



# Color stability of bulk-fill and nanohybrid composite resins after immersion in various beverages

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## Abstract

**Objective:** This study aimed to investigate the effect of various beverages on the color stability of nanohybrid and bulk-fill resin composites.

**Methods:** In this experimental study, 36 disk-shaped composite samples (6 mm diameter, 4 mm thickness) were prepared from three types of composite resins (n=12): a nanohybrid composite (Filtek Z550), a bulk-fill composite (Tetric EvoCeram Bulk Fill) and a flowable bulk-fill composite (Filtek Bulk Fill Flowable). The samples from each composite were then divided into four subgroups based on the applied staining solution (n=3) and immersed for 120 hours in either distilled water, chocolate milk, cola, or orange juice. Color measurements were conducted at baseline and after immersion in staining solutions by a VITA Easyshade Compact according to the CIELAB color system. Color changes ( $\Delta E$ ) were analyzed by a two-way ANOVA at the significance level of  $P < 0.05$ .

**Results:** All composites exhibited clinically unacceptable color change values ( $\Delta E > 3.3$ ) after immersion in various beverages. The greatest color changes were usually found in Filtek Bulk Fill Flowable composite. Both bulk fill composites showed significantly greater color changes than the nanohybrid composite after immersion in distilled water and chocolate milk ( $P < 0.05$ ). Tetric EvoCeram Bulk Fill showed significantly different color change values after exposure to various beverages ( $P = 0.023$ ).

**Conclusions:** Filtek Bulk Fill Flowable exhibited greater discoloration than Filtek Z550 and Tetric EvoCeram bulk-fill composites. Both the composite structure and the type of beverage influence the color stability of composite resins, but the effect of the composite structure is more potent.

**Keywords:** Beverages, Bulk fill, Composite resins, Nanohybrid composite, Tooth color, Tooth discoloration

## Introduction

The color matching of esthetic restorative materials is crucial for the success of dental treatments (1). Among various direct restorative materials, composite resin is the preferred choice because it allows conservative cavity preparation and optimal adherence to teeth with compatible adhesive systems (2, 3). However, the color of composites may change due to internal and external

factors in the oral environment (4-6). Studies have shown composite resins are susceptible to discoloration when exposed to beverages commonly consumed by patients (4, 7, 8).

The rate of beverage consumption is high among young adults and children. The US Nutrition Examination Survey reported that about 64% of children and adolescents aged 2-19 consume sweetened beverages daily (9). In Iran, the average intake of sugar-sweetened beverages, such as sodas and juices, is approximately  $38.5 \pm 0.75$  grams per day among children (10). The coloring ability of beverages varies depending on their composition and properties (6).

The incremental layering method is recommended for composite resin restorations with thicknesses greater than 2 mm. This method improves light penetration,

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ensures complete polymerization, and reduces shrinkage during polymerization (11, 12). However, incremental application can be time-consuming and lead to air bubble entrapment and moisture contamination, potentially deteriorating physical and mechanical properties and causing early failure of restorations (13). To address these issues, bulk-fill composite resins have been developed. According to manufacturers, these composites can achieve an incremental thickness of 4 mm without affecting polymerization shrinkage, degree of conversion, or adaptive capacity (14). These materials have gained popularity due to their simplicity in restoring primary and permanent teeth and reducing the risk of contamination thereby extending the restoration's durability (15).

Flowable bulk-fill composite resins offer additional advantages in restorative and pediatric dentistry. Their fluidity and complete adaptation to cavity walls reduce the risk of air entrapment and voids in the restoration (16, 17). Ehlers et al. (18) reported excellent clinical performance of flowable bulk-fill restorative materials on primary molars, with no restorations failing after one year.

Nanohybrid resin composites are composed of conventional particles with nanometric fillers, providing better esthetic finishes. Nasim et al. (19) found that nanofilled composite resins experienced more discoloration than microhybrid resins after immersion in various beverages. However, Maran et al. (20) found no significant differences in stain absorption between

nanohybrid and microhybrid composites. There are a few studies that compared the color stability of various bulk-fill and flowable bulk-fill composites with nanohybrid composites. Therefore, this in vitro study evaluated the discoloration susceptibility of bulk-fill, flowable bulk-fill, and nanohybrid resin composites after exposure to commonly consumed beverages.

Materials and methods

This experimental study was approved by the Ethics Committee of Ardabil University of Medical Sciences, Ardabil, Iran (IR.ARUMS.REC.1398.293).

Sample preparation

Table 1 lists the compositions of different resin composites used in this study. Thirty-six disk-shaped samples (6 mm diameter and 4 mm thickness) were prepared from A2 shade of three resin composites (n=12). The study groups were as follows:

Group 1: The specimens were prepared from a universal nanohybrid composite resin (Filtek Z550; 3M ESPE, St. Paul, MN, USA). The conventional composite was applied in 2 mm increments to ensure effective light penetration.

Group 2: The samples were prepared from a bulk-fill composite resin (Tetric EvoCeram Bulk Fill; Ivoclar-Vivadent, Schaan, Liechtenstein).

Group 3: The specimens were prepared from a flowable bulk-fill composite resin (Filtek Bulk Fill Flowable Restorative; 3M ESPE)

Table 1. Characteristics of the resin composites used in this study

| Commercial name                             | Composition                                                                                                                                             |                              | Composite type                              | Filler amount<br>weight%, volume% | Manufacturer                               |
|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|---------------------------------------------|-----------------------------------|--------------------------------------------|
| Filtek Z550                                 | BisGMA,<br>BisEMA,<br>TEGDMA,<br>zirconia/silica                                                                                                        | UDMA,<br>PEGDMA,<br>Modified | Nanohybrid<br>universal<br>restorative      | 81.8%, 67.8%                      | 3M ESPE,<br>St. Paul, MN, USA              |
| Tetric EvoCeram<br>Bulk Fill                | Dimethacrylates: Bis-GMA, Bis-EMA, UDMA, barium glass, ytterbium trifluoride, mixed oxide and prepolymer additives, catalysts, stabilizers, and pigment |                              | Bulk-fill<br>posterior<br>restorative       | 81%, 61%                          | Ivoclar-Vivadent,<br>Schaan, Liechtenstein |
| Filtek Bulk<br>Fill Flowable<br>Restorative | BisGMA,<br>Procry-lat,<br>Zirconia<br>or<br>ytterbium trifluoride                                                                                       | BisEMA,<br>UDMA,<br>silica,  | Flowable bulk-fill<br>posterior restorative | 76.5%, 58.4%                      | 3M ESPE,<br>St. Paul, MN, USA              |

**Table 2.** Means and standard deviations of  $\Delta E$  values for three different resin composites after immersion in four different beverages

|                           | Distilled water      | Chocolate milk       | Coca-cola            | Orange juice         | P-value |
|---------------------------|----------------------|----------------------|----------------------|----------------------|---------|
| Filtek Z550               | $3.84 \pm 2.50^a$    | $3.96 \pm 0.17^a$    | $7.16 \pm 1.87^a$    | $6.55 \pm 0.76^a$    | 0.072   |
| Tetric EvoCeram Bulk Fill | $7.99 \pm 1.35^{bA}$ | $7.11 \pm 2.20^{bA}$ | $3.62 \pm 0.18^{bB}$ | $7.00 \pm 1.11^{aA}$ | 0.023   |
| Filtek Bulk Fill Flowable | $8.71 \pm 4.83^b$    | $8.79 \pm 2.41^b$    | $9.08 \pm 2.68^a$    | $10.95 \pm 2.20^b$   | 0.081   |
|                           | 0.001                | 0.012                | 0.009                | 0.010                |         |

$P < 0.05$  indicates a statistically significant difference between groups according to one-way ANOVA.

Different lowercase letters indicate statistically significant differences between composite resins at  $P < 0.05$ .

Different uppercase letters indicate statistically significant differences between beverages at  $P < 0.05$ .

The composites were placed in a polyethylene mold. A Mylar strip (SS White Co., Philadelphia, PA, USA) was placed on top of the mold and pressed with a glass slide to achieve a flat surface and remove the excess material. The upper surfaces of all samples were cured for 20 seconds ( $1,000 \text{ mW/cm}^2$ ) using an LED light-curing device (Ivoclar Vivadent AG, Schaan, Liechtenstein). The samples were then incubated at  $37^\circ \text{C}$  in 100% humidity for 24 hours.

#### Color measurement

The  $\text{Lab}^*$  color values of the samples were evaluated at baseline using a VITA Easyshade Compact (VITA Zahnfabrik, Bad Sackingen, Germany) (Figure 1). First, the VITA Easyshade was calibrated with its calibration block as per the manufacturer's instructions. The probe tip was then placed perpendicular to the center of each sample for accurate measurements. During measurements, samples were held in front of a white background to eliminate background light. Measurements were repeated three times, and the mean value was recorded for each specimen.

#### Staining process

The samples from each group were randomly divided into four subgroups for immersion in four different solutions ( $n=3$ ). The staining solutions were distilled water as control, chocolate milk (Kalleh, Iran), cola (Coca-Cola; Khoshgozar, Iran), and orange juice (Sunich, Iran).

The standard storage time for the beverages was set at 120 hours. Assuming an average consumption of 3.2 cups per day and 15 minutes per cup, this storage time simulated beverage consumption over 5 months (21). Discoloration solutions were renewed every 24 hours (22). After 120 hours, specimens were removed with

sterile forceps, rinsed under distilled water for 1 minute, and dried with a tissue before color measurement (4). Color changes ( $\Delta E$ ) between baseline and post-immersion measurements were calculated using the following formula:

$$\Delta E = [(L1^* - L0^*)^2 + (a1^* - a0^*)^2 + (b1^* - b0^*)^2]^{1/2}$$

#### Statistical analysis

Data were analyzed using SPSS version 25 software (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test confirmed the normal distribution of  $\Delta E$  values in all groups. Two-way analysis of variance (ANOVA) was used to study the effects of beverages and composite types on the mean color changes of resin composites. A  $P$ -value less than 0.05 was considered statistically significant.

#### Results

As Table 2 shows, the immersion of all three types of composite resins in different solutions caused color change values after immersion that were beyond the clinically acceptable range ( $\Delta E > 3.3$ ).

Two-way ANOVA indicated that the effect of composite resin type ( $P = 0.006$ ) and the staining solution ( $P < 0.001$ ) was significant on  $\Delta E$  values. However, a significant interaction was found between the two variables ( $P < 0.001$ ). Therefore, further analyses were made using one-way ANOVA followed by a Tukey post hoc test for pairwise comparisons.

According to ANOVA, there were significant differences between the color change values of composite resins in all staining solutions ( $p < 0.05$ ; Table 2). In distilled water and chocolate milk, both bulk-fill composites showed significantly greater color changes than the nanohybrid Filtek Z550 group ( $P < 0.05$ ). In cola, Tetric EvoCeram Bulk Fill showed a significantly lower color change value than the other two groups ( $P < 0.05$ ;

Table 2). In orange juice, Filtek Bulk Fill Flowable composite showed a significantly greater color change than the other two groups ( $P < 0.05$ ; Table 2)

A comparison of different staining solutions in each composite revealed that Tetric EvoCeram Bulk Fill showed significantly different color change values after exposure to various beverages ( $P = 0.023$ ). Pairwise comparisons revealed that the color change values after immersion in cola were significantly lower than in other beverages ( $P < 0.05$ ; Table 2). In the nanohybrid Filtek Z250 and Filtek Bulk Fill Flowable groups, there were no statistically significant differences between the  $\Delta E$  values after immersion in various solutions ( $P = 0.072$  and  $P = 0.081$ , respectively).

## Discussion

This in vitro study assessed the discoloration effects of commonly consumed beverages on one nanohybrid and two bulk-fill composites. The resin matrix plays a crucial role in staining susceptibility (6). All composites in this study contained bisphenol A-glycidyl methacrylate (BisGMA) in their resin matrices, which is the most susceptible agent to discoloration. According to previous studies,  $\Delta E$  values greater than 3.3 indicate a clinically unacceptable color change (23). In this study, all composite resins showed mean  $\Delta E$  values greater than 3.3 after 120 hours of immersion in beverages, which was considered clinically unacceptable (24).

The highest  $\Delta E$  values after 120 hours of immersion in beverages were generally noted in the Filtek Bulk Fill Flowable composite. This finding indicates that composites with lower filler content exhibit more significant discoloration. Previous studies also reported similar findings. De Moraes Sampaio et al. (25) reported lower color changes in high-filler composites compared to those with lower filler content. Tekce et al. (4) noted that packable composites showed lower color changes compared to flowable composites.

In the present study, all materials showed color changes after 120 hours of immersion in water, which is consistent with previous studies (4, 26, 27). Water absorption can cause filler matrix detachment or hydrolytic degradation, leading to discoloration. It can also lead to microcrack formation through plasticization and expansion of the resin components, allowing dye penetration and discoloration (28, 29).

Different beverages caused comparable color changes in the nanohybrid Filtek Z550 and Filtek Bulk Fill Flowable composite resins. In contrast, Tetric EvoCeram Bulk Fill showed lower color changes after immersion in cola than other beverages. Although the acidity of

beverages like cola can affect resin properties by softening the matrix, the absence of yellow colorants in cola may reduce its staining effect (8). Tekçe et al. (4) found that black tea and water caused similar color changes in resin composites after 30 days. Afzali et al. (30) revealed that all staining agents caused discoloration across all composite materials with no significant difference and independent of the solution used. In contrast, Patel et al. (31) reported that the type of beverage influenced color change values more than the type of composite resin.

In this study, both bulk-fill composites showed significantly more significant color changes than the nanohybrid composite. This finding agrees with some previous studies (32, 33) and may be due to the increased thickness of bulk fill composites in restorations. Other studies reported that increased layer thickness was associated with greater color changes (4, 29). In contrast to the outcomes of this study, Bahbishi et al. (34) reported greater color stability in bulk-fill materials than in hybrid composites. This discrepancy is possibly due to using samples with 2 mm thickness in the study of Bahbishi et al. (34), which may reduce color changes.

In the present study, nanohybrid composites like Filtek Z550 demonstrated higher color stability. This result aligns with the findings of Reddy et al. (35), who also found that nanofilled composites had less color change due to smaller particle sizes and smoother surfaces. Nanoparticles fill gaps between large particles, reducing void production and water absorption (8, 29).

This study has limitations, including the lack of full oral environment simulation. In reality, restorative materials are dynamically exposed to saliva when in contact with staining liquids. Other factors like temperature cycling and abrasion were not evaluated in this study. Future studies should include various composite materials and staining substances to validate these findings. Long-term clinical studies are recommended to substantiate the findings of in vitro studies in the clinical setting.

## Conclusions

Within the limitations of the present study, the following statements are concluded:

- 1- Both bulk fill composites (Tetric EvoCeram Bulk Fill and Filtek Bulk Fill Flowable) showed significantly greater color changes than the nanohybrid composite (Filtek Z550) in distilled water and chocolate milk. Filtek Bulk Fill Flowable composite exhibited significantly greater discoloration than other groups after exposure to orange juice.

- 2- Tetric EvoCeram Bulk Fill showed significantly different color change values after exposure to various beverages.
- 3- The color changes of resin composite materials were influenced by the composite structure and the type of beverage, but the effect of composite type was more potent.

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## Conflict of interest

The authors declare no conflict of interest.

## Authors contributions

SH contributed to the conception or design of the work. MA and SH contributed to the data acquisition, analysis, and interpretation. NB helped in data collection and drafted the manuscript. All authors have read and approved the manuscript.

## Ethical approval

The protocol of this *in vitro* study was approved by the ethics committee of Ardabil University of Medical Sciences (IR.ARUMS.REC.1398.293).

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