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Effects of staining and bleaching on a nanohybrid composite with or without surface sealant

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ABSTRACT

Objective: The effect of different staining solutions and a bleaching procedure on color stability and surface roughness of a nanohybrid resin composite were evaluated with or without liquid resin polishing (RP). **Materials and Methods:** Ninety-six disc-shaped resin composite specimens (A1 Shade, Z550 Filtek 3M ESPE, St. Paul, MN, USA) were prepared and divided randomly into two groups ($n = 48$). Liquid RP (BisCover LV, Bisco Inc., Schaumburg, IL, USA) was applied in one group (RP) and not in the other (P). Specimen color and surface roughness were determined using a colorimeter and profilometer, respectively. After baseline measurements, each group was divided into four subgroups ($n = 12$) for immersion in a control (distilled water) or three different staining solutions (ice tea, red wine, and cola) for 1 week. Color and surface roughness were then reevaluated. After measurements, all specimens were bleached using a 35% hydrogen peroxide gel. The color and surface roughness of the specimens were reevaluated. **Statistical Analysis:** Data were subjected to an analysis of variance for repeated measurements among the groups ($P < 0.05$). **Results:** Staining and bleaching did not change the surface roughness of the RP and P groups ($P > 0.05$). Discoloration in the red wine group was higher than for the other staining solutions for the RP ($P < 0.001$) and P groups ($P = 0.018$). **Conclusion:** Application of liquid RP did not enhance the color stability and surface roughness of the composite resin restoration.

Key words: Bleaching, nanohybrid composite, staining, surface roughness, surface sealant

INTRODUCTION

Nanotechnology offers unique solutions to resin technology by providing new formulations that offer esthetic high translucency, high polish, superior gloss, and adequate mechanical properties that are suitable for high stress-bearing restorations.[1,2] However, discoloration leading to esthetic failure and the need for replacement is a significant esthetic problem for direct resin composite restorations.[3,4]

Application of surface sealant, unfilled low-viscosity resin, after polishing, may be an advanced method to ensure resin composite surfaces are smooth.[5,6] Recently, a liquid polishing system (BisCover LV, Bisco Inc., Schaumburg, IL, USA) has been introduced to reduce or eliminate the need for clinical polishing of restorations. BisCover LV is a light-curing resin used to seal restorations and is claimed to form a smooth polished surface without a sticky air-inhibited layer.[7] Tooth-bleaching agents used to improve the esthetics of natural dentition have become increasingly popular. During bleaching, hydrogen peroxide contacts the teeth and the restorative materials for extended periods.[8]

Thus, the aim of this *in vitro* study was to evaluate the effect of different staining solutions and bleaching

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procedure on the color stability and surface roughness of a nanohybrid resin composite with or without liquid resin polishing (RP).

MATERIALS AND METHODS

Ninety-six disc-shaped resin composite specimens (A1 Shade, Z550 Filtek 3M ESPE, St. Paul, MN, USA) were prepared using a custom polyethylene 10 mm diameter and 2 mm high mold. The mold with composite resin was held between two glass slides each covered with a transparent polyester strip, and the glass slides were pressed together gently to obtain a flat surface without bubble formation. All specimens were polymerized using a light-emitting diode light-curing unit (light intensity: 1000 mW/cm^2; Smart Lite PS, Dentsply De Trey, Konstanz, Germany), with 20 s of exposure to the top and bottom surfaces. The specimens were finished and polished using 600, 800, and 1200-grit silicon-carbide abrasive paper.[9] Then they were divided randomly into two subgroups (n = 48). Liquid RP (BisCover LV, Bisco Inc., Schaumburg, IL, USA) was applied to one group (RP) and not to the other (P). In the RP group, the specimen surfaces were etched with 32% H_3PO_4 solution (UNI-ETCH, Bisco Inc., Schaumburg, IL, USA) for 15 s, rinsed with water for 15 s, and dried with an air syringe. One thin coat of sealant was applied, air thinned to ensure its even distribution, and cured with a light curing unit following the manufacturer's instructions. All prepared specimens were stored in distilled water for 24 h before baseline color assessment and surface roughness evaluation.

Color measurements of all specimens were performed according to the Commission Internationale de l'Eclairage L^* a^* b^* color scale using a colorimeter (Minolta CR 321, Ltd. Radiometric Instruments Operations, Osaka, Japan). The colorimeter was calibrated before use with a black and white ceramic tile provided by the manufacturer. All specimens were wiped dry using tissue paper and then placed in the colorimeter. The L^*, a^*, and b^* values of each specimen were measured 3 times.

The specimen surface roughness was measured using a profilometer (Mitutoyo Surftest SJ-201 Surface Roughness Tester, Mitutoyo Corporation, Tokyo, Japan) whose needle was positioned on the specimen surface and moved at a constant speed of 0.05 mm/s using a cutoff of 0.25 mm. Roughness tracings were taken on each surface with three random readings to obtain a roughness average, R_a.

Each group (RP and P) was divided further into four subgroups (n = 12), from which specimens were immersed in a control and into three different staining solutions: Distilled water (as the control), ice tea (Ice Tea Lemon, Unilever, Corlu, Turkey), red wine (Pamukkale Anfora Shiraz 2007, Denizli, Turkey), and Coca-Cola (Coca-Cola, Coca-Cola Co., Bursa, Turkey). Specimens in each group were immersed in vials containing 5 mL of staining solution for 1 week at room temperature, and the solutions were renewed daily. After immersion in staining solution, the samples were washed with distilled water and stored in distilled water for 24 h. Color assessment and surface roughness evaluation were reevaluated by the same operator as described previously for the baseline measurements. The color difference, ΔE, was calculated from the mean L^*, a^*, and b^* values for each specimen using:[10]

ΔE (L^* a^* b^*) = $[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, where ΔL^*, Δa^*, and Δb^* are differences in L^*, a^*, and b^* values, respectively.

After the measurements had been conducted, all specimens were subjected to bleaching (35% hydrogen peroxide, Pola Office Bleaching, SDI Limited, Bayswater, Victoria, Australia) for 24 min (3 times at 8 min each) following the manufacturers' instructions.[11] Samples were kept in distilled water for 24 h, and their color and surface roughness were reevaluated by the same operator.

Statistical analysis was accomplished using the software SPSS for Windows, version 15.0 (SPSS Inc., Chicago, IL, USA). Data were subjected to an analysis of variance for repeated measures among groups. Multiple comparisons were evaluated using the Bonferroni test ($P < 0.05$).

RESULTS

The mean surface roughness values (R_a) and standard deviations of the RP and P groups are given in Table 1. The staining and bleaching procedures did not change the surface roughness of the RP and P groups ($P > 0.05$), except distilled water in P group ($P = 0.038$). However, the RP groups presented higher surface roughness than the P groups with respect to each staining solution, including the control group ($P < 0.001$ for each staining solution). The P values for all RP versus P for the baseline, after staining, and after bleaching were below 0.001 for all staining solutions.

Table 2 shows the means of the color change values (ΔE) of the RP and P groups. ΔE values higher than 3.3 were evaluated as visually perceptible and clinically unacceptable.[12,13] Red wine staining revealed a visually perceptible staining effect on the RP group ($\Delta E = 4.47 \pm 1.40$). In the RP group, the discoloration (ΔE) of the red wine and cola groups after staining was different from the other staining solutions ($P < 0.001$ and $P = 0.049$, respectively) and in the P group, the values of the red wine group were different from the others ($P = 0.018$).

A comparison of the liquid RP group (RP) with the polish group (P) with respect to staining solutions shows that red wine and cola caused higher ΔE values in the RP than in the P groups ($P = 0.008$ and $P = 0.014$, respectively).

DISCUSSION

Tristimulus colorimeters can detect color differences below the threshold of visual perception. ΔE represents relative color changes that an observer may report for materials after immersion in staining solutions or after bleaching. Thus, ΔE is more meaningful than individual L^* a^* b^* values.[10] ΔE values >3.3 should produce a visually or clinically unacceptable specimen discoloration.[14]

In this study, red wine had a higher color change after staining and bleaching for the RP and P groups than other solutions ($\Delta E = 4.47 \pm 1.40$ and $\Delta E = 3.22 \pm 0.95$, respectively). Color differences of this magnitude are characterized as unacceptable for *in vitro* conditions, in which optimal lightening was used with monochromatic specimens. The wine used in the study contains 13.5% alcohol by volume. Aguiar *et al.*, using alcoholic and aqueous solutions to test the susceptibility of restorative materials to staining, showed higher staining mean values for alcoholic than aqueous solutions.[14] Other authors compared red wine with coffee, water, and cola, and reported that the alcoholic solutions caused more discoloration than the nonalcoholic solutions.[15,16]

Alcohol causes the composite resin surface to soften by removing its polymer structure such as unreacted monomers, oligomers, and linear polymers.[15] This facilitates the absorption of pigment agents and increases wear.[17]

Distilled water, ice tea, and cola caused visible color changes that are clinically acceptable (ΔE from 1.79 to 2.58 after staining; ΔE from 1.55 to 1.82 after bleaching). The low pH of cola soft drinks (2.36) did not influence the color change since higher pH solutions such as red wine (3.41) cause greater staining.[18] Cola soft drink contains carbonic[19] and phosphoric[20] acids, and red wine contains tartaric acid.[21] The different acids in the beverages could explain such results because of different organic structures. It is noticeable that beverages with different acid have

Table 1: Surface roughness values (mean±standard deviation) of resin polish and polish groups (µm)

Staining solution	RP applied groups (RP)				Non-RP groups			
	Baseline	After staining	After bleaching	Row *P*	Baseline	After staining	After beaching	Row *P*
Distilled water	0.526±0.152	0.540±0.149	0.555±0.157	0.828	0.299±0.191	0.193±0.016	0.193±0.021	0.038
Red wine	0.476±0.095	0.477±0.090	0.474±0.097	0.998	0.226±0.062	0.223±0.066	0.223±0.056	0.997
Ice tea	0.495±0.137	0.476±0.124	0.501±0.138	0.862	0.271±0.111	0.283±0.113	0.242±0.059	0.670
Cola	0.499±0.152	0.507±0.153	0.505±0.169	0.984	0.226±0.082	0.224±0.035	0.258±0.135	0.734
Column *P*	0.775	0.495	0.398		0.333	0.292	0.563	

RP: Resin polish

Table 2: ΔE values (mean±standard deviation) of resin polish and polish groups between baseline, after staining, and after bleaching color measurements

Staining solution	RP applied groups			Non-RP groups			RP versus non-RP (*P*)	
	Baseline-after staining (ΔE_1)	After staining-after bleaching (ΔE_2)	Row *P*	Baseline-after staining (ΔE_1)	After staining-after bleaching (ΔE_2)	Row *P*	Baseline-after staining (ΔE_1)	After staining-after bleaching (ΔE_2)
Distilled water	1.79±1.42	1.88±1.01	0.846	1.55±0.99	1.31±1.05	0.592	0.609	0.215
Red wine	4.47±1.40	2.76±1.49	<0.001	3.22±0.95	2.12±0.98	0.018	0.008	0.173
Ice tea	2.42±1.39	2.08±1.28	0.458	1.82±0.95	1.27±0.54	0.234	0.195	0.081
Cola	2.58±1.65	1.67±0.78	0.049	1.44±0.50	1.24±1.00	0.665	0.014	0.356
Column *P*	<0.001*	0.106		<0.001*	0.170			

*Red wine group is statistically different from the other staining solution groups. RP: Resin polish also different properties, for example, buffering properties or titratable acid level.[21] Catelan *et al*.[22] found that red wine resulted in higher discoloration levels than cola. They attributed this result to the acid content in the staining solutions and not to the solution pH.

Polishing procedures remove oxygen inhibition layers, which causes samples to be more prone to staining than polished layers of resin composite surfaces.[23] Liquid RP applications can create new oxygen inhibition layers on the polished surface. Similarly, in our study, all RP groups showed higher ΔE values than the P groups after staining. A newly developed oxygen inhibited layer on the surface may be responsible for these results. The liquid RP contains dipentaerythritol pentaacrylate esters as monomer and these monomers may be more prone to staining than the monomers used in Filtek Z550 resin composite formulation. A previous study reported that dipentaerythritol pentaacrylate esters containing surface sealant had less stain resistance than methacrylate-based materials.[24] Furthermore, the composite material that used in this study is a methacrylate-based composite, ΔE values of nanohybrid composite are lower than surface sealant. In addition, the surface roughness and the discoloration of the materials are influenced by many material properties, for example, the type, shape, size, and distribution of the inorganic fillers.[25]

In this study, the surface roughness of all RP groups was higher than the P groups ($P < 0.001$ for each staining solution). The P values for all RP versus P for the baseline, after staining, and after bleaching were below 0.001 for all staining solutions. However, immersion in staining solutions and bleaching had no effect on composite resin or RP roughness. The RP can mask resin composite surface defects, but it is difficult to obtain a smooth surface using liquid polish.

Within the limitations of our current study, commonly consumed cold beverages were examined as staining solutions. In further investigations, staining media can be extended to solutions such as sports drinks, berries, and sauces. Because it had been reported that bleaching increases the surface roughness of resin composites,[16] it may be expected that composite restorations would stain more easily after bleaching because mechanically, rough surfaces tend to retain surface stains more than smoother surfaces.[23,26] However, in this study, bleaching was found to have no effect on surface roughness and staining susceptibility of the resin when immersed in three different staining solutions.

CONCLUSION

Within the limitation of this *in vitro* study, the following conclusions can be made:

1. Staining and bleaching did not affect the nanohybrid composite surface roughness with or without surface sealant
2. All staining solutions, except for red wine, caused clinically acceptable discoloration values (ΔE <3.3)
3. Bleaching after red wine staining caused a color change for the RP and P groups.

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Conflicts of interest
There are no conflicts of interest.

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