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Effect of Dental Sealants on Color Stability and Surface Roughness of Nanocomposites

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Abstract

Objective: This study investigated the effect of different sealants on the color stability and surface roughness of nano-composite resins after immersion in coffee solution.

Materials and Methods: Ninety samples (15 samples in 4 experimental groups and 2 control groups) of two nanohybrid (Z250 XT 3M-SHADE A1) and nanofilled composite resins (Tokuyama-Estelite Sigma Quick) were examined. The samples were prepared by a Teflon mold measuring 2 mm × 10 mm. The samples were divided into 6 groups, and all samples were polished. The groups without sealants were called the control group, and the groups with two types of sealants (G Coated Plus [GC] and Permaseal [Ultradent]) on the surface of each nanofilled and nanohybrid composite resins were called the test group. The samples were thermocycled (30 seconds of submersion), 3000 cycles at 5/55ºC). Measurements of surface roughness and color parameters were made by a profilometer and a digital spectrophotometer before and after immersion in the coffee solution at 37°C for 7 days. The recorded data were statistically analyzed by two-way ANOVA and Tukey HSD tests (α=0.05).

Results: Sealants did not significantly affect Ra in both types of composite resin. In both types of composite resin, the sealants reduced ΔE00. The reduction of ΔE00 with the GC sealant was similar in the two composite resin types. However, the Ultradent sealant caused a further reduction of ΔE00 in the nanohybrid than in nanofilled composite resin.

Conclusion: Sealants increased the color stability of nanofilled and nanohybrid composite resins but did not change surface roughness.

Keywords: Sealants; Nanofilled composite resin; Nanohybrid composite resin; Color stability; Surface roughness

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Introduction

Today, composite resin restorative materials are widely used to restore anterior and posterior teeth due to their esthetic, mechanical properties, and good bonding strength; however, it also has limitations such as marginal leakage due to polymerization shrinkage, low color stability, and the possibility of plaque accumulation due to surface roughness.

Nano-composite resins contain nanometer particles (1 nm to 100 nm) throughout the resin matrix. The inclusion of nanoparticles in composite resins improves their mechanical properties, application, and polishing [1,2].

Surface roughness of the restored tooth not only affects the color stability and, therefore, the appearance of the restored tooth but also affects the plaque accumulation, causing gingivitis and the development of secondary caries and reducing wear resistance [3,4]. Since more food debris remains on a rough surface and the accumulation of oral microorganisms increases, the possibility of plaque formation increases [5,6]. On the other hand, to maintain a beautiful appearance, it is imperative to have color-resistant restorations [7,8].

The color stability of tooth-Colored Restorative materials (composite resins) depends on the quality of the finishing and polishing procedures [7,9,10]. However, even with proper polishing and finishing, microscopic cavities might form around the composite resin filler particles due to the use of finishing and polishing tools, compromising the restoration surface [11,12].

In addition, microscopic cracks may occur between the composite and enamel restorations due to polymerization shrinkage, causing surface defects [13,14].

Sealants were marketed as polishing agents to fill surface defects, prevent microleakage, improve

the marginal seal, increase abrasion resistance, and improve stain resistance. However, the achievement and longevity of these sealants on composite resins are still unknown.

This *in vitro* study investigated the effect of different sealants on the color stability and surface roughness of various nano-composite resins (nanofilled and nanohybrids).

Material and Methods

Ninety samples (15 samples in 4 experimental groups and 2 control groups) of two types of nano-composite resins [nanohybrid composite resin (Z250 XT 3M-SHADE A1) and nanofilled composite resin (Tokuyama-Estelite sigma quick) (Table 1)] were prepared using a Teflon mold with disk-shaped cavities (10 mm × 2 mm).

The materials were placed in the mold between two polyester strips, and a glass plate was pressed onto the surface of the composite resin. When a tight contact was achieved with the plastic mold, the extra material was removed, and each sample was photopolymerized for 20 sec with a Light-Emitting Diode (LED) polymerization unit (Elipar Free Light 2; 3M ESPE) at 750 mW/cm^2. The light-polymerized samples were removed from the mold and kept in distilled water at 37°C for 24 h. Before polishing and surface treatment, the samples were finished with a tungsten carbide bur in a wet state with a sandblasting machine (for 15 seconds, 100 rev/min) with 400-grit silicon carbide abrasive paper.

All the samples were polished with a series (coarse, medium, fine, and superfine) of aluminum oxide disks (Soflex; 3M ESPE) for 15 sec for each disk.

For each experimental group, surface sealants (G-coated Plus, Permaseal) were added using a soft brush in a thin, uniform layer in one direction without any agitation to prevent air bubble formation and then cured by an LED device according to the manufacturer's instructions [15,16]. All the steps were performed by an operator as recommended by the manufacturers. All the procedures were performed by one operator.

Then the samples were thermocycled (30 seconds of submersion, 3000 cycles at 5/55°C). The surface Roughness (Ra) of the samples was measured using a contact profilometer (Perthometer C3A and Perthograph C40; Mahr Perthen) and determined by moving the instrument's diamond stylus (NHT-6) on the surface of the specimen (sample surface) under constant pressure. The pressure was calibrated by a device (FRN-10) for all the samples before the test measurements were made. The mean for the measurement results was calculated in three different directions for each sample [6].

The color parameters of the samples were measured with a digital spectrophotometer (SpectroShade Micro II Digital Shade-Matching Device). The device was calibrated before measuring the color of each group. The measurements were made in a Teflon mold, with the measuring point of the spectrophotometer at the center of the samples. The spectrophotometer recorded the measurements with a common international color system (The International Commission on Illumination (CIE) L*a*b* color system) where, L* represents the optical coordinates with the values from 0 (black) to 100 (white) and a* and b* are the coordinates of the red-green and yellow-blue axes, respectively [12,17-20].

The initial color measurements were repeated three times for each sample, and the means were recorded as L0*, a0*, and b0*.

Then all the samples were placed on wax plates to cover the unrefined surfaces during the painting process. The staining solution was prepared by adding 7.5 g of coffee (Nescafé Classic; Nestlé) to 500 mL of boiled distilled water. All the samples in wax plates were immersed in a stainless-steel container with a coffee solution and kept at 37°C for 7 days in a dark environment to simulate intraoral conditions [14].

The staining solution was changed every two days during the test, and after staining, each sample was washed under water and air-dried. After staining, color measurements were performed for each sample, and the data were recorded as L1*, a1*, and b*, and (ΔE00) was used:

$$(\Delta L'/K_L S_L)^2 + (\Delta C/KcSh)^2 + (\Delta H/KHSH)^2 + RT\ (\Delta C'/KCSC)\ (\Delta H'/KHSH) = \sqrt{(\Delta E00)}$$

The formula (CIEDE2000) was used to calculate the color change of composite resins.

In the present study, the parametric factors of the CIEDE2000 color difference formula were set to one. Also, the understandable threshold was set to ΔE00 ≤ 1.30 units, and the clinical acceptance threshold was set to ΔE00 ≥ 2.25 units [21,22].

The Ra and ΔE00 results were separately analyzed by two-way ANOVA to evaluate the effects of surface treatment materials, composite resin techniques, and their interactions. The mean ΔE00 values were compared by the Tukey HSD test. All the computational work was performed with statistical software (SPSS v24.0; IBM Corp).

Results

According to two-way ANOVA (Table 2), there is significant relationship between the sealant and composite resin parameters for ΔE00 values (P<0.001); however, Ra values were not significant. The interaction between the composite resin and surface treatment parameters was not significant for both the Ra and ΔE00 values. The mean Ra and ΔE00 values and Standard Deviations (SD) are presented in Table 3, with Tukey HSD test results in Table 4.

The use of sealant had no significant effect on Ra in both composite resin types (Table 3). In both composite resin types, the use of sealants reduced discoloration. The reduction of discoloration with GC sealant was similar in the two composite resin types. However, the Ultradent sealant caused a further reduction in ΔE00 in the nanohybrid composite resin compared to the nanofilled composite resin (Table 4) (Figure 1, 2).

Discussion

In the present study, the use of sealants significantly affected the color change of nanohybrid composite resins. Both sealants produced the same amount of color change, which was less than the control group. In nanofilled composite resins, the sealant type affected color change. Only the Permaseal sealant was resistant to color changes, and the G-coated Plus sealant did not affect color stability.

The results of a study by Pedroso et al. regarding the effect of sealants on the color stability of microhybrid and nanofilled composite resins showed a positive effect of sealants on the color stability of composite resins. In this study, a low-viscosity sealant was used, with the ability to improve the structural defects of composite resin. Researchers have also shown that microhybrid composite resin samples have better color stability than nanofilled composite resins if no sealants are used [23]. According to these researchers,

Table 1: Tested materials.

Material	Type	Composition	Manufacturer
Estetlite sigma quick	Supra-nanofilled composite resin	Bis-GMA, TEGDMA fillers: 82% wt (71% by volume), zirconia/silica particles (particle size: 0.2 µm)	Tokuyama, Tokyo, Japan
Filtek Z250 XT	Nanohybrid composite resin	bis-GMA, UDMA, TEGDMA, PEGDMA, bis EMA; 81.8% wt (67.8% by volume) combination of non-agglomerated/ non-aggregated silica filler, non-agglomerated/ non-aggregated zirconia filler, and aggregated zirconia/silica nano-cluster/cluster filler) particle size: 0.1-10 µm	3M ESPE Dental products, St. Paul, MN, USA
Permaseal	Surface sealant agents	Ethyl alcohol Acetone(denaturant) (unfilled resin)	Ultradent
G-coat Plus	Surface sealant agents	poly methyl methacrylate (PMMA), methyl methacrylate (MMA), silica filler, photoinhibitor (nanofilled resin)	GC

Table 2: Two-way ANOVA to investigate the effect of composite resin and sealant on color changes (ΔE00) and surface Roughness (Ra).

	Source	Type III Sum of Squares	Df	Mean square	F	P-value
ΔE	Composite resins	25.261	1	25.261	16.903	0
	Sealant	52.784	2	26.392	17.66	0
	Composite resin * sealant	9.007	2	4.504	3.013	0.056
	Error	101.625	68	1.494		
	Total	1613.285	74			
Surface roughness	Composites	0.002	1	0.002	0.434	0.512
	Sealant	0.004	2	0.002	0.47	0.627
	Composite resin * sealant	0.008	2	0.004	1.057	0.352
	Error	0.327	84	0.004		
	Total	12.893	90			

Table 3: Comparison of ΔE and surface roughness between nano filled and nanohybrid composite resins with two sealant types.

	Sealant	Nanofilled		Nanohybrid		P-value*
		Mean	SD	Mean	SD	
ΔE	Control	4.75	1.16	6.67	0.76	<0.001
	Ultradent Permaseal	3.29	1	4.71	1	0.002
	G-coated Plus	3.68	1.75	3.91	1.19	0.72
	P-value	**0.016**		**<0.001**		
Surface roughness	Control	0.387	0.072	0.378	0.0345	0.921
	Ultradent Permaseal	0.371	0.06	0.37	0.0637	0.988
	G-coated Plus	0.35	0.081	0.385	0.0527	0.613
	P-value	**0.38**		**0.721**		

P-value: One-way ANOVA
P-value: Independent t-test

the difference in filler size could affect the study results. This positive effect on nanofilled composite resins was also observed in low-viscosity Permaseal sealants in the present study.

In a study by Patel et al. to compare the staining capacity of unfilled resins with filled resins, unfilled resins exhibited more resin matrix than filled resins; therefore, they had less color change [24]. In the present study, Permaseal (Ultradent) sealant, as an unfilled resin, exhibited less color change. Therefore, it improved the color stability of both composite resins. In addition, lower viscosity helped better surface coverage with less thickness [25-27].

The reason for the similarity of color change in both composite resin types with G-coated sealant can be the higher viscosity of this filler-containing sealant. According to previous studies, this viscosity can increase the thickness, the possibility of peeling, and the inability to function as a cover [25-27].

The thickness of the sealant is also effective in changing its color, as in the study by Lee et al. A higher thickness of the surface sealant applied on the composite resin is prone to color changes due to its viscosity. It is not possible to apply the thickness of the sealant to the same standard as the whole surface of composite resin. The thickness of the sealant also depends on the operator's skill [28]. In the present study, G-coated Plus sealant increased the thickness of the sealant and thus increased its color change due to its high viscosity.

Sahin et al. also introduced Palaseal and Optiglaze sealants compared with the conventional polishing method for color stability and surface roughness [28]. In the present study, the Permaseal sealant exhibited more color stability than the conventional polishing method (control group).

According to a study by Saijai Tanthanuch et al. on the discoloration of nanofilled and nanohybrid composites, the smaller the filler particles of a composite, the less the color change [30]. According to previous studies, the higher the percentage of the filler, the higher the color stability or resistance to color changes [12,30-32].

Table 4: Tukey test to compare sealants in terms of ΔE in nanofilled and nanohybrid composite resins.

(I)	(J)	Nanofilled		Nanohybrid	
		Mean difference (I-J)	**P-value**	**Mean difference** (I-J)	**P-value**
Control	Ultradent Permaseal	1.462	0.015	1.953	0.000
Control	G-coated Plus	1.071	0.058	2.756	0.000
Ultradent Permaseal	G-coated Plus	-0.392	0.717	0.803	0.190

P-value: Tukey test

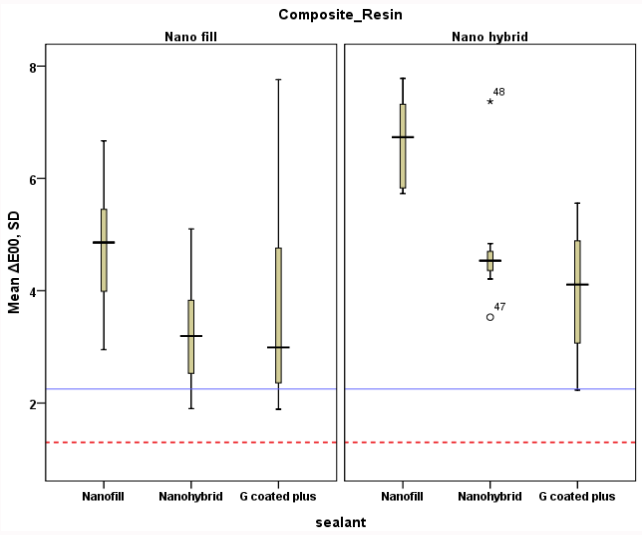

Figure 1: Mean ΔE00 (± SD) values of test groups. The dotted line represents the visual perceptibility threshold level (ΔE00=1.30), and line (-) represents the clinical acceptability threshold level (ΔE00=2.25).

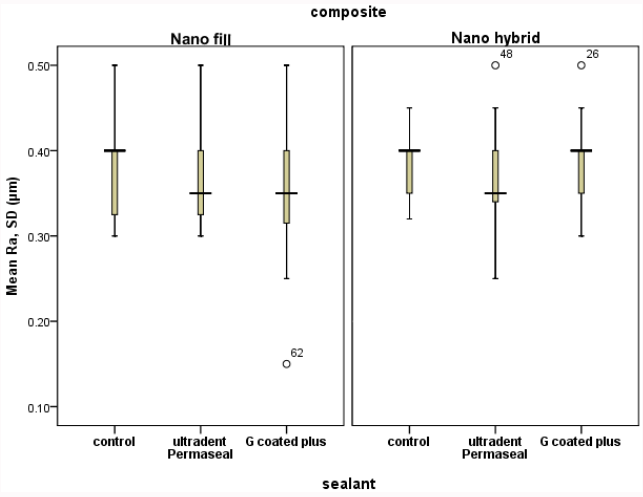

Figure 2: Mean Ra (± SD) values of the test groups.

Therefore, the high color stability of nanofilled composite resin without the use of sealants (control group) in the present study could be attributed to the small particle size of the filler and the high filler percentage.

In the present study, both composite resin types were nano-composite resins to keep the amount and size of the fillers close to each other to minimize the effect of the type and amount of filler as much as possible. However, the ratio of the size and amount of nanofilled and nanohybrid filler were slightly different, affecting the staining of these two composite resin types. In the present study, the same results were achieved with the Permaseal sealer.

Methods to measure surface roughness include profilometry, electron microscopy, and visual methods. In the present study, a profilometer was used. This device provides topographic information about the surface of the material. It is available to use it in two types: Contact and non-contact. In this study, a contact device was used [33].

In the present study, the surface roughness of the nanofilled and nanohybrids composite resins was similar with each sealant. Furthermore, in both composite resins, the surface roughness of the samples with and without sealant was similar. These findings showed that the sealants did not significantly affect the surface roughness of composite resins.

Ruschel et al. observed that applying sealants on polished composite resins without sealant did not result in a significant difference in surface roughness [34]. The researchers reported that different composite resins have different surface smoothness patterns [35,36], and the organic matrix is more easily abraded than the filler particles remaining on the surface and are prone to separation from the material [35-37].

The loss of these materials leads to surface defects, making them more irregular [33]. Since sealants are highly fluid [38,39] and materials are applied in a thin layer to the composite resin, the sealants are likely to penetrate the surface defects of the composite resin and thus maintain the microtopography of the previous surface, consistent with the present study.

Lopes et al. reported that surface sealants did not affect the surface roughness of nano-composite resins [5]. In the present study, although all Ra values in all the groups were above the threshold of 0.2 µm (bacterial accumulation limit) [41], none of the groups showed a significant difference from the control group and using or not using sealant resulted in differences.

This finding might be attributed to the thermocycling process, which causes the sealant layer to contract and expand, and as a result, the temperature difference created during this process creates microcracks and peels off surface particles, which are nano-tagged. As a result of this process, the potential effect of reducing the surface roughness of the sealer has been neutralized [7].

Senawongse and Gönülol concluded that nanohybrid composite resins have a higher level of surface roughness than nanofilled composite resins. The cause was reported to be loss of the matrix contact surface due to the peeling of pre-polymerized fillers [6,11]. However, in the present study, the surface roughness of nanofilled and nanohybrid composite resins did not show a significant difference, which seems to be related to the polishing technique used, how the operator operates, and maintaining the surface topography even after applying the sealant.

In 2020, Gurbuz et al. examined the surface roughness and hardness in three composite resin types with and without a sealant (BisCover LV) and observed that the lowest surface roughness and surface hardness belonged to sealant samples [42], which is different from the results of the present study. Such discrepancy might be attributed to differences in composite and sealant types used and the particle size and distribution.

Zimmerli et al. reported that due to similar results in conventional polishing methods and the use of sealants, and considering the cost and time required to apply sealants, the use of surface sealants has no advantages in the direct repair of composite resins [43].

Since the performance and adhesion of different sealants decrease over time, mechanical polishing may be more suitable for the long-term repair of composite resins, but the advantages of sealants in temporary restorations should be considered. In addition, their use is recommended since the sealants do not affect surface roughness but can significantly affect the color stability of composites.

Conclusion

The use of both sealants increased color stability. The use of sealants with the nanohybrid composite resin significantly affected its color stability, but the type of sealant had no significant effect. In the nanofilled composite resin, Permaseal (Ultradent) sealant significantly affected its color stability, but G-Coated sealant (GC) did not significantly affect color stability. In addition, the sealant had no significant effect on surface roughness in both composite resin types.

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