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Research Article



# Effect of surface sealant on the color stability and whiteness index of single-shade resin composites after staining and bleaching

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**Conflict of Interest**
No potential conflict of interest relevant to this article was reported.

**Author Contributions**
Conceptualization: Fidan M, Yağcı O; Data curation: Fidan M, Yağcı O; Formal analysis: Fidan M, Yağcı O; Funding acquisition: Fidan M, Yağcı O; Investigation: Fidan M, Yağcı O; Methodology: Fidan M, Yağcı O; Project administration: Fidan M, Yağcı O; Resources: Fidan M, Yağcı O; Software: Fidan M, Yağcı

## ABSTRACT

**Objectives:** The aim of the current study was to evaluate the effect of polishing systems and surface sealant on the color stability and whiteness index of single-shade resin composites after staining and bleaching.
**Materials and Methods:** Three single-shade (Omnichroma, Charisma Diamond One, Zenchroma) and one multi-shade (Filtek Z250) materials were tested. From each resin composite, 40 specimens were prepared. The specimens were divided into 4 subgroups ($n = 10$) according to the surface treatments: 1-step polishing, 1-step + Biscover LV, 2-step polishing, and 2-step polishing + Biscover LV. Color differences ($\Delta E_{00}$) were calculated after being immersed in the coffee solution for 12 days. After the staining, the specimens were immersed in a whitening mouthrinse (Crest-3D White) for 12 hours. Whiteness index differences ($\Delta WI_D = WI_D$ after staining − $WI_D$ after bleaching) values were recorded. The generalized linear model was used for analysis ($p < 0.05$).
**Results:** The lowest and highest $\Delta E_{00}$ values were found for Zenchroma and Charisma Diamond One respectively. Sealed groups indicated higher $\Delta E_{00}$ values than nonsealed groups with significant differences ($p = 0.008$). The lowest and highest $\Delta WI_D$ values were found for Zenchroma and Charisma Diamond One respectively. Sealed groups indicated lower $\Delta WI_D$ values than nonsealed groups with significant differences ($p = 0.022$).
**Conclusions:** The use of surface sealant increased the discoloration and showed less whiteness change in resin materials. When the 1-step was compared with the 2-step polishing, the effects on the color stability and whiteness index values of the resin materials were similar.

**Keywords:** Color; Composite dental resin; Dentistry; Spectrophotometry

## INTRODUCTION

The increasing demand for esthetics has led to the widespread utilization of resin materials, driven by their improved physico-mechanical and esthetic properties [1-3]. The demand for a perfect smile has made esthetic procedures a necessity in dentistry. Resin composite restorations play a crucial role in recreating both esthetics and functionality of restoring the appearance and function of the teeth [4]. The complex process of color selection for resin

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composites is affected by various factors, including different color shades and technical sensitivities [5]. Clinicians may simplify the color shade selection process by utilizing the chameleon effect of dental materials. This effect refers to the ability of these materials to mimic the natural tooth color of the surrounding teeth and effectively compensate for color mismatches, thus simplifying the process of selecting the right shade [6]. Recently, single-shade materials have been introduced that offer simplified applications and these materials are claimed to match different shades of teeth [5,7].

Color stability plays a significant role in the longevity of resin composite restorations [8,9]. The surface characteristics and color change of resins may be subject to alteration due to factors such as particle size and compositions, as well as the compositions of the organic matrix [10,11]. The color stability of resin materials may be altered by internal and external factors [12,13]. Researchers have reported that bleaching treatments do have an impact on the color change of colored resin composites and the ability to return them to their original color. Bleaching can be accomplished with treatments conducted in the dentist's office, treatments provided by the dentist but completed at home, or with over-the-counter treatments [14]. As a result of the success of whitening treatments, patient requests for whitening have increased, encouraging the marketing of over-the-counter products for home whitening. These products offer alternative whitening treatments at a lower cost than traditional professionally applied products [15]. In recent years, due to low cost, and accessibility, mouthrinses have become a popular choice for over-the-counter whitening [14].

Finishing/polishing plays a crucial role in the color stability of restorations [16]. The color stability of resins is affected by external factors, as well as the properties of particles, polishing system types, and compositions [17]. Finishing/polishing materials currently on the dental market differ according to their content and use [18]. However, finishing/polishing does not provide completely smooth surfaces and rough surfaces may be discolored by adsorption of stains [19-21]. Application of surface sealant, unfilled low-viscosity resin, after polishing, maybe an advanced method to ensure resin material surfaces are smooth [22]. In addition, surface sealants are used to provide a smooth polished surfaces without an adhesive air-blocking layer [23]. However, it has been noted in the literature that the effectiveness of surface sealants is controversial [24].

Research on the impact of various polishing systems and surface sealants on the color stability and whiteness index of resin composites is insufficient. This study aims to assess the effect of polishing systems and surface sealant on the color stability and whiteness index of single-shade resin composites after immersion in coffee and whitening mouthrinse. The first null hypothesis is that polishing systems do not have a significant effect on the color stability and whiteness index of single-shade materials after immersion in coffee and whitening mouthrinse. The second null hypothesis is that the surface sealant does not has a significant effect on the color stability and whiteness index of single-shade resin composites after immersion in coffee and whitening mouthrinse.

## MATERIALS AND METHODS

### Specimen preparation

Detailed composition of the tested materials used is presented in **Tables 1** and **2**. Using a standard size (8-mm diameter, 2-mm thickness) Teflon mold, we prepared 160 disc-shaped

**Table 1.** List of materials used in this study

| Resin composites | Manufacturer | Type | Composition | Filler(w/v)% | Lot No. |
|---|---|---|---|---|---|
| Filtek Z250 (multi-shade/A2) | 3M ESPE, USA | Micro-hybrid | Bis-GMA, UDMA, Bis-EMA, zirconia/silica, 0.01–3.5 μm | 78/60 | 6020A2 |
| Omnichroma (single-shade) | Tokuyama, Japan | Nanofilled | UDMA, TEGDMA, uniform sized supra-nano spherical filler (260 nm spherical $SiO_2$-$ZrO_2$) and filler | 79/68 | 076E12 |
| Zenchroma (single-shade) | President Dental, Germany | Micro-hybrid | Bis-GMA, Tetramethylene dimethacrylate, Diurethane dimethacrylate. Glass powder, silicon dioxide inorganic filler (0.005–3.0 μm) | 75/53 | 2022003395 |
| Charisma Diamond One (single-shade) | Kulzer, Germany | Nano-hybrid | Advanced TCD, Matrix, BPA-free, and BrF $B_2O_3$-F-$Al_2O_3$-$SiO_2$, silica, $TiO_2$, fluorescent pigments, metallic oxide pigments, organic pigments, 5 nm–20 μm | 81/64 | K010024 |

The data were provided by the manufacturers.
Bis-GMA, bisphenol A glycol dimethacrylate; Bis-EMA, bisphenol A ethoxylated dimethacrylate; TEGDMA, triethylene glycol dimethacrylate, UDMA, urethane dimethacrylate, $SiO_2$, silicon oxide (silica); $ZrO_2$, zirconium oxide; $YbF_3$, ytterbium trifluoride; $B_2O_3$-F-$Al_2O_3$-$SiO_2$, boro-fluoro-aluminosilicate; TCD, tricyclodecane.

**Table 2.** List of sealant and mouthrinse used in this study

| Materials/Manufacturer | Contents | Lot No. |
|---|---|---|
| Biscover LV/BISCO Inc., Schaumburg, IL, USA (sealant) | Dipentaerythritol penta-acrylateesters and ethanol | 2200004920 |
| Crest 3D White/Procter & Gamble, Cincinnati, OH, USA (mouthrinse) | Water, glycerin, hydrogen peroxide, propylene glycol, sodium hexametaphosphate, Poloxamer 407, sodium citrate,flavor, sodium saccharin, citric acid (alcohol free) | 21115395UD |

specimens from 3 single-shade resin composite materials, including Omnichroma (Tokuyama Dental, Tokyo, Japan), Charisma Diamond One (Heraeus Kulzer, Hanau, Germany), and Zenchroma (President Dental, Allershausen, Germany), and one multi-shade material Filtek Z250/A2 (3M ESPE, St. Paul, MN, USA). During the preparation of the disc-shaped materials, a Mylar strip was placed on the top of the Teflon molds to create a smooth surface. A glass plate was placed on top of the Mylar strip, and a pressure of 1 kg (9.8 N) was applied for 30 seconds [25]. After, the weight and glass plate were removed, and the materials were cured using a polymerization device (tip diameter 10 mm) (Elipar S10, 3M ESPE) with an intensity of 1,200 mW/cm$^2$ for 20 seconds. The specimens were removed from the mold and polished with 1,200-grit silicon carbide paper. The flow chart is presented in **Figure 1**. G*Power 3.1 software (Heinrich- Heine-Universität Düsseldorf, Düsseldorf, Germany) was used to calculate the sample size. Input conditions: alpha-type error is 0.05, power ($1 - \beta$) of 0.85, an effect size (f) of 0.38, and the sample size was calculated as 10 per subgroup [22].

### Polishing and surface sealant procedures

A total of 160 disc-shaped materials were prepared (40 samples in each of the material groups). The resin composite groups were randomly allocated into 2 subgroups ($n = 20$). One group was treated with a 1-step polishing system (Optragloss, Ivoclar Vivadent, Schaan, Liechtenstein), using a diamond-embedded spiral wheel for 30 seconds in wet conditions. The other group was treated with a 2-step polishing system (Nova Twist, President Dental, Munich, Germany) ($n = 10$). The Nova Twist polishing system includes prepolishing and high-shine polishing diamond-embedded spirals. Each spiral wheel was applied for 15 seconds under wet conditions. The Optragloss polishing system includes a high-shine polishing diamond-embedded spiral. The spiral wheel was applied for 30 seconds under wet conditions. The polishing systems were applied using a handpiece at a speed of 10,000 rpm. The final thicknesses of the resin discs were measured using a digital caliper with a tolerance of ± 0.1 mm (2.0 ± 0.1 mm).

In the Nova Twist + BisCover LV and Optragloss + BisCover LV groups, where BisCover LV (BISCO Inc., Schaumburg, IL, USA) surface sealer was applied in each subgroup, the application procedure in accordance with the manufacturer's recommendations was as follows: phosphoric acid (K-Etchant, Kuraray Noritake Dental, Tokyo, Japan) was applied

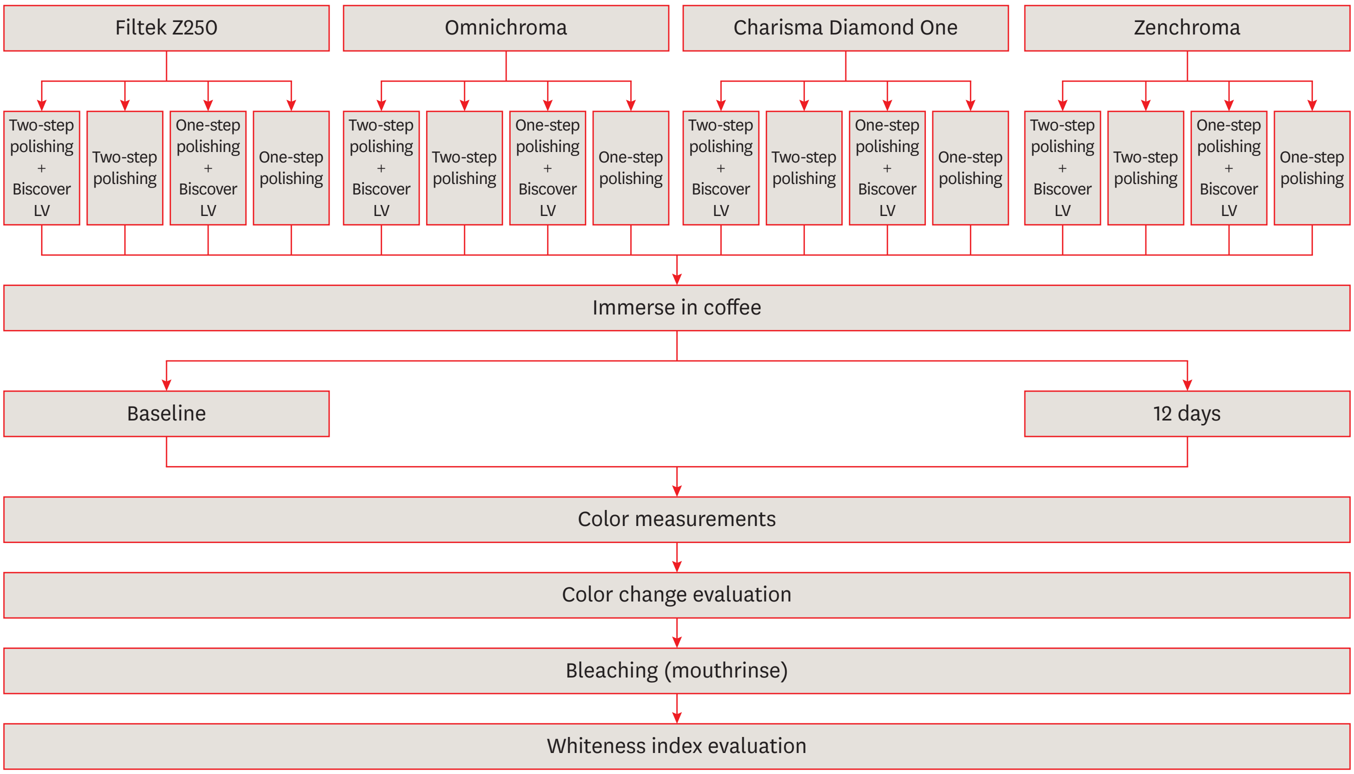


**Figure 1.** Flow chart of the study.

to the resin composites for 15 seconds and washed for 15 seconds and dried for 10 seconds using an air-water syringe. A thin layer of BisCover LV was then applied to the sample surface, using disposable adhesive application brushes. Air was applied for 15 seconds to remove solvents, and then polymerization (Elipar S10, 3M ESPE) was achieved for 30 seconds. All specimens were kept in 37°C distilled water in an incubator for 24 hours.

## Staining procedure

After the baseline color measurements, the specimens were immersed in 3.6 g of coffee powder (Nescafe Classic, Nestle, Vevey, Switzerland) in 300 mL of distilled water for 10 minutes and then filtered [26]. The specimens were kept in the solution for 12 days at 37°C. The solution was refreshed daily. To remove any excess staining agent, the specimens were washed with distilled water for 1 minute and then dried.

## Color differences evaluation

Each specimen was measured 3 times, and the average values (L, a, and b) were obtained. Color values were determined using a spectrophotometer (Vita Easyshade V, Vita Zahnfabrik, Bad Sackingen, Germany) on a white background (L*:89.5, a*:1.4, and b*:6.7). The device was calibrated after each color measurement. To determine color differences ($\Delta E_{00}$) at the baseline and after staining for 12-day intervals color values were calculated using the CIEDE2000 formula [27]:

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

The color changes ($\Delta E_{00}$) were determined using the formula where $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the differences in lightness, chroma, and hue between the 2 specimens compared. The weighting functions for the lightness, chroma, and hue components were $S_L$, $S_C$, and $S_H$, respectively. Additionally, $K_L$, $K_C$, and $K_H$ were parametric factors, and in this study, they were set to 1. The thresholds for perceptibility and acceptability were set at 0.8 and 1.8 [28].

### Bleaching procedure

After the staining procedure, each specimen was thoroughly rinsed for 120 seconds. The specimens were immersed in 100 mL of tested whitening mouthrinse (Crest 3D White, Procter & Gamble, Cincinnati, OH, USA) for 12 hours in a dark bottle, which was found to be equivalent to 1 year of daily mouthrinse use at 2 minutes per rinse per day [29].

### Whiteness index ($WI_D$) evaluation

Color values of resin composite specimens were obtained using a Vita Easyshade V (Vita Zahnfabrik) on a black background (L*:1.0, a*:9.5, and b*:17.5) after immersion in coffee and whitening mouthrinse. The $WI_D$ is a linear formulation, which can be calculated using the following equation [30]:

$$WI_D = 0.511L^* - 2.324a^* - 1.100b^*$$

$WI_D$ variations ($\Delta WI_D$) between the materials after immersion in coffee and after whitening mouthrinse were evaluated. In this study, differences in the $WI_D$ ($\Delta WI_D$) were assessed using the whiteness 50%:50% perceptibility (WPT) and 50%:50% acceptability (WAT) thresholds, which were determined in previous research and correspond to 0.72 $\Delta WI_D$ units and 2.60 $\Delta WI_D$ units, respectively [31].

### Statistical analysis

For the statistical analysis, IBM SPSS 25.0 software (IBM, Armonk, NY, USA) was used. To assess the data distribution of normality, the Kolmogorov-Smirnov test and skewness and kurtosis were evaluated. To evaluate differences between groups, the generalized linear model was used for color change ($\Delta E_{00}$) and whiteness index change ($\Delta WI_D$) to determine the "resin composite" factor, "polishing system" factor, and "sealant," and their interaction (resin composite × polishing system × sealant). The significance level was accepted as $p < 0.05$.

## RESULTS

### Color differences results

The generalized linear model test results for color differences are indicated in **Table 3**. The acceptability threshold is shown in **Figure 2** for the groups. The mean and standard deviation values of the $\Delta E_{00}$ for the resin composites are shown in **Table 4**. Regardless of polishing and sealant, Charisma Diamond One indicated the highest $\Delta E_{00}$ values (6.7 ± 0.6), with significant differences ($p < 0.001$) compared with the other resin materials. Zenchroma indicated the lowest $\Delta E_{00}$ values (4.0 ± 0.6), with significant differences ($p = 0.005$) compared with the other resin composites. However, the $\Delta E_{00}$ values of Zenchroma (4.0 ± 0.6) and Omnichroma (4.4 ± 1.2) were similar ($p > 0.05$). Regardless of polishing and resin composite, sealed groups indicated higher $\Delta E_{00}$ values (5.1 ± 1.3) than nonsealed groups, with significant differences (4.7 ± 1.4) ($p = 0.008$).


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**Table 3.** Generalized Linear Model results for color change and whiteness index change

| Variables | Wald $\chi^2$ | df | Sig. |
|---|---|---|---|
| Color change | | | |
| Resin composite | 272.011 | 3 | < 0.001 |
| Polishing system | 0.488 | 1 | 0.485 |
| Sealant | 6.932 | 1 | 0.008 |
| Resin composite × Polishing system | 0.953 | 3 | 0.813 |
| Resin composite × Sealant | 2.981 | 3 | 0.395 |
| Polishing system × Sealant | 1.134 | 1 | 0.287 |
| Resin composite × Polishing system × Sealant | 3.792 | 3 | 0.285 |
| Whiteness index change | | | |
| Resin composite | 38.381 | 3 | < 0.001 |
| Polishing system | 1.125 | 1 | 0.289 |
| Sealant | 5.213 | 1 | 0.022 |
| Resin composite × Polishing system | 5.463 | 3 | 0.141 |
| Resin composite × Sealant | 9.950 | 3 | 0.019 |
| Polishing system × Sealant | 0.734 | 1 | 0.392 |
| Resin composite × Polishing system × Sealant | 4.731 | 3 | 0.193 |

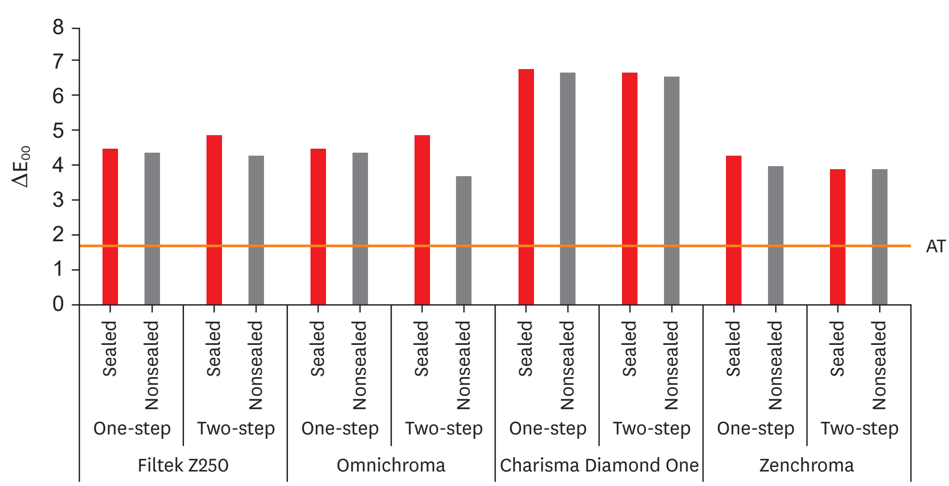


**Figure 2.** The mean variations of all groups of $\Delta E_{00}$ values.
$\Delta E_{00}$, color differences; AT, acceptability threshold of 1.8 units.

**Table 4.** Means and standard deviations for color change values and differences

| Polishing | Sealant | Resin composites | | | | Total mean |
|---|---|---|---|---|---|---|
| | | Filtek Z250 | Omnichroma | Charisma Diamond One | Zenchroma | |
| One-step | Sealed | 4.5 ± 0.5 | 4.5 ± 1.5 | 6.8 ± 0.6 | 4.3 ± 0.6 | 5.1 ± 1.4 |
| | Nonsealed | 4.4 ± 0.8 | 4.4 ± 1.1 | 6.7 ± 0.6 | 4.0 ± 0.7 | 4.8 ± 1.3 |
| | Total mean | 4.5 ± 0.7 | 4.4 ± 1.3 | 6.8 ± 0.7 | 4.1 ± 0.7 | 5.0 ± 1.4 |
| Two-step | Sealed | 4.9 ± 1.0 | 4.9 ± 1.9 | 6.7 ± 0.7 | 3.9 ± 0.5 | 5.1 ± 1.3 |
| | Nonsealed | 4.3 ± 1.0 | 3.7 ± 1.0 | 6.6 ± 0.7 | 3.9 ± 0.6 | 4.6 ± 1.5 |
| | Total mean | 4.6 ± 1.0 | 4.3 ± 1.1 | 6.7 ± 0.7 | 3.9 ± 0.6 | 4.9 ± 1.4 |
| Total mean | Sealed | 4.7 ± 0.8 | 4.7 ± 1.2 | 6.8 ± 0.6 | 3.9 ± 0.7 | 5.1 ± 1.3$^{x}$ |
| | Nonsealed | 4.4 ± 0.9 | 4.0 ± 1.1 | 6.7 ± 0.6 | 4.1 ± 0.6 | 4.7 ± 1.4$^{y}$ |
| | Total mean | 4.5 ± 0.8$^{A}$ | 4.4 ± 1.2$^{AB}$ | 6.7 ± 0.6$^{C}$ | 4.0 ± 0.6$^{B}$ | 4.9 ± 1.4 |

There is a difference between different capital letters (A–C) in the row (main effect; composites). There is a difference between different lower letters (x, y) in the column (main effect; sealant). When the main effect and interactions were analysed in **Table 3**, no letters were applied to values that did not exhibit a statistically significant difference.

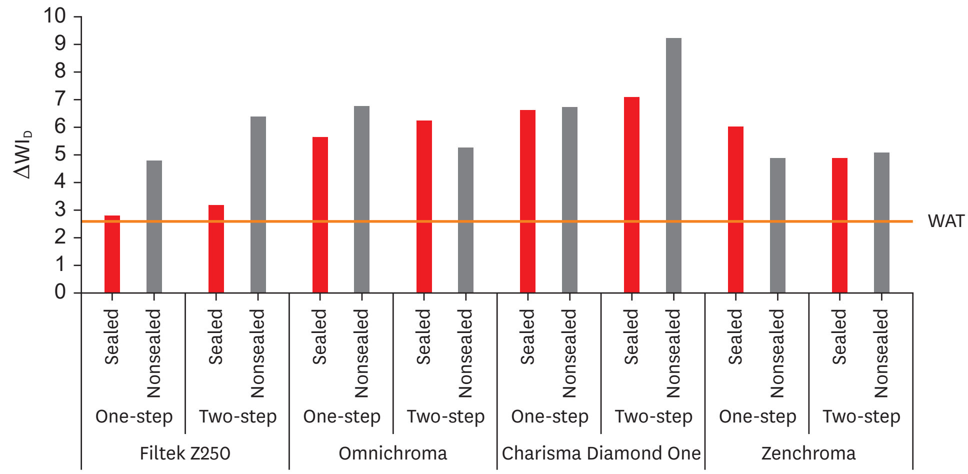


**Figure 3.** The mean variations of all groups of $\Delta WI_D$ values.
$\Delta WI_D$, whiteness index variations; WAT, acceptability threshold of 2.60 units.

### Whiteness index differences results

The generalized linear model test results for the whiteness index differences are shown in **Table 3**. The acceptability threshold (WAT) is shown in **Figure 3** for the groups. **Table 5** represents the mean and standard deviation values of the $\Delta WI_D$ for the materials. Regardless of polishing and sealant, Charisma Diamond One indicated the highest $\Delta WI_D$ values (7.42 ± 2.59), with significant differences ($p < 0.001$) compared with the other resin materials. Filtek Z250 indicated the lowest $\Delta WI_D$ values (4.28 ± 2.48), with significant differences. However, the $\Delta WI_D$ values of Zenchroma (5.21 ± 2.28) and Filtek Z250 (4.28 ± 2.48) were similar ($p > 0.05$). Regardless of polishing and resin composite, sealed groups indicated lower $\Delta WI_D$ values (5.29 ± 2.81) than nonsealed groups, with significant differences (6.14 ± 2.73) ($p = 0.022$). The combination of Charisma Diamond One with Biscover LV indicated the highest $\Delta WI_D$ value (8.00 ± 3.02) among all materials. However, the combination of Charisma Diamond One with and without Biscover LV indicated a similar $\Delta WI_D$ value.

## DISCUSSION

The first hypothesis that polishing systems (main effect) have no significant effect on the color stability and whiteness index of single-shade resin composite materials after immersion

**Table 5.** Means and standard deviations for whitenes index change values and differences

| Polishing | Sealant | Resin composites | | | | Total mean |
|---|---|---|---|---|---|---|
| | | Filtek Z250 | Omnichroma | Charisma Diamond One | Zenchroma | |
| One-step | Sealed | 2.79 ± 2.29 | 5.62 ± 4.08 | 6.61 ± 1.71 | 6.00 ± 2.59 | 5.25 ± 3.08 |
| | Nonsealed | 4.79 ± 1.60 | 6.75 ± 3.10 | 6.72 ± 1.99 | 4.87 ± 1.31 | 5.78 ± 2.25 |
| | Total mean | 3.79 ± 2.18 | 6.18 ± 3.57 | 6.67 ± 1.81 | 5.43 ± 2.08 | 5.52 ± 2.69 |
| Two-step | Sealed | 3.16 ± 2.25 | 6.22 ± 2.19 | 7.06 ± 2.31 | 4.87 ± 1.84 | 5.33 ± 2.55 |
| | Nonsealed | 6.37 ± 2.22 | 5.25 ± 1.80 | 9.28 ± 3.42 | 5.08 ± 3.13 | 6.49 ± 3.12 |
| | Total mean | 4.77 ± 2.72 | 5.73 ± 2.01 | 8.17 ± 3.06 | 4.98 ± 2.50 | 5.91 ± 2.89 |
| Total mean | Sealed | 2.97 ± 2.21[b] | 5.92 ± 3.20[a] | 6.84 ± 1.99[d] | 4.98 ± 2.34[c] | 5.29 ± 2.81[x] |
| | Nonsealed | 5.58 ± 2.05[ac] | 6.00 ± 2.59[a] | 8.00 ± 3.02[d] | 5.43 ± 2.26[abc] | 6.14 ± 2.73[y] |
| | Total mean | 4.28 ± 2.48[AC] | 5.96 ± 2.87[B] | 7.42 ± 2.59[D] | 5.21 ± 2.28[BC] | 5.71 ± 2.79 |

There is a difference between different capital letters (A–D) in the row (main effect; composite). There is a difference between different lower letters (x,y) in the column (main effect; sealant). There is a difference between different lower letters (a–d) (interaction; composite × sealant). When the main effect and interactions were analysed in **Table 3**, no letters were applied to values that did not exhibit a statistically significant difference.

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in coffee and whitening mouthrinse was accepted. The second hypothesis that surface sealant (main effect) has no significant effect on the color stability and whiteness index of single-shade resin composites after immersion in coffee and whitening mouthrinse was rejected. The esthetic properties of resin composites are not only dependent on their compositions but also on the environmental impact of the food and beverage products to which they are exposed [26]. A wide variety of colorants, such as coffee, fruit juices, mouthrinses, and foods, can affect the color change of resin composite materials in different ways [32]. However, coffee is a drink that forms a dense stain and is used daily by most people [26]. Therefore, coffee was chosen as the coloring agent in our study. Also, the construction of esthetic resin composite restorations on anterior and posterior teeth has been noted for its numerous and time-consuming procedural steps, which pose challenges for dentists, but single-shade resin materials which have the advantage of reducing restoration construction time and shade selection time have recently been introduced [26]. Therefore, single-shade resin materials were chosen for our study. All the specimens were immersed for 12 days, the equivalent of 1 year of coffee consumption. A temperature of 37°C and continuous exposure to the coloring solution were recommended to simulate oral conditions [10].

The application of surface sealants may provide better resistance to staining by filling surface defects on the resin composites and supporting the surface quality of the resin composites [8,33]. However, the findings of the current study indicated that the immersion procedure induced discoloration of the resin composites, and the surface sealant caused more staining of the resin composites. The interaction of the factors examined in this study in terms of color stability was not significant as shown in **Table 3**. In our study, the surface sealant-treated groups indicated higher $\Delta E_{00}$ values compared with non-surface sealant groups after immersion in coffee. This can be interpreted as the use of Biscover LV negatively affects the color stability of resin materials. In the literature, the findings of studies on the discoloration of resin composite materials after surface sealant are controversial [13,20]. In the previous study, indicated that sealant application did not improve the color stability and surface roughness of the composite resin restoration [22]. In another study, it was reported that the surface roughness values were higher than the plaque accumulation value for all groups with and without sealant application in nanohybrid composites [19]. Due to irregularities on the restoration surfaces, the restoration may become prone to water absorption, and increased discoloration may occur [34]. This may be interpreted as a negative effect of Biscover LV on the color stability of materials. Also, dipentaerythritol pentaacrylate esters, one of the monomers in the liquid system, may be more prone to discoloration. In a previous study, dipentaerythritol pentaacrylate esters containing surface sealants were found to have lower stain resistance than methacrylate-based products [19]. In a previous study conducted on specimens with and without BisCover LV surface sealant, the specimens were kept in mucin, chlorhexidine, and tea solutions, and the color changes were examined after 24 and 72 hours. The study results did not show any significant difference in terms of color change between the samples with and without surface sealant [9]. In a study on coloring solutions and ultraviolet light aging, it was stated that the application of BisCover LV surface sealer did not affect color stability [13]. Another previous study, which investigated the color change after immersion in coffee solution and brushing cycles, found that sealants and traditional finish polishing methods had similar results, that there was no advantage gained from using sealants in terms of time and cost, and that the sealants tended to dissolve [20]. Another study investigated the effects of polishing systems on the color change of different materials. The specimens were immersed in a colorant solution for 48 hours, and the highest color change values were found for samples with BisCover LV [12]. These studies support the results of our study regarding the color change values of the surface sealer. The color change can be associated with surface quality, and the surface after polishing procedures can greatly affect the color stability of the resin composites [12,20].

In this study, the Charisma Diamond One indicated the most color change among the materials tested. This material contains a tricyclodecane, which provides high resistance to discoloration. However, the lower filler contents and the presence of nanoclusters may be the reasons for the high color change [26]. In addition, a recent investigation reported that Charisma Diamond One indicated notably lower surface smoothness compared with Omnichroma [6]. In this study, the lowest color change was found in resin composites with microhybrid content (Zenchroma) and nano filler content (Omnichroma). These findings are similar to those stated in a previous study supporting the lack of current *in vitro* evidence of better smoothness of nano-filler or submicron resin composites compared to conventional microhybrids [35]. The lower color change indicated in the Omnichroma and Zenchroma materials can be attributed to the structure properties of their inorganic filling. According to the manufacturers, Zenchroma, a monochromatic resin composite, has a micro-hybrid filler content. Also in a study, the results of instrumental analysis showed that the color change values of Zenchroma were significantly higher among the tested materials when compared to Omnichroma and a multi-shade of shade group A1 [36]. This difference may be due to the different filler contents and experimental conditions. In addition, Charisma Diamond One contains pigment. This may explain why this material had the highest color change. The high color change of Charisma Diamond One among the tested materials may be attributed to the filler particles, which can lead to weak cross-linking between the polymer matrix and the filler [3]. The bis-acryloyloxymethyl tricyclododecane monomer in the Charisma Diamond One has been stated to have a significant affinity for the low polarity beverage of coffee, so this monomer may be the reason for the low color stability [10]. The color resistance of resins is affected by their resin matrices, filler types, sizes and concentrations, pigment types, types and concentrations of initiator, inhibitor types and activators, and the unreacted carbon bonds [37]. These factors may have also affected the color change of the materials in our study. In a previous study, the clinically acceptable color change threshold value was stated as $\Delta E_{00} \leq 1.8$ [27]. In the current study, the $\Delta E_{00}$ value of the materials after immersion in coffee was found to be above the clinically acceptable threshold. The mechanism of coffee discoloration was explained by the adsorption and absorption of yellow colorants through the organic phase of resin composite materials [1].

Color difference formulas are often used to assess changes in color. Besides color change, aging and staining can actually affect other parameters, such as whiteness, which is very important in esthetic and whitening procedures [30]. The whiteness threshold values used in our study were WPT = 0.72 $\Delta WI_D$ units and WAT = 2.60 $\Delta WI_D$ units [31]. When we investigated the whiteness variations after immersion in whitening mouthrinse, we found that all the resin groups had values above the WAT value. The combination of Filtek Z250 with Biscover LV indicated the lowest $\Delta WI_D$ value compared with the other tested materials. Filtek Z250, a multi-shade material, can play a role in whiteness index change due to its content. The optical properties can affect the whiteness index such as the opacity agents or fillers they contain can cause these differences. We found that sealed resin composite groups had lower $\Delta WI_D$ values than nonsealed groups. A previous study stated that the duration of immersion in mouthrinses can be an important factor for color recovery and whiteness change [14]. The Charisma Diamond One exhibited the highest values of whiteness index change. Previous studies underlined this better color adjustment observed for Charisma Diamond One can be attributed to its higher translucency [38]. The lack of sufficient evidence in the literature in this field constitutes a limitation of this resin material. The perception of whiteness of the materials increased after the resin materials were immersed in a whitening mouthrinse. This situation is thought to be caused by hydrogen peroxide in Crest 3D White. For this study, an immersed time simulating 1 year was chosen. The effect of bleaching over a longer period can be studied in future research.

Nova Twist is used as a 2-step polishing system with fine diamond particles embedded in spiral wheels, while Optragloss is used as a 1-step polishing system with fine diamond particles embedded in spiral wheels. Various factors affect the surface quality of the resin material, including the polishing instruments and operator-related factors [11]. A previous study has found that multi-step polishing techniques provide better performance than 1-step polishing techniques [18]. The texture of the final surface depends on the technique and material used, but there is no consensus on the materials and techniques that provide the smoothest surfaces for resin composite materials [16]. A previous study determined that 1-step polishing techniques are as efficient as multi-step polishing techniques [39]. In this study, the 2-step system used was found to be better than the 1-step system in terms of both color improvement and whiteness change, but a significant difference was not indicated. This can be important depending on the application context. A 1-step system may be preferable for those who want to achieve smooth surfaces in less time, but a 2-step system can be used for those who focus on achieving higher quality surfaces. The results emphasize that the materials and techniques used can vary in terms of achieving better quality surfaces.

Achieving color harmony between the tooth and the resin composite is important to achieve an esthetic appearance. Discoloration can affect dental esthetics, so clinicians can use various treatment methods to minimize or correct discoloration. As a result, when evaluating these factors, dentists can offer a variety of cost-effective treatment options for individuals to achieve a more esthetic smile. This study has some limitations. Due to the constraints in our experimental setup and the scope of this study, we were unable to investigate these aspects thoroughly. Understanding the influence of oxygen inhibition on the polymerization process and its impact on the degree of conversion is crucial for a comprehensive evaluation of the material properties. This omission might limit the depth of our findings and their application in broader contexts. Future studies should focus on these areas to provide a more holistic understanding of the material's behavior under different conditions. Specifically, we recommend conducting detailed studies on the polymerization kinetics and the role of oxygen inhibition in affecting the surface degree of conversion. Such investigations would offer valuable insights and enhance the robustness of the conclusions drawn from this and similar studies. Despite these limitations, the current study contributes valuable preliminary data and sets a foundation for future in-depth research in this field. Clinical factors such as the effect of saliva, diet, and tooth brushing should also be considered. In this study, the surface sealant used was applied to well-polished surfaces, which may have caused debonding issues during the coloring process. In addition, the surface sealant was applied according to the manufacturer's instructions, but the surface sealant thickness could have varied. Therefore, the findings of the current study should be confirmed by further research.

## CONCLUSIONS

The composition of resin composites and surface sealant had a significant effect on the color stability and whiteness index. Sealant-treated groups showed fewer whiteness differences after being immersed in whitening mouthrinse compared with nonsealad-treated groups.

Surface sealant application may not always be advantageous in terms of color stability, and there may be a tendency to increase discoloration and decrease whiteness differences. Clinicians need to be careful after surface sealant application, especially in esthetic areas.

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