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Evaluation of color stability after the coloring process in bulk-fill composites

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Abstract

Aim: Bulk-fill composites have been developed to overcome the disadvantages encountered in the incremental technique, such as the risk of contamination between layers, bonding problems, and gaps. Bulk-fill composites are frequently used in dentistry. The aim of this study was to evaluate the color stability of three different bulk-fill composites after a staining period with tea, coffee, red wine, and distilled water.

Methodology: Three different flowable bulk-fill composites were used in the study (3M Filtek One, Dentsply Sirona SDR, Tokuyama Estellite Bulk-fill Flow). Composite disks with a diameter of 13 mm and a thickness of 1.5 mm were prepared for each subgroup using polytetrafluoroethylene molds. After polymerization, both surfaces of the samples were polished. The samples were incubated in distilled water at 37°C for 24 hours. Initial color measurements were taken using a spectrophotometer. The samples were then immersed in the coloring solutions for 72 hours. Color measurements were taken again, and ΔE_{00} values were calculated using the CIEDE2000 formula. The data were statistically analyzed using three-way variance analysis (ANOVA) and Tukey HSD multiple comparison tests.

Results: A significant difference in ΔE_{00} values was observed between the three groups. The values in the SDR group were significantly higher than those of the 3M and Tokuyama groups. In the black tea group, the values were significantly lower than those of the red wine and coffee groups but significantly higher than those of the control group ($p<0.05$). In the red wine group, the values were significantly lower than those of the coffee group but significantly higher than in the control group ($p<0.05$). The values in the coffee group were significantly higher than those of the control group.

Conclusion: Coloring solutions have an effect on the color stability of bulk-fill composites. Further studies and research should be done to improve bulk-fill composites.

Keywords: Composite, bulk-fill, color change, staining, CIEDE2000, flowable composite

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Introduction

Composite resins are used frequently in restorative dentistry. Advancements in the mechanical and aesthetic qualities of composite resin materials for restoring posterior teeth have also raised expectations for ease of use (1).

The amount of monomer converted into polymer during the polymerization of composite resins is called the degree of conversion or polymerization (2). Composite resins are placed in the cavity in layers (incremental technique), each of which is polymerized separately after cleaning the caries and performing the necessary adhesive procedures to reduce the polymerization shrinkage. In the incremental technique, the composite resin is placed in the cavity in layers of 1-2 mm. This technique has many disadvantages, such as the risk of contamination between layers, bonding errors, and gaps between layers, as well as the long time required to apply the layers (3). To overcome these disadvantages, manufacturers have developed bulk-fill composites that can be applied as a single layer up to a thickness of 4-5 mm. There are two different types of bulk-fill composites: flowable and paste-based. Flowable bulk-fill composites are used in narrow, hard-to-reach cavities exceeding 4 mm, whereas paste bulk-fill composites are used in larger and wider cavities.

Although they are widely used in restorative dentistry, resin-based materials can change their color over time. Composite resin materials tend to discolor over time in the oral environment (4). Patients become dissatisfied with their existing restorations because of discoloration over time. The color stability of a restoration is crucial for aesthetic success. Achieving long-term aesthetic success with composite restorations relies not only on the mechanical and physical properties of the material, but also on external factors, such as the patient's regular consumption of drinks (5). Juice, tea, coffee, and cola are among the commonly consumed liquids that cause more discoloration of dental materials (4).

This study aimed to assess the color stability of flowable bulk-fill composite resins after their exposure to coloring solutions.

The null hypothesis of this study states that neither the coloring solution nor the type of composite resin used affects the extent of color change.

Materials and Methods

Preparation of samples

Three different flowable bulk-fill composite resins were used in this study (SDR-Plus bulk-fill, A2 shade; 3M Filtek One bulk-fill, A2 shade; Tokuyama Estellite Flow bulk-fill, A2 shade). The contents of the materials used in this study are provided in Table 1.

Bulk-fill composite resin sample preparation

Bulk-fill composite resin samples were prepared using polytetrafluoroethylene molds with circular cavities of 13 mm diameter and 1.5 mm thickness, with the bottom surface covered using a mylar strip. The top of the molds was also covered with Mylar strips, and polymerization was performed using an LED light device (Vega, Dentac, Türkiye) with a 1600 mW/cm^2 wave.

The prepared samples were incubated at 37°C for one day to complete polymerization. For surface standardization, polishing procedures were completed on both surfaces under water cooling using medium, fine, and ultra-fine polishing discs (Kerr Optidisc, Kerr Dental, Brea, CA, US).

The prepared samples were divided into four subgroups consisting of three different coloring solutions (coffee, tea, and red wine) and one control group (distilled water), each with n = 10.

Coloring Protocol

The coloring solutions used were coffee (Nescafe Classic; Nestle, Switzerland), black tea (Yellow Label, Lipton, Istanbul, Turkey), red wine (Buzbağ, Boğazkere, Elazığ, Türkiye), and distilled water (control group). The coffee solution was prepared by adding 3 g coffee to 50 ml of boiled water. For the black tea solution, one tea bag was steeped in 50 ml of boiled water for 5 minutes.

The samples were kept in the solutions for 72 hours, and the solutions were changed daily to prevent algae formation and bacterial accumulation. After the coloring process, the samples were washed under running water.

Evaluation of Color Stability

Color measurements were performed for each sample at two different time points (before and after staining). The initial color measurements recorded after the polishing procedures served as the baseline color. Post-staining measurements recorded the final color after immersion in the solutions. The initial and final color measurements were performed using a spectrophotometer (Vita Easyshade V; VITA Zahnfabrik, Bad Säckingen, Germany).

Each color measurement was repeated three times per sample, and the L*, a*, and b* color parameters were recorded. The device was calibrated after each measurement. The CIEDE2000 formula was used to obtain the color change (ΔE_{00}) values, as shown in Figure 1.

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}}$$

Figure 1. CIEDE2000 formula

Table 1. Contents of the materials used in the study

Composite	Filler Content	Filler Type	Matrix Type	Manufacturer
SDR-Plus	Weight: 68% Volume: 44%	Ba-Al-F-B silicate glass, Sr-A-F silicate glass	Modified UDMA, TEGDMA, EBPDMA	Dentsply, US
Filtek One Bulk-Fill	Weight: 64.5% Volume: 42,5	Zirconia/Silica, Ytterbium Trifluoride	Bis-GMA, UDMA, Bis-EMA, and Procrylat	3M ESPE, US
Estellite Bulk Fill Flow	Weight: 70% Volume: 56%	Silica-zirconia and composite filler	Bis-GMA, TEGDMA, Bis-MPEPP	Tokuyama, Japan

***Bis-GMA;** bisphenol A-glycidyl methacrylate, **EBPDMA;** ethoxylated bisphenol-A-dimethacrylate, **TEGDMA;** triethylene glycol dimethacrylate, **UDMA;** urethane dimethacrylate, **Bis-EMA;** ethopxylated bisphenol-A-dimethacrylate

Statistical analysis

Data were analyzed using IBM SPSS V25 software (SPSS version 25, IBM, Armonk, NY, US).

A two-way ANOVA test was used for primary data analysis, and post-hoc multiple comparisons were conducted using Tukey's test. A significance level of 0.05 was applied, with $p<0.05$ indicating a significant difference and $p>0.05$ indicating no significant difference.

Results

Significant differences in the ΔE_{00} values were observed among the three different brands of composites ($p<0.05$). Multiple comparisons indicated that the color change values for samples in the SDR group were significantly higher than those in the 3M and Tokuyama groups ($p<0.05$). Furthermore, the color change values for the samples in the Tokuyama group were significantly higher than those in the 3M group ($p<0.05$).

Significant differences in the ΔE_{00} values were also observed among the four different solutions. Comparative values are provided in Table 2.

The total values in the black tea group were significantly lower than those in the red wine and coffee groups but significantly higher than those in the control group. In the red wine group, the values were significantly lower than those in the coffee group, but significantly higher than those in the control group. The values were significantly higher in the coffee group than in the control group.

The color changes in the 3M samples were significantly lower in the black tea group than in the red wine and coffee groups but significantly higher than in the control group. The values were significantly higher in the red wine group than in the control group. The values were significantly higher in the coffee group than in the control group.

For SDR samples, in the black tea group, the values were significantly lower than those in the coffee group but significantly higher than those in the control group. In the red wine group, the values were significantly lower than those in the coffee group, but significantly higher than those in the control group. The values were significantly higher in the coffee group than in the control group.

Regarding the Tokuyama samples, the values in the black tea group were significantly lower than those in the coffee and red wine groups. In the red wine and coffee groups, these values were significantly higher than those in the control group.

Table 2. Comparisons of different coloring solutions

	Estimates ΔE_{00}				ANOVA	
	Mean	Std. Error	95% Confidence Interval		F	*p*
			Lower Bound	Upper Bound		
Black Tea	8.762	0.461	7.839	9.685	93.19	0.0001
Red Wine	11.331	0.461	10.408	12.254		
Coffee	14.313	0.461	13.390	15.236		
Distilled water	3.802	0.461	2.879	4.725		

Discussion

Based on the obtained data, the null hypothesis initially stated as "there is no effect of coloring solution and type of composite used on the level of color change" has been rejected.

Composite resin restorations are frequently exposed to colored foods and beverages in the oral environment. Many studies have shown that both glass ionomers and resin composites are not resistant to staining when exposed to various beverages (6).

Numerous studies have examined the effects of beverages such as tea and coffee on staining of resin materials after immersion (7). Various factors, including tea, coffee, cola, wine, soy sauce, grape juice, food coloring, chlorhexidine, vinegar, yogurt drink (ayran), orange juice, and yogurt, have been investigated for their staining effects on composite resins (8).

In this study, coffee, tea, and red wine were used as coloring solutions, while distilled water was used as the control group.

The tea used contains tannic acid, coffee contains yellow pigments, and red wine contains alcohol and red pigments (9).

Guler et al. used tea, coffee, and cola for color change in their studies. According to their study, red wine had the highest coloring effect on composites (10).

Çelik et al. immersed their samples in coffee, red wine, cola, and distilled water for 3 hours daily, measuring color changes on the 1st, 7th, 15th, and 30th days using a spectrophotometer (11).

In a study by Barutçugil et al. resin samples were immersed in turnip juice, Turkish coffee, cranberry juice, mulberry juice, and distilled water after initial color measurements were taken. The color changes in the samples were measured using a spectrophotometer at 24 h, 72 h, and 1 week. In this study, we measured color stability after 72 h (4).

Türkün and Leblebicioğlu compared the effects of coffee, tea, and cola on the color changes in three direct resin composites. According to this study, coffee caused the most color change, whereas cola caused the least color change (12).

In a study comparing the color stability of silorane and dimethacrylate-based composites, samples were immersed in solutions of tea, coffee, cola, and red wine, with red wine showing the most significant color change (13).

In a study conducted by Erçin et al. on bulk-fill composites in 2024, the greatest color change was observed in discs with a thickness of 3 mm colored red wine. In contrast, in the total values of our study, we found that the red wine groups had significantly lower values than the coffee groups (14).

In a 2005 study by Bagheri et al. samples from six different composite materials were prepared and stored in distilled water at 37°C for one week. The samples were then immersed in red wine, coffee, tea, soy sauce, and cola for two weeks. The color values of the samples were measured using a spectrophotometer. This study revealed that all materials, except for those in water, were sensitive to coloring solutions, particularly coffee, red wine, and tea (15).

Recently, bulk-fill materials (BF) have been developed as a restorative alternative for posterior teeth in an effort to simplify the operating method and shorten clinical processes (17). In order to reduce chair time, especially in deep and wide cavities, these new composites permit single-layer placement with a thickness of up to 4–5 mm as opposed to the traditional 2 mm. Bulk-fill composites include changes in the resin matrix, the type of photo-initiator, and the size and distribution of the filler particles (18-20). These include more reactive photoinitiators, various forms of nanosized fillers, and novel stress-reducing monomers. Numerous studies have examined how these features affect optical qualities, such as color stability and physio-mechanical properties, including fracture resistance, elastic modulus, flexural strength, degree of conversion, monomer elution, and surface hardness (20-22).

Color and color difference are measured using the CIELAB color space and associated $\Delta E^*_{ab,}$ and this system has been used to quantify color and color changes in most dental studies. It computes the color change (ΔE) based on variations in the lightness-darkness, red-green, and blue-yellow coordinates, where + L* denotes lightness, − L* denotes darkness, + a* denotes red, − a* denotes green, + b* denotes yellow, and − b* denotes blue. (23, 24). Three enhanced color difference formulas—CMC, CIE94, and CIEDE2000 have been created with the goal of enhancing the adjustment between computed and perceived color differences of the CIELAB formula. The Commission Internationale de l´Eclairage CIE now advises using the CIEDE2000 formula (the CIEDE2000 total color difference formula (ΔE_{00}) (25). Therefore, we used the CIEDE2000 system in this study.

Conclusion

Coloring solutions have a remarkable effect on color stability, regardless of their type, on bulk-fill composites. Further studies and research should be done to improve bulk-fill composites.

Disclosures

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