

RESEARCH AND EDUCATION

Influence of resin-coating agents on the roughness and color of composite resins



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The pursuit of the perfect smile has made esthetic procedures essential in dental offices, and novel materials and techniques for increasing the reliability and efficiency of treatments are constantly being developed.¹ Composite resin restorations reestablish esthetics and function in both the anterior and posterior area.¹⁻³

Color is one of the main reasons for restoration replacement, and color stability is a major element in the long-term success of esthetic restorations.^{1,4,5} The surface quality of composite resins, as well as color stability, can be affected by filler particle size and composition, organic matrix composition, and crack formation and propagation over time.^{1,3,6-8}

The color of composite resins can change as a result of external stain or plaque accumulation, surface damage from material degradation and color pigment impregnation, and intrinsic physico-chemical reactions in the organic matrix.^{1,4,5,9-12}

ABSTRACT

Statement of problem. Resin-coating agents can be used to fill microstructural defects within composite resin restorations, which might result in a smoother surface. Nevertheless, data about the color stability and surface roughness of coated restorations are lacking.

Purpose. The purpose of this in vitro study was to compare the surface roughness and color stability of restorations before and after application of different resin-coating agents.

Material and methods. Forty specimens of composite resin (Filtek Z250) (diameter×height, 6×2 mm) were divided into 5 groups according to the surface treatments (n=8 per group): control (CTR), Fortify (FT), Lasting touch (LT), BisCover (BIS), and Fill Glaze (FG). The specimens were evaluated for surface roughness by using a profilometer with 3 readings for each specimen (separated by 300 μm) before immersion in a staining solution (coffee) and after 5 days immersed in coffee and for color stability (ΔE) by using a spectrophotometer before being immersed in coffee (initial reading) and after 6 hours, 12 hours, 1, 2, 3, 4, and 5 days.

Results. Two-way ANOVA with repeated measures and the Tukey test showed that the CTR group showed the highest roughness values, similar to those of the FT and LT groups. The BIS and FG groups showed lower roughness than the other groups but similar results when compared with each other. All groups, except LT, showed increased roughness values after immersion in coffee solution, and the BIS group showed the lowest variation over time. Color alterations were found for all groups, with the CTR group showing the lowest ΔE values when compared with the other groups except for the BIS group. No correlation was found between surface roughness and degree of color change ($P=.401$).

Conclusions. The BisCover surface sealant showed the lowest surface roughness and the best color stability. Surface sealants can be used to fill microcracks and microgaps but should not be used as a substitute for polishing. (J Prosthet Dent 2019;122:332.e1-e5)

Although it may not be possible to identify a single factor as responsible for color changes because of the heterogeneity of the composite resin structure, surface roughness is highly associated with color stability as a

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Clinical Implications

Resin-coating agents can reduce the surface roughness of composite resin restorations, as well as improve their color stability. Nevertheless, such effects depend on the composition and properties of the resin-coating agent.

rougher surface (Ra over 0.2 μm) is more prone to plaque growth and staining.^{1,3,6,13-16}

Finishing and polishing play a major role in the color stability of restorations.^{1,3,7} As conventional finishing and polishing do not provide a completely smooth surface,^{3,7} the use of resins to coat the restorative material could fill microstructural defects through the capillary effect, improving both mechanical properties and staining resistance.^{3,16-20}

However, studies on the effect of different surface sealants on the color stability and surface roughness of composite resin restorations are lacking. The purpose of this *in vitro* study was to evaluate the influence of surface sealants on the roughness and color stability of composite resins. The null hypothesis tested was that no differences would be found in surface roughness or color stability when coated and noncoated restorations were compared.

MATERIAL AND METHODS

Forty composite resin specimens (Filtek Z250; 3M) were made by using a 2-part stainless steel matrix (diameter \times height, 6 \times 2 mm) in a single increment. The surface was covered with a Mylar strip and compressed with a glass slide to standardize the dimensions and roughness. The glass slide was removed, and the material was light-polymerized by using an LED light-polymerization unit (VALO; Ultradent Products, Inc) with 1000 mW/cm² for 40 seconds. The specimens were immersed in 5 mL of deionized water at 37 °C and stored for 7 days in the absence of light, followed by polishing for 1 minute with silicon carbide (SiC) papers (400, 600, and 1200 grit; Extec Corp), adapted on a polisher machine at 300 rpm with a 1.69-N load, under water cooling. After each polishing cycle (corresponding to the paper grit), the specimens were immersed in an ultrasonic bath (T7; Thornton) for 5 minutes to remove debris.

The specimens were randomly divided into 5 groups (n=8 per group) based on random numbers in a spreadsheet (Excel; Microsoft Corp). Four groups received surface treatment and coating with surface sealants (test groups), and 1 group served as control (no treatment) (Table 1). For the test groups, the composite resin surface was etched with 37% phosphoric acid for 15

Table 1. Resin-coating materials tested

Group	Product	Manufacturer	Composition
	Filtek Z250	3M	60% fillers, bisphenol-glycidyl methacrylate, urethane dimethacrylate, ethoxylated bisphenol-A dimethacrylate, and ethoxylated bisphenol-A dimethacrylate.
CTR	No sealant	NA	NA
FT	Fortify	Bisco Inc	Urethane dimethacrylate and ethoxylated Bis-GMA
LT	Lasting touch	Dentsply Sirona	Nanofillers, acetone, organic solvent, photoinitiator, stabilizer, urethane resin, organic acid
BIS	BisCover	Bisco Inc	Dipentaerythritol pentaacrylate, ethanol
FG	Fill Glaze	Vigodent SA	Methyl methacrylate, photoinitiator, and acrylates

seconds, followed by water rinsing for 15 seconds. The specimens were air-dried, and sealants were applied on the surface by using a microbrush. After excess sealant removal (by using a dry microbrush), the specimens were light-polymerized for 30 seconds (FT), 15 seconds (LT), 10 seconds (BIS), and 20 seconds (FG) by using an LED light-polymerization unit according to the recommendations of the respective manufacturers. For the control group, the specimens were just immersed in distilled water. After surface sealant application, the specimens were stored for 24 hours in distilled water, as previously described.

Each specimen surface was evaluated in 3 different areas (separated by 300 μm) by using a profilometer (Hommel Tester T1000 basic; Hommelwerke GmbH) with a diamond needle (without any load). The parameters used for the surface roughness were as follows: tolerance (T) minimum (0.01 μm) and T maximum (8.0 μm), where tolerance represented the extreme values to be considered for readings; trail limit (Lt) of 5 mm (corresponding to the real extension traveled by the tip); measuring limit (Lm) of 4.5 mm (corresponding to the extension considered for readings); and cutoff (Lc) of 0.25 mm (corresponding to filtering/minimizing the interference of surface ripple).²¹ The mean value of the 3 readings was computed and used as the roughness (Ra) value for the specimen. Measurements were performed at baseline (after 24 hours storage in distilled water) and after 5 days of specimen immersion in the coffee staining solution (Table 2).

Specimens' shade was assessed by using a spectrophotometer (Easyshade; VITA Zahnfabrik) and the CIE-Lab system. The variable a* corresponds to the green (-a) - red (+a) color axis, and the variable b* corresponds to the blue (-b) - yellow (+b) axis. The a* and b* axes represent the dimension of color tonality (chroma). The third axis (L*) is perpendicular to the a*b* plane and indicates luminosity (value).

After dark storage for 24 hours, each specimen was rinsed under deionized water, dried with absorbent

Table 2. Surface roughness and color assessment times

Group	Description of Time	Roughness	Color
Initial	After 24 h from treatment application (immersed in deionized water)	X	X
6 h	After 6 h immersed in coffee staining solution		X
12 h	After 12 h immersed in coffee staining solution		X
1 d	After 1 d immersed in coffee staining solution		X
2 d	After 2 d immersed in coffee staining solution		X
3 d	After 3 d immersed in coffee staining solution		X
4 d	After 4 d immersed in coffee staining solution		X
5 d	After 5 d immersed in coffee staining solution	X	X

paper, and placed on a white background. Before color assessment, the spectrophotometer was calibrated under a light source comprising of 30 LED lamps arranged in a circular pattern. The measurement times are described in Table 2, and the ΔE was calculated by using the initial measurements as the baseline.

The mean value of the 3 readings was computed and used to calculate the color alterations (ΔE) according to the following formula (CIE, 1986):

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

After initial roughness and color assessment, specimens were immersed in a coffee solution prepared with 200 mL of deionized water (heated in a microwave until 100 °C) and 5 g of coffee (Traditional Nescafé; Nestlé). The solution was allowed to cool to 37 °C, and 10 mL was poured into each specimen flask. The solution was replaced every 24 hours, and the specimens were stored in an incubator at 37 °C (Table 2).

Data normality was assessed with the Kolmogorov-Smirnov test for both analyses (surface roughness and ΔE), followed by 2-way ANOVA with repeated measures and the Tukey HSD test. The Pearson correlation test was used to assess the correlation between surface roughness and degree of color change ($\alpha=.05$).

RESULTS

For roughness measurements, both different surface treatments and time of measurement resulted in significant differences ($P<.001$ for both). The CTR groups showed the highest roughness values for both initial and final readings, similar to those of the FT and LT groups. The BIS and FG groups had similar initial and final roughness values but lower than those of the CTR, FT, or LT groups. With the exception of the LT group, all groups showed increased roughness after immersion in the coffee solution. The BIS group showed the lowest variation in measurements (Fig. 1).

Considering the degree of color change, different surface treatments and time showed significant

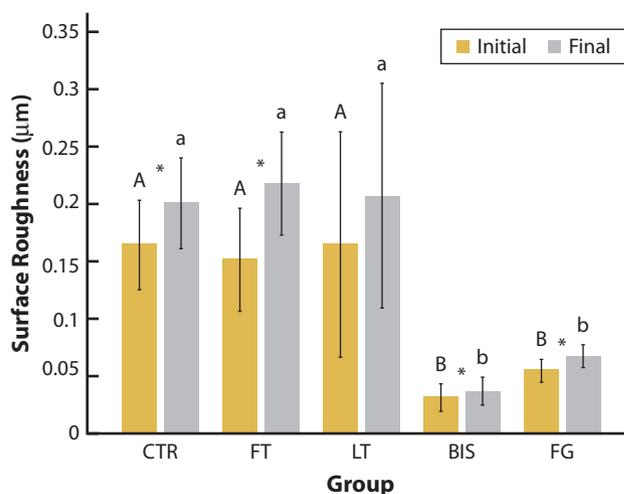


Figure 1. Surface roughness (Ra) before and after immersion in staining solution. *Statistically significant difference between initial and final roughness for each group (same coating material); Initial roughness—different uppercase letters denote statistically significant difference between different groups. Final roughness—different lowercase letters denote statistically significant difference between different groups.

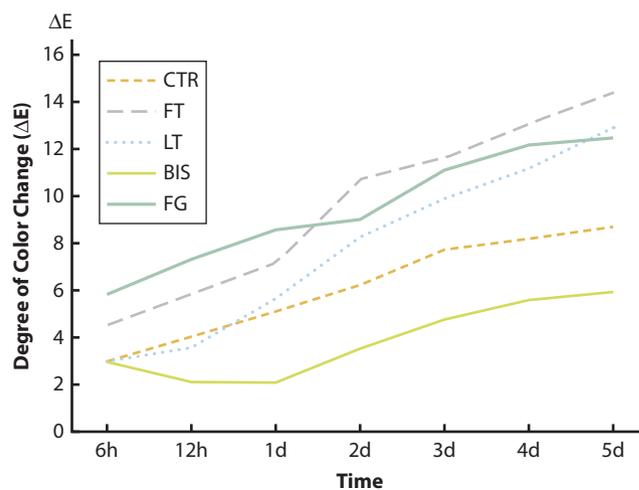


Figure 2. Degree of color change (ΔE).

differences ($P<.001$ for both). The CTR group showed the lowest results when compared with the other groups, except for the BIS group (similar after 6 hours and lower for the other time points) and the LT group (similar up to the first day but higher subsequently) for all time points. All groups showed increased ΔE after the different colorimetric evaluations, with FT and FG showing the highest values at all time points. After 5 days, the LT group displayed similar color alteration values to those of FT and FG. The color change of the BIS group had the lowest variations when compared with the other groups (except for the 6-hour reading when compared with CTR and LT) (Fig. 2 and Table 3). The Pearson correlation test

Table 3. Degree of color change over time (mean \pm standard deviation)

Time/ Group	CTR	BIS	LT	FT	FG
6 h	2.95 \pm 0.61 ^{Aa}	2.93 \pm 0.77 ^{Aa}	2.96 \pm 0.92 ^{Aa}	4.50 \pm 0.56 ^{Ba}	5.81 \pm 1.40 ^{Ba}
12 h	4.01 \pm 0.86 ^{Ab}	2.09 \pm 0.36 ^{Bb}	3.56 \pm 1.13 ^{Aa}	5.78 \pm 0.75 ^{Cb}	7.32 \pm 1.29 ^{Db}
1 d	5.10 \pm 0.80 ^{Ac}	2.07 \pm 0.81 ^{Bb}	5.62 \pm 0.86 ^{Ab}	7.15 \pm 0.82 ^{Cc}	8.56 \pm 1.18 ^{Dc}
2 d	6.22 \pm 1.13 ^{Ad}	3.51 \pm 0.63 ^{Ba}	8.23 \pm 1.28 ^{Cc}	10.70 \pm 1.10 ^{Dd}	8.99 \pm 1.57 ^{Dd}
3 d	7.71 \pm 0.58 ^{Ae}	4.73 \pm 0.59 ^{Bc}	9.87 \pm 1.47 ^{Ccd}	11.60 \pm 0.93 ^{Dd}	11.08 \pm 1.26 ^{CDd}
4 d	8.18 \pm 0.80 ^{Aef}	5.55 \pm 0.52 ^{Bd}	11.15 \pm 1.33 ^{Cde}	13.07 \pm 1.25 ^{De}	12.17 \pm 1.27 ^{CDe}
5 d	8.71 \pm 0.69 ^{Af}	5.89 \pm 0.75 ^{Bd}	12.90 \pm 2.07 ^{Ce}	14.38 \pm 0.90 ^{Cf}	12.46 \pm 1.37 ^{Ce}

Different superscript uppercase letters denote statistically significant difference between groups. Different superscript lowercase letters denote statistically significant difference within same group.

did not show any correlation between surface roughness and degree of color change ($P=.401$).

DISCUSSION

Considering the results of the present study, the null hypothesis was rejected. Esthetic restorations need to reestablish tooth shape, shade, and texture. A shade mismatch in an esthetic area represents one of the main reasons for the clinical failure and replacement of restorations.^{1,3,4} Coating procedures can reduce resin-based materials' surface roughness, although they do not fill all surface irregularities.^{3,15,16}

In the present study, resin coatings reduced the surface roughness of polished restorations, raising questions about the necessity for surface polishing because it is time-consuming and dependent on the abilities of the operator. Despite the adequate initial performance of such coatings, they tend to debond or abrade after different challenges.^{6,13,17,18} Thus, coating materials might not be able to provide longer-lasting outcomes than noncoated surfaces.¹⁵

Although the coherence of the coating materials was not assessed in the present study, a general increase in surface roughness was observed in most groups, probably from early debonding of the coating agents even in the absence of mechanical or abrasive challenges; this supports previously reported results.^{4,16,17} Therefore, a polished composite resin surface is fundamental to ensure better surface quality despite the fact that rougher surfaces could increase the bond between the composite resin and the sealant.^{3,16} Although the sealant might be removed from the surface, it still might be present at the restorative interface and within microcracks or surface gaps, which could result in lower wear and better long-term marginal sealing.²⁰

Filled sealants have higher Ra values than unfilled ones.^{13,14,19,21} In some cases, the initial smoother surface provided by the sealant agent can be jeopardized by an increased layer thickness that is prone to absorbing stains.³ This effect was observed in the LT (nanofilled sealant) group. Ra results that showed increased average roughness values together with an increase in standard

deviation may be explained by an uneven surface thickness because of increased viscosity and air bubbles trapped inside the coating layer.

The FG surface sealant is composed of hydrophilic methyl-methacrylate and acrylate monomers that can easily degrade in humid environments, resulting in increased color changes despite the surface smoothness (Figs. 1, 2). The BIS surface sealant contains dipentaerythritol pentaacrylate that provides flexibility and resistance against moisture, which explains its improved performance in the present study and in previous reports.^{1,5} The FT surface sealant contains UDMA, which has a relatively higher viscosity than other acrylates and may explain the significantly higher Ra values.

Color alterations are caused by intrinsic (type of composite resin, organic and inorganic matrix compositions) and extrinsic factors (staining agents and surface roughness) that are influenced by acid, thermomechanical challenges, and/or dietary habits.^{1,3,5,7,9-11} Surface roughness is frequently associated with color stability, especially when the Ra values are higher than 0.2 μm .^{6,9,13,14} In the present study, all groups stayed below 0.2 μm , except FT and LT after immersion in coffee. The BIS and FG groups showed very low Ra values at both time points.

Lower filled composite resins tend to present lower color stability^{1,5,9,10} because of the hydrophilic nature of the composite resin matrix which degrades in humid environments.^{3,8,10-12} A frequently used methodology of testing staining resistance is immersion in a coffee solution. Coffee has a high staining potential because particles are absorbed and adsorbed on the composite resin surfaces and into the matrix.^{8,13,21} In the present study, 5 days of coffee immersion was chosen because it has been reported that the greatest proportional amount of discoloration occurs within the first week, thus allowing the prediction of a material's long-term color stability.^{5,11}

The LT, FT, and FG groups showed higher color alterations over time than the CTR (noncoated) group (except for the LT group for up to 2 days). The BIS group had the lowest color alteration up to 5 days of all groups, being similar to the CTR group at the last reading. These

results are similar to those of previous reports that showed the heterogeneous behavior of composite resin coatings. This is related to a material's composition and rheological properties, which determine viscosity, penetration of material into surface irregularities, layer thickness, and long-term success.^{3,4}

The oxygen-inhibited layer is more susceptible to staining than polished surfaces.⁴ Composite resin finishing and polishing procedures remove the inhibited layer that is regenerated after the surface sealant application.¹² Therefore, a significant advantage of the BIS surface sealant consists in the lack of oxygen-inhibited layer generation, leading to improved staining resistance.⁴

The color alterations observed in the CTR group can be explained by degradation of the composite resin organic matrix in the presence of humidity. Nevertheless, the color alteration in the CTR group was lower than that in the unfilled or lower filler content-coating resins (FT, LT, and FG), probably because of the hydrophobic matrix.³ Nevertheless, all groups presented higher ΔE than the clinical threshold (3.3)⁹ after the third day of staining challenge, although the CTR and BIS were the most stable groups.

Only a microhybrid composite resin restorative material was assessed in the present study. Materials with different composition and physical properties can generate different results, although microhybrid composite resins tend to be rougher and more difficult to polish.^{3,6,14} Such characteristics increase susceptibility to staining and wear.⁸ In addition, unlike a clinical environment, the entire specimen was immersed in the staining solution, which could overestimate the results. Therefore, future research may need to evaluate the long-term effectiveness of resin coatings with erosive and abrasive tests to simulate the oral cavity environment and to account for different composite resin material properties.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. BisCover sealant provided the lowest surface roughness and the best color stability.
2. Surface sealants can be used to fill microcracks and microgaps but should not be used as a substitute for polishing procedures.

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