 1000 mW/cm^2 for 20 seconds through the glass plate and for 20 seconds without it. Immediately after, all faces of the specimens were finished and polished with a medium, fine, and extra-fine sandpaper disc (Diamond Pro, FGM Produtos Odontológicos, Joinville, Brazil) for 20 seconds per disc. A felt disc (Diamond Flex, FGM Produtos Odontológicos) with extra-fine (2-4 μm) diamond paste (Diamond Excel, FGM Produtos Odontológicos) was subsequently used for 20 seconds to achieve final polishing. New discs were used for each specimen. Specimens were rinsed and gently dried with gauze before every disc usage. One previously trained blinded operator carried out all the procedures. A digital caliper (Absolute Digimatic, Mitutoyo, Tokyo, Japan) was used to measure specimen thickness, and specimens with thicknesses that varied by more than 0.05 mm were discarded. Specimens were lightly marked with a diamond disc on their bottom surface. These markings were used to obtain a standardized position in the spectrophotometer and the roughness tester.

In the study's first phase, specimens of each composite were randomly allocated into two groups (bleached or nonbleached, n = 28) using information from Random.org.[23] The specimens in both groups were kept in artificial saliva at 37°C for 24 hours until initial hydration.

Bleaching Treatment

A standard Teflon mold (with cylindrical holes of 3-mm depth and 10-mm diameter) was designed to hold and fix the specimens in place and to standardize the bleaching procedures. Specimens were inserted into the mold with the top surface exposed and recessed 1 mm from the mold surface. Bleaching gel (35% hydrogen peroxide, Total Blanc Office, Nova DFL, Rio de Janeiro, Brazil) was manipulated as per the manufacturer's recommendations and applied

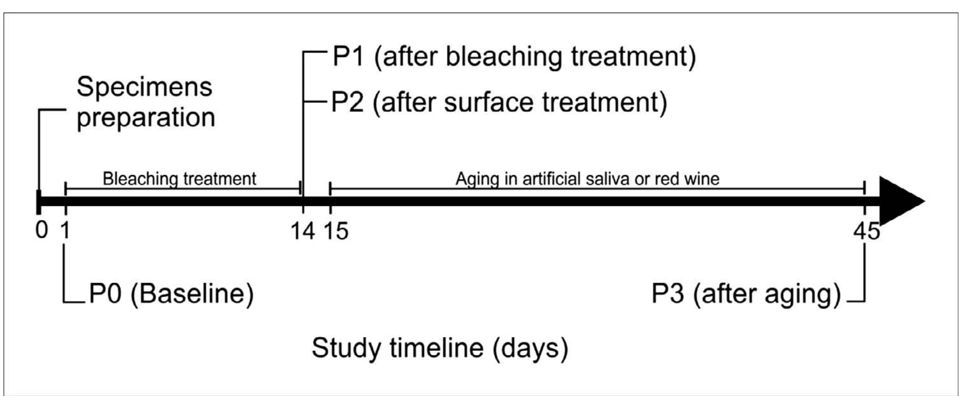

Figure 1. *Time line from the specimen preparation to the end of the experiments.*

over the top surface of each specimen in the bleached group. During each gel application, the mold containing specimens was placed over humid gauze inside a plastic container and kept at 37°C, ensuring constant humidity until the next application. Each specimen in the bleached group was submitted to two bleaching applications of 20 minutes per session. A total of three sessions were conducted at seven-day intervals. The specimens were rinsed and dried with absorbent paper after each session and returned to the closed bottles containing artificial saliva.

Nonbleached groups were kept immersed in artificial saliva at 37°C during this phase. Saliva bottles were refilled every two days.

Surface Treatment

Immediately after the bleaching procedure, each group was subdivided into two groups according to the top surface treatment employed (repolished or unrepolished). A random number sequence divided into two columns (one corresponding to each treatment) was generated using Random.org.[23] Repolished groups had their top surface treated with the same extra-fine sandpaper discs and the felt discs with a diamond paste that were used in the polishing procedures. The polishing discs used in this research (Diamond Pro) had the same diameter of the specimens (8 mm), and their surfaces were fully covered with abrasive grains. Repolishing was performed on all specimens by a single trained operator with a low-speed motor (Kavo Dental, Biberach, Germany) associated to a contra angle hand piece at 10,000 rpm (median motor speed) (Kavo Dental). Pressure was applied to the surface by an air compressor (80-100 psi) and by the equipment weight (130 g). The polishing discs were positioned in parallel to the specimen's top surface, and the low-speed motor was activated and kept on for 20 seconds. The discs were changed every two specimens. Next, specimens were cleaned under running water and gently dried with gauze. Unrepolished groups were kept in closed saliva bottles at 37°C. Specimen thickness was assessed before and after the surface treatment through a digital caliper, and wear of about 0.02 mm was observed from the repolishing. After the surface treatment (P2), all specimens were kept for 24 hours in saliva bottles before the next phase in order to permit the release of any bleaching agent remnants.

Aging Procedure

All groups were again subdivided after surface treatment according to the employed aging conditions (red wine or artificial saliva). A two-column number sequence (one corresponding to each aging condition) was generated as mentioned above. The authors chose red wine because it is an acidic and alcoholic medium rich in staining agents, which could somewhat represent the complex association of erosion, degradation, and pigment sorption. The groups aged in red wine remained in contact with the beverage for 15 min/d (at 37°C) for 30 days. After each daily immersion, the specimens were rinsed and dried with gauze and were stored in closed bottles containing saliva at 37°C until the next contact with the wine. The other groups remained immersed in artificial saliva, which was refilled every two days. The pH values of red wine and saliva were assessed using a pH meter (400-QA, Quimis, Diadema, Brazil). Red wine pH was measured when the bottle was opened (pH=3.55) and seven days after (estimated bottle duration) (pH=3.56). Artificial saliva pH was assessed on the first day of the study (pH=6.38), after 14 days (bleaching phase, pH=6.32), and again after an additional 30 days (aging phase, pH=6.28).

Color Evaluation

Color measurements were conducted at four points: 24 hours after specimen fabrication and hydration in artificial saliva (baseline, P0), after bleaching (P1), after surface treatment (P2), and after aging (P3). An SP60 spectrophotometer (X-Rite, Grand Rapids, MI, USA) in analysis mode, using D65 illuminant, a 10° observer angle, and the CIE$L^*a^*b^*$ color system (Commission Internationale de l'Éclairage), was used for measurements. Color parameters were measured over a neutral gray background (CIEL^*=50.30, a^*=−1.41, b^*=−2.37) (Mennon gray cards, Mennon Photographic and Technical Co, Beijing, China). In the CIE $L^*a^*b^*$ system, L^* is the luminosity axis with values varying from 0 (black) to 100 (white), and a^* and b^* are the color coordinates on a green-red axis and a blue-yellow axis, respectively. A coupling substance (glycerol, $C_3H_8O_3$) (Vetec Química Fina Ltda, Rio de Janeiro, Brazil) with a refractive index of 1.47 was used to minimize light scattering by eliminating the presence of an air layer between the specimen and the background.[24] Before measurements, the spectrophotometer was calibrated according to manufacturer guidelines. For each specimen, the values of L^*, a^*, and b^* coordinates were collected three times, and the median of those readings was used for statistical analysis. Color changes (ΔE_{00}) for all phases were calculated using the CIEDE2000 formula:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{\frac{1}{2}} \quad (1)$$

where ΔL, ΔC, and ΔH are the differences in lightness, chroma, and hue, respectively, for a pair of measurements and R_T is a function (the so-called rotation function) that accounts for the interaction between chroma and hue differences in the blue region. Weighting functions S_L, S_C, and S_H adjust the total color difference for variation in the location of the color difference pair in L', a', b' coordinates, and the parametric factors k_L, k_C, and k_H are correction terms for deviation from reference experimental conditions. In the present study, these parametric factors of the CIEDE2000 color difference formula were set as 1.

The ΔE_{00} values described by Paravina and others[25] of 0.8 and 1.8 were considered as clinical thresholds for perceptibility and acceptability, respectively.

The specimens were rinsed after each measurement in order to remove the coupling substance and dried with gauze afterward.

Roughness Evaluation

The smoothness parameter was assessed along with color measurements at P0 (baseline), P1 (bleaching phase), P2 (repolishing phase), and P3 (aging phase). Quantitative measurements were performed with a previously calibrated SJ-410 roughness tester (Mitutoyo, Takatsu-Ku, Japan). The Ra parameters (average roughness in μm) were assessed with a 0.80-mm cutoff, 0.0001-μm resolution (8-μm range), 0.5 mm/s speed, and total length of 4 mm according to ISO 4287.[26] Three measurements of the *x*- and *y*-axes were performed for each specimen, and the average value was used in the analysis. As resin composite roughness has no agreed on clinical threshold for unacceptable values, this study considered two thresholds: 1) Ra values below 0.2 μm associated with reduced plaque accumulation, risk for caries, and periodontal inflammation[27] and 2) Ra values below 0.3 μm associated with the comfort of the patient since most patients do not detect rough surfaces below this threshold.[28]

Statistical Analysis

Color change (ΔE_{00}) and smoothness (Ra) data were analyzed by the statistical software SigmaPlot, version 11.0 (Systat Software Inc, San Jose, CA, USA). Analyses were carried out separately according to the employed aging conditions. The data were tested for normality (Shapiro-Wilk test) and homoscedasticity (Levene test) and then submitted to repeated measures two-way analysis of variance. All pairwise multiple comparison procedures were conducted using the Tukey test. The correlation between color change and roughness was tested using the Pearson correlation test. The significance level was set at 5% for all analyses.

RESULTS

Groups Aged in Artificial Saliva

Color change (ΔE_{00}) values, standard deviation, and differences found among groups after bleaching treatment (P1), surface treatment (P2), and aging in artificial saliva (P3) are described in Table 2. Interaction between the experimental group (material+treatment) and study phase was not significant ($p=0.481$), and no significant differences were found among the different phases in any experimental condition. On the other hand, the interaction among groups was significant ($p<0.001$). As expected, bleached groups of both composites in P1 presented greater color change than the nonbleached groups. In P2, repolishing did not have any effect on bleached or nonbleached resin composites. In P3, no significant differences among the Filtek Z250 groups were noted. The bleached and repolished groups achieved higher values of ΔE_{00} than the nonbleached repolished Z350 XT group. All groups had clinically perceptible color change ($\Delta E_{00}>0.8$), except for the nonbleached and repolished group, but none had clinically unacceptable alterations ($\Delta E_{00}>1.8$). No difference was perceived between the microhybrid and nanofilled resin composites at any phase ($p>0.05$).

Roughness (Ra) means, standard deviations, and differences found among groups in each of the phases are described in Table 3. Interaction between experimental group (material+treatment) and study phase was significant ($p=0.010$). Significant interaction was also observed within experimental groups ($p=0.013$). Significant differences among phases were detected after surface treatment (P1 vs P2) in almost all repolished groups. Bleaching (P1) did not alter the smoothness of either the microhybrid or nanofilled composites. After repolishing (P2),

Table 2: *Means (Standard Deviation) of ΔE_{00} Values of Groups Aged in Artificial Saliva*[a]

	P1 (After Bleaching)		P2 (After Repolishing)		P3 (After Aging)	
	ΔE_{00}	Clinically Visible Change	ΔE_{00}	Clinically Visible Change	ΔE_{00}	Clinically Visible Change
Filtek Z250						
BR	1.51 (0.25) Aa	Yes	1.25 (0.51) Aab	Yes	1.24 (0.45) Aa	Yes
BU	1.44 (0.46) Aa	Yes	1.44 (0.46) Aa	Yes	1.38 (0.52) Aa	Yes
NR	0.72 (0.48) Ab	No	0.76 (0.30) Ab	No	0.77 (0.28) Aa	No
NU	0.80 (0.20) Ab	Yes	0.80 (0.20) Ab	Yes	1.00 (0.75) Aa	Yes
Filtek Z350 XT						
BR	1.22 (0.31) A1	Yes	1.15 (0.50) A12	Yes	1.18 (0.25) A1	Yes
BU	1.31 (0.24) A1	Yes	1.31 (0.24) A1	Yes	1.12 (0.12) A12	Yes
NR	0.45 (0.28) A2	No	0.49 (0.32) A3	No	0.51 (0.07) A2	No
NU	0.53 (0.37) A2	No	0.53 (0.37) A23	No	0.80 (0.21) A12	Yes

[a] *Different uppercase letters in the same line indicate phases differences, distinct lowercase letters in the same column indicate differences in bleaching procedures for Z250, and numbers indicate differences in bleaching procedures for Z350 XT (Tukey test,* $p<0.05$*). BR, bleached repolished; BU, bleached unrepolished; NR, nonbleached repolished; NU, nonbleached unrepolished.*

bleached Z350 XT showed a significant smoothness reduction (bleached and repolished vs bleached and unrepolished). This difference remained after aging in saliva (P3). Roughness values of all phases and conditions were maintained below the thresholds used in this study (Ra<0.2 μm and Ra<0.3 μm).

There was no significant correlation between the color change and smoothness of groups aged in artificial saliva (p=0.616, r=0.0421).

Groups Aged in Red Wine

Color difference (ΔE_{00}) values, standard deviations, and differences found among groups after P1, P2, and P3 are described in Table 4. The interaction between the experimental group (material+treatment) and study phase as well as the interaction within experimental groups were significant (p<0.001 in both). All groups presented a significant and clinically unacceptable color change (ΔE_{00}>1.8) after 30 days of immersion (P3). No difference was detected among experimental conditions for either resin composites after aging in wine (P1 and P2). Also, the greatest color change was perceived in bleached unrepolished groups after aging for both resin composites. In contrast, similar ΔE_{00} values were attained by bleached repolished and nonbleached groups. Differences between the composites were observed at P3 in all groups, except for nonbleached unrepolished groups (Figure 2).

Roughness (Ra) means, standard deviations, and differences found among groups for all the four phases

Table 3: *Means (Standard Deviation) of Ra Values of Groups Aged in Artificial Saliva*[a]

	P0 (Baseline)	P1 (After Bleaching)	P2 (After Repolishing)	P3 (After Aging)
Filtek Z250				
BR	0.15 (0.06) Aa	0.16 (0.10) ABa	0.11 (0.03) Ba	0.12 (0.04) ABb
BU	0.14 (0.02) Aa	0.17 (0.07) Aa	0.17 (0.07) Aa	0.19 (0.03) Aa
NR	0.15 (0.05) Aa	0.14 (0.06) Aa	0.12 (0.06) Ba	0.10 (0.03) Bb
NU	0.13 (0.03) Aa	0.15 (0.03) Aa	0.15 (0.03) Aa	0.13 (0.02) Aab
Filtek Z350 XT				
BR	0.13 (0.03) A1	0.13 (0.03) A1	0.08 (0.02) B2	0.08 (0.02) B2
BU	0.15 (0.03) A1	0.16 (0.03) A1	0.16 (0.03) A1	0.15 (0.04) A1
NR	0.15 (0.02) AB1	0.16 (0.06) A1	0.10 (0.03) B1	0.12 (0.03) B12
NU	0.16 (0.04) A1	0.15 (0.04) A1	0.15 (0.04) A1	0.16 (0.03) A1

[a] *Different uppercase letters in the same line indicate phases differences, distinct lowercase letters in the same column indicate differences on bleaching procedures for Z250 and numbers indicate differences on bleaching procedures for Z350 XT (Tukey test,* $p<0.05$*). BR, bleached repolished; BU, bleached unrepolished; NR, nonbleached repolished; NU, nonbleached unrepolished.*

Table 4: *Means (Standard Deviation) of ΔE_{00} Values of Groups Aged in Red Wine*[a]

	P1 (After Bleaching)		P2 (After Repolishing)		P3 (After Aging)	
	ΔE_{00}	Clinically Visible Change	ΔE_{00}	Clinically Visible Change	ΔE_{00}	Clinically Visible Change
Filtek Z250						
BR	1.46 (0.28) Ba	Yes	1.27 (0.43) Ba	Yes	8.12 (1.18) Ab	Yes
BU	1.39 (0.53) Ba	Yes	1.39 (0.53) Ba	Yes	9.26 (1.47) Aa	Yes
NR	0.90 (0.56) Ba	Yes	0.81 (0.48) Ba	Yes	7.30 (1.32) Ab	Yes
NU	0.86 (0.30) Ba	Yes	0.86 (0.30) Ba	Yes	8.07 (0.71) Ab	Yes
Filtek Z350 XT						
BR	1.25 (0.34) B1	Yes	1.04 (0.27) B1	Yes	9.87 (1.62) A2	Yes
BU	1.15 (0.23) B1	Yes	1.15 (0.23) B1	Yes	11.81 (1.51) A1	Yes
NR	0.61 (0.21) B1	No	0.61 (0.13) B1	No	9.61 (0.88) A23	Yes
NU	0.62 (0.18) B1	No	0.62 (0.18) B1	No	8.55 (0.60) A3	Yes

[a] *Different uppercase letters in the same line indicate phases differences, distinct lowercase letters in the same column indicate differences on bleaching procedures for Z250 and numbers indicate differences on bleaching procedures for Z350 XT (Tukey test, $p<0.05$). BR, bleached repolished; BU, bleached unrepolished; NR, nonbleached repolished; NU, nonbleached unrepolished.*

are described in Table 5. Interaction between experimental group (material+treatment) and study phase was significant ($p=0.019$), but interaction within experimental groups was not ($p=0.505$). Statistically significant differences among phases were observed after repolishing (P1 vs P2) in almost all repolished groups. No significant differences were noted among experimental conditions and between the materials ($p>0.05$) when each phase was independently analyzed. Roughness values in all phases and conditions were maintained below the thresholds used in this study (Ra<0.2 μm and Ra<0.3 μm).

There was no significant correlation between color change and smoothness of groups aged in red wine ($p=0.756$, $r=-0.0241$).

DISCUSSION

Repolishing led to lesser color change in bleached groups that had contact with the staining agent. The results show that Filtek Z250 and Z350 XT bleached unrepolished groups aged in red wine had ΔE_{00} values 14% and 19% greater than the bleached repolished groups, respectively. On the other hand, the surface treatment caused no difference in the color stability of bleached groups that were not immersed in red wine. Since red wine has a low pH (3.55), it may have caused resin matrix softening.[29] Repolishing also made surfaces smoother (P1 vs P2), but the Tukey test did not detect this effect in all groups; it also did not detect differences among all bleached repolished vs bleached unrepolished groups

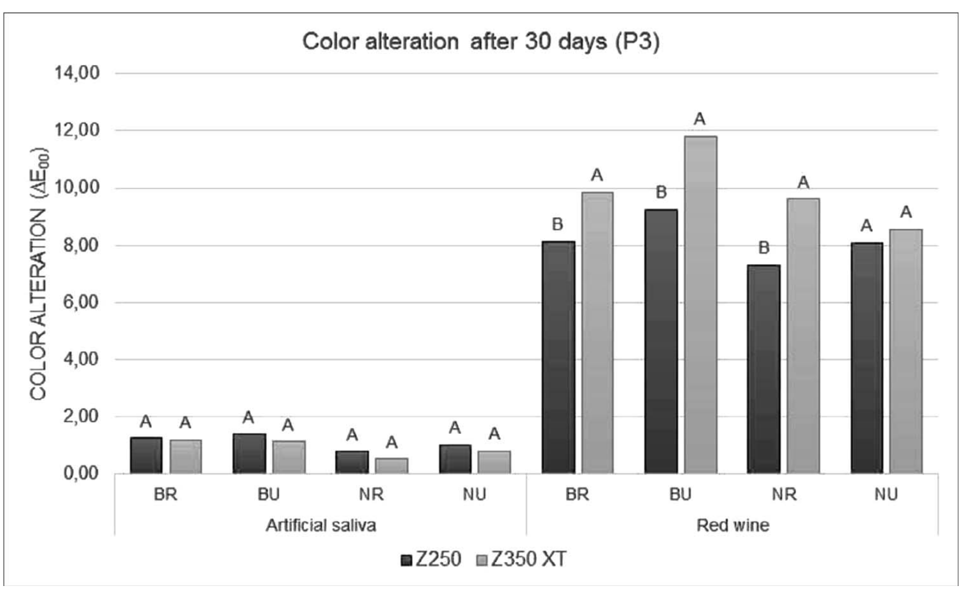

Figure 2. *Groups of microhybrid and nanofilled composite resins after 30 days of aging (P3). Distinct letters in the same experimental condition (surface treatment+aging solution) indicate difference between composite resins (Tukey test, $p<0.05$). BR, bleached repolished; BU, bleached unrepolished; NR, nonbleached repolished; NU, nonbleached unrepolished.*

Table 5: *Means (Standard Deviation) of Ra Values of Groups Aged in Red Wine*[a]

	P0 (Baseline)	P1 (After Bleaching)	P2 (After Repolishing)	P3 (After Aging)
Filtek Z250				
BR	0.14 (0.03) ABa	0.16 (0.04) Aa	0.09 (0.01) Ba	0.10 (0.05) Ba
BU	0.15 (0.03) Aa	0.15 (0.07) Aa	0.15 (0.07) Aa	0.17 (0.07) Aa
NR	0.13 (0.03) ABa	0.14 (0.04) Aa	0.10 (0.02) Ba	0.09 (0.01) Ba
NU	0.15 (0.01) Aa	0.14 (0.08) Aa	0.15 (0.09) Aa	0.14 (0.07) Aa
Filtek Z350 XT				
BR	0.14 (0.02) A1	0.14 (0.04) A1	0.11 (0.04) A1	0.11 (0.04) A1
BU	0.15 (0.03) A1	0.14 (0.04) A1	0.14 (0.04) A1	0.15 (0.05) A1
NR	0.16 (0.03) A1	0.16 (0.08) A1	0.10 (0.04) B1	0.10 (0.02) B1
NU	0.14 (0.03) A1	0.16 (0.05) A1	0.16 (0.05) A1	0.15 (0.04) A1

[a] *Different uppercase letters in the same line indicate phases differences, distinct lowercase letters in the same column indicate differences on bleaching procedures for Z250 and numbers indicate differences on bleaching procedures for Z350 XT (Tukey test,* $p<0.05$*). BR, bleached repolished; BU, bleached unrepolished; NR, nonbleached repolished; NU, nonbleached unrepolished.*

(Tables 3 and 5). Despite polishing and repolishing procedures having been carried out by a single calibrated operator, the results are not as accurate as those obtained using an automated device. Thus, the differences among results were probably caused due to operator bias. However, roughness did not reach unacceptable thresholds (0.2 μm) in any study phase, which suggests that these differences in smoothness caused by the treatments may not have clinical relevance. Therefore, the first listed hypothesis is partially accepted.

Barakah and Taher[30] evaluated the effect of polishing systems on the color stability of composites and concluded that polishing improves the color stability of resin composites. Güler and others[31] observed that polishing with similar discs and diamond paste to those used in this study decreased the color change in resin composites. However, to date, there is no further research regarding the effects of repolishing immediately after bleaching. Our results show that this procedure also significantly improves the color stability of composites. The literature suggests that the bleaching action may cause matrix softening and a decrease in the microhardness and smoothness of restorative materials.[14,32,33] Our roughness analysis has not shown a statistical difference in all bleached repolished vs bleached unrepolished groups (of both composites and each aging condition) after the repolishing phase (P2). Furthermore, the Pearson correlation test did not detect a significant correlation between color alteration and smoothness. In each measurement, the roughness tester probe tip passed by six points on the specimen's surface. As resin composite is a material handled by the operator, it is possible that minimal defects remained on its surface. Although these defects may not be large enough to be detected by the roughness tester, they still can lead to clinically significant color alteration. However, repolishing may have eliminated any minimal defects, which seems to interfere with composites' color stability, resulting in a surface that is less susceptible to staining.

Bleaching treatment was unable to promote a greater color change in all groups or an increase in smoothness in any group when compared to nonbleached groups, which leads to the second tested hypothesis being partially accepted. For P1, ΔE_{00} values from bleached groups of both composites (exposed later to saliva or red wine) were similar to and greater than nonbleached composites, but the Tukey test highlighted statistical differences between bleached vs nonbleached groups, but only in the specimens aged in artificial saliva. Nevertheless, no ΔE_{00} value for P1 reached 1.8, which means there was no clinically unacceptable change. A color change in nonstained specimens has been explained by the presence of pigments inherent in the composites and/or by amine compound oxidation or the incomplete breakdown of the polymer of the resin matrix.[34] Previous studies have shown that ΔE_{ab} values of resin composites measured immediately after hydrogen peroxide bleaching ranged from 0.56 to 3.71.[9,30,31] It appears that results can vary according to the resin composite type and bleaching protocol. Moreover, the chosen formula to calculate color alteration can also lead to a variation in results; while CIELAB is commonly employed, we chose to use CIEDE2000 because it is more sophisticated than its predecessors[35] and utilizes hue and chroma concepts, reinforcing the importance of the conceptual developments of Munsel.[36]

Previous studies that used different bleaching agents in distinct concentrations have also not reported significant smoothness alterations in resin composites,[37,38] whereas other studies observed significant changes.[39,40] This contrast highlights the material-dependent effect of bleaching on the smoothness of restorative materials. Cengiz and others[41] evaluated the effect of 10% hydrogen peroxide on the smoothness of five commercial resin composite brands, and they detected significant smoothness alterations in bleached groups compared to those in the control group. The present study used a higher concentration of hydrogen peroxide, and significant smoothness alterations caused by bleaching (P1) were not observed. However, the composites and bleaching gels used in the aforementioned study were not the same (type and/or commercial brands) as those used in our research, which may have led to different results. Varanda and others[33] also evaluated the influence of bleaching agents, including 35% hydrogen peroxide, on the smoothness of nanofilled (the same as in the present study) and microhybrid resin composites. In the former, the authors did not find significant alteration, while the latter presented little smoothness alteration, which was suggested might be eliminated by repolishing.

The third tested hypothesis is partially accepted since no color differences were detected between resin composites aged in artificial saliva. Nevertheless, all nanoparticle resin groups that had undergone any treatment (bleaching and/or repolishing) attained higher ΔE_{00} values than the microhybrid groups when exposed to red wine (P3). In addition, no differences in smoothness were observed between the materials in any phase or immersion media, corroborating the results obtained by Kaizer and others.[42] They conducted a systematic review and did not find enough scientific evidence to show differences in smoothness and gloss between microhybrid and nanofilled resin composites.

Resin composite color changes have been related to the hydrophobic and hydrophilic nature of resin matrix compounds,[43] which determines the material's liquid sorption degree. Water sorption causes expansion and plasticizes the resinous compound, hydrolyzing the union agent silane and causing microcracks on the interface of filler particles and resin matrix. In this way, fluids and pigments infiltrate the matrix and cause discoloration.[44] Higher levels of water sorption have been attributed to composites containing a low concentration of TEGDMA and Bis-GMA monomers in its composition.[45] Z250 has a low TEGDMA concentration, which seems to favor its color stability. Moreover, particle size (microhybrid vs nanofilled) also influences fluid sorption. Nanoclusters of composite Z350 XT present microporosities, which facilitate fluid sorption and pigment retention.[46,47] The quantum effect is a phenomenon that makes the nanoparticles susceptible to different surface interactions, such as adsorption of substances to which they are exposed.[48,49] The smaller the particle, the more pronounced the quantum effect on them is,[48,49] which may be another factor contributing to the greater color change of nanofilled composites.

The staining procedures used in our study involved immersion in red wine for 15 minutes per day, which is clinically plausible since a person can easily keep restorations in contact with staining beverages for at least 15 minutes in a day. However, it is known that brushing reduces composite staining,[50] and this factor was not included in our research. This fact certainly contributed to the ΔE_{00} values being well above the unacceptability threshold and was considered the main limitation of our study. Since people usually brush their teeth at least once a day, our data cannot be directly inferred to clinical situations. In spite of the limitations of an *in vitro* study, our results indicate that when clinicians choose to maintain a resin composite restoration after a bleaching treatment, the simple act of repolishing it immediately after the last bleaching gel application can minimize susceptibility to color change, especially when the patient's diet is rich in pigments.

CONCLUSIONS

Repolishing immediately after bleaching improves the color stability of resin composites when exposed to staining agents. This procedure may also improve its smoothness. Bleaching by itself does not promote clinically unacceptable changes in color or in smoothness. Color and smoothness of both tested composites were affected by bleaching and surface treatments after aging. In addition, the nanofilled resin composite has a greater tendency to staining than the microhybrid resin composite.

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Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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