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# Color stability of a novel self-cure bulk-fill composite compared to light-cure bulk-fill and injectable composite resins

Burak Çarıkçıoğlu[1], İdil Ay Şimşek[1], Volkan Arıkan[2] and Evren Sarıyılmaz[3*]

## Abstract

**Objective** This study aimed to assess the color stability of a novel self-cure bulk-fill composite (automix and capsule forms), in comparison to a light-cure bulk-fill composite and a conventional flowable composite after immersion in common beverages.

**Materials and methods** Four composite resins (Stela Automix, Stela Capsule, Filtek Bulk Fill Flowable, and G-ænial Universal Injectable) were evaluated on 160 disc-shaped specimens. Specimens were randomly assigned to four subgroups ($n=10$) and immersed in tea, coffee, cola, or distilled water (control). Color measurements were performed using a spectrophotometer at baseline, 6 and 12 days, and color changes ($\Delta E_{00}$) were calculated using the CIEDE2000 formula. Statistical analyses were performed using one-way ANOVA with Tukey's post-hoc tests and paired sample T-tests to evaluate time-dependent changes ($p<0.05$).

**Results** All composites showed increased discoloration over time, with coffee causing the most significant color change, followed by cola, while tea had a milder effect. Self-cure bulk-fill composites showed significantly higher $\Delta E_{00}$ values than their light-cure composites. Stela Automix showed the greatest color change after Stela Capsule.

**Conclusion** The results suggest that self-cure bulk-fill composites have lower color stability than light-cure composites. Filler characteristics, particularly particle size and loading, have a greater influence on color stability than resin matrix composition.

**Keywords** Composite resin, Bulk-fill composite, Color stability, Staining, Self-cure composite

*Correspondence:
Evren Sarıyılmaz
evren.sariyilmaz@comu.edu.tr; evrensariyilmaz@yahoo.com
[1]Department of Pediatric Dentistry, School of Dentistry, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye
[2]Department of Pediatric Dentistry, School of Dentistry, Kırıkkale University, Kırıkkale, Türkiye
[3]Department of Endodontics, School of Dentistry, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye

## Introduction

Composites are widely used for direct restorations due to their ability to mimic naturaltooth appearance, ease of handling, and improved mechanical properties. Over the years, advances in filler technology, resin chemistry, and polymerization techniques have significantly improved the performance of these materials, making them the preferred choice for both anterior and posterior restorations [1, 2]. However, challenges such as polymerization shrinkage, marginal adaptation, and color stability remain critical factors affecting the longevity and esthetic success of composite restorations [3].

A significant advancement in composite technology has been the development of light-cure bulk-fill composites. These materials are designed to overcome the limitations of light attenuation, allowing for deeper curing and reduced chair time, especially in posterior restorations [4]. Light-cure bulk-fill composites can be placed in thicker increments (up to 4–5 mm) compared to conventional composites, which typically require 2-mm incremental layering to ensure adequate polymerization [5, 6]. Improved formulations, characterized by higher photoinitiator content, increased translucency, and optimized filler distribution, have been shown to provide similar or superior physicomechanical properties compared to conventional composites [7]. In addition, many studies show that the color stability of bulk-fill composites can be comparable to conventional composites [8].

Dual-cure bulk-fill composites have been developed to combine light activation with a self-cure mechanism for cases where light access is limited in deep cavities, while retaining the rapid curing advantages of light-cure bulk-fill composites [9]. In addition to photocuring via photoinitiators, these materials have the ability to self-cure via chemical reaction of their two-component systems [10]. However, previous studies have shown that if the material is not exposed to sufficient light, the degree of monomer conversion can remain low, which may prevent optimal mechanical properties from being achieved [11, 12].

Self-cure bulk-fill composites were introduced to overcome the depth limitations of light-cure systems and to reduce polymerization shrinkage stress in deep restorations [13, 14]. Unlike light-cure composites, self-cure composites rely entirely on chemical initiators and can polymerize in a single bulk increment without light activation. This makes them particularly useful in clinical situations where light curing is impractical, such as in deep cavities or under opaque restorations [15]. Self-cure composites generally offer an effectively infinite depth of cure and reduced polymerization shrinkage stress, which can help minimize marginal gap formation and postoperative sensitivity [14, 16].

Stela (SDI, Victoria, Australia) is a novel self-cure bulk-fill composite system that has recently been introduced. It consists of a base composite (Automix syringe and capsule forms) used in conjunction with a specialized primer. Stela's resin matrix combines urethane dimethacrylate (UDMA) with glycerol dimethacrylate (GDMA) and it has a high filler content (61–77 wt%, depending on the form). The high cross-linking potential of GDMA in the matrix is intended to provide strong polymer networks, contributing to superior flexural and compressive strength compared to many other self-cure composites. Stela also exhibits low water absorption and solubility, factors that are important for the long-term durability of restorations [13, 14]. These properties make Stela a promising option for clinicians seeking a reliable self-cure bulk-fill composite for challenging restorative scenarios.

The color stability of composite restoratives is a critical factor in clinical success, as discoloration can compromise esthetics and lead to patient dissatisfaction. Discoloration of composites can result from intrinsic factors (resin matrix composition, filler type, degree of conversion) or extrinsic factors (staining from beverages such as coffee, tea, red wine) [17]. Research indicates that the color stability of bulk-fill composites varies depending on their chemical composition and filler content [8, 18]. In particular, dual-cure bulk-fill composites may be more susceptible to intrinsic discoloration over time due to chemical initiators that procedure colored oxidation by-products [18].

Utilizing a primer-initiated curing mechanism, Stela is a self-cure bulk-fill composite offered in capsule and automix forms, distinguishing itself from previous self-cure systems with features like high filler content and a highly crosslinked UDMA-GDMA matrix. However, to date, no published studies have specifically evaluated the color stability of this novel material. Therefore, the purpose of this study was to compare the color stability of different commercial forms of Stela (Stela Automix syringe and Stela Capsule), a light-cure bulk-fill composite, and a flowable composite when immersed in common beverages for different periods of time. The following null hypotheses were tested:

1. Solution exposure and immersion time have no effect on the color stability of the composites.
2. The type of composite does not affect the color stability of the composites.
3. The commercial form of the self-cure bulk-fill composite (Automix syringe and Capsule) does not affect the color stability of this material.

## Materials and methods

A conventional high-viscosity injectable composite (G-ænial Universal Injectable, GC), a light-cure bulk-fill flowable composite (Filtek Bulk Fill Flowable, 3M), and a novel self-cure bulk-fill composite (Stela, SDI) in two commercial forms (Automix syringe and Capsule) were evaluated. Table 1 provides details of the materials used in this study, including composition and manufacturer.

### Specimen preparation

Power analysis ($\alpha = 0.05$, power = 0.95, effect size = 0.7) using G*Power 3.1 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) indicated that at least 10 specimens per group were required for meaningful comparisons [19]. Accordingly, 40 disc-shaped specimens (5 mm diameter × 2 mm thickness) were prepared for each of the four composite groups

**Table 1** Materials used in this study

| Composites | Composition | | | Manufacturer | Lot Number |
|---|---|---|---|---|---|
| | Monomer | Inorganic matrix | Filler (wt%/vol%) | | |
| G-ænial Universal Injectable | Bis-EMA, dimethacrylate co-monomers, UDMA | Silica, barium glass | 69/50 | GC, Tokyo, Japan | 2,308,821 |
| 3 M Filtek Bulk Fill Flowable | Bis-GMA, Bis-EMA, Procrylat, UDMA | Zirconia/silica, YbF3, camphoroquinone | 64.5/42.5 | 3 M ESPE, St. Paul, USA | 10,698,940 |
| Stela Automix | UDMA, GDMA | Fumed silica, barium aluminoborosilicate glass, fluoro aminosilicate glass, YbF3, calcium aluminate, initiators, stabilizers, pigments | 61.2/36.4 | SDI, Victoria, Australia | 1,241,102 |
| Stela Capsule | UDMA, GDMA | Fumed silica, YbF3, fluoroaluminosilicate glass, calcium aluminate, initiators, stabilizers, pigments | 76.8/55.4 | SDI, Victoria, Australia | 1,210,396 |
| Stela Primer | UDMA, 10-MDP, dimethacrylates, MEK, initiators, stabilizers | - | - | SDI, Victoria, Australia | 1,240,275 |

*Abbreviations:10-MDP* 10-methacryloyloxydecyl dihydrogen phosphate, *Bis-GMA* bisphenol-A glycidyl dimethacrylate, *Bis-EMA* bisphenol-A diglycidyl methacrylate ethoxylated, *GDMA* glycerol dimethacrylate, *MEK* methyl ethyl ketone, *UDMA* urethane dimethacrylate, *$YbF_3$* ytterbium trifluoride

(total $N = 160$). Stainless steel molds were used to form the specimens. Each composite was placed in the mold according to the manufacturer's instructions. Mylar strips and glass slides were applied to the mold surfaces and pressed to extrude excess material and achieve a smooth, flat surface. For the two self-cure composite groups (Stela Automix and Stela Capsule), one drop of Stela Primer was applied with a bonding brush, left for 5 s, then air-dried for 3 s before injecting the composite. These self-cure specimens were allowed to self-polymerize (Stela Capsule cured in approximately 4 min; Stela Automix in 4–8 min) [20]. For the light-cure composites (Filtek Bulk Fill Flowable and G-ænial Injectable), the filled molds were light-polymerized for 20 s using an LED curing unit (3M Elipar Freelight II, 1200 mW/cm²). Light intensity was checked after every five specimens to ensure an output of > 1000 mW/cm². After curing, all specimens were removed from the molds. Thickness was checked using electronic caliper (± 0.01 mm accuracy). All specimens were then polished on their top surface using a series of aluminum oxide abrasive discs (Sof-Lex XT, 3M ESPE) at 10,000 rpm in dry conditions. The same operator (İ.A.Ş.) performed all specimen preparation and polishing procedures to ensure consistency.

## Staining procedure and color measurement

A spectrophotometer (VITA Easyshade V, Bad Säckingen, Germany) was used to measure the Commission International de l'Eclairage (CIE) values (L*, a*, b*) for each disc against a neutral gray background under standard illuminant D65. The spectrophotometer was calibrated according to the manufacturer recommendations before every color measurement. All color measurements were conducted by the same operator (İ.A.Ş.). Each specimen was dried, and three measurements were taken from the center of the specimen and then averaged to obtain baseline L*, a*, b* values.

Baseline color measurements were taken after the specimens were immersed in distilled water at 37 °C for 24 h. Subsequently, the specimens were randomly allocated into four equal subgroups ($n = 10$) and immersed in one of the four test solutions: tea, coffee, cola, or distilled water (control). Group allocation was performed using a computer-generated randomization sequence (random.org), and the operator conducting the spectrophotometric measurements was blinded to the group assignments. Prior to immersion in each solution group, specimens were numbered 1 to 10. The tea (Yellow Label, Lipton, Türkiye) solution was prepared by steeping a standard black tea bag in 250 mL of boiling water for 5 min. The coffee (Nescafe Classic, Nestle, Spain) solution was prepared by dissolving 3.6 g of instant coffee in 300 mL of boiling water and stirring for 10 min [21]. The specimens in the cola group were immersed in Coca-Cola (Coca-Cola Company, Türkiye), and the control group was immersed in distilled water. Specimens from each subgroup were stored together in a single sealed container with 20 ml of the relevant solution. This solution was replaced daily to prevent saturation and degradation. All containers were kept in an incubator at 37 °C (EN055, Nuve, Ankara, Türkiye). The total immersion time was 12 days, with interim color measurements taken on days 6 and 12. At each time point, specimens were removed, rinsed under running water for five minutes, and gently dried with filter paper before color measurement according to the previously described protocol.

Color change was quantified using the following CIEDE2000 color difference formula ($\Delta E_{00}$) [22], which accounts for human perceptual differences more accurately than the older CIELab ΔE formula.

$$\triangle E_{00} = \left[ \left( \frac{\triangle L'}{K_L S_L} \right)^2 + \left( \frac{\triangle C'}{K_C S_C} \right)^2 + \left( \frac{\triangle H'}{K_H S_H} \right)^2 + \mathrm{R_T} \left( \frac{\triangle C'}{K_C S_C} \right) \left( \frac{\triangle H'}{K_H S_H} \right) \right]^{\frac{1}{2}}$$

The color difference values were clinically interpreted by comparison with the literature acceptability threshold (A.T. = 1.8 $\Delta E_{00}$), and $\Delta E_{00}$ values above this threshold were considered clinically noticeable [23].

### Statistical analysis

Data were analyzed using SPSS 26.0 statistical software (IBM, Armonk, NY, USA). Shapiro-Wilk tests were used to analyze the normality of the data. The $\Delta E_{00}$ values for the composites immersed in different solutions at days 6 and 12 were compared by one-way ANOVA for each time point separately and significant differences were evaluated by pairwise comparisons with Tukey HSD test. Changes in $\Delta E_{00}$ values over time within the same solution were analyzed using paired sample T-tests. A *p* value of < 0.05 was considered statistically significant.

**Table 2** Mean $\Delta E_{00}$ values ± standard deviations of the composites after 6 and 12 days of immersion

| | Tea | Coffee | Cola | Water | *p* value |
|---|---|---|---|---|---|
| $\Delta E_{00}$ 6-day | | | | | |
| G-ænial Injectable | 1.1 ± 0.6 b A | 1.5 ± 1.4 c A | 0.7 ± 0.5 b A | 0.7 ± 0.2 c A | 0.094 |
| 3 M Filtek Flowable | 1.4 ± 0.7 b BC | *2.7 ± 0.5 c A | *1.9 ± 0.8 b B | 0.8 ± 0.3 bc C | **< 0.001** |
| Stela Automix | 1.4 ± 0.6 b C | *5.7 ± 1.6 b A | *2.9 ± 0.8 b B | 1.2 ± 0.4 b C | **< 0.001** |
| Stela Capsule | *3.2 ± 1.5 a B | *9.9 ± 3.5 a A | *9.2 ± 6.8 a A | 1.3 ± 0.7 a B | **< 0.001** |
| *p* value | **< 0.001** | **< 0.001** | **< 0.001** | **< 0.001** | |
| $\Delta E_{00}$ 12-day | | | | | |
| G-ænial Injectable | 1.1 ± 0.8 b B | *2.2 ± 1.4 c A | 1.1 ± 0.5 c B | 1.1 ± 0.6 a B | **0.011** |
| 3 M Filtek Flowable | *3.5 ± 1 ab A | *3.7 ± 0.7 bc A | *3 ± 1 bc A | 1.2 ± 0.4 a B | **<0.001** |
| Stela Automix | *4.1 ± 1.1 a B | *6.4 ± 1.3 b A | *5.2 ± 1.4 b AB | 1.5 ± 0.6 a C | **<0.001** |
| Stela Capsule | *5.2 ± 3.9 a B | *13.6 ± 5.8 a A | *11.4 ± 5 a A | 1.5 ± 0.6 a B | **< 0.001** |
| *p* value | **0.001** | **< 0.001** | **< 0.001** | 0.055 | |

Lowercase letters within columns indicate significant differences between composites in the same solution; uppercase letters within rows indicate differences between solutions for the same composite ($p < 0.05$)

*$\Delta E_{00}$ >A.T. (1.8)

## Results

After 6 days and 12 days of immersion, all specimens showed color changes ($\Delta E_{00}$) in the solutions. The mean $\Delta E_{00}$ values and standard deviations are shown in Table 2.

After 6 days of immersion, significant differences among solutions were observed for all composite groups except for G-ænial Injectable (F = 2.296, $p = 0.094$). Statistically significant effects of solutions were found in 3 M Filtek Flowable (F = 8.647, $p < 0.001$), Stela Automix (F = 31.389, $p < 0.001$), and Stela Capsule (F = 11.297, $p < 0.001$) groups. When evaluating solutions, all tested beverages, tea (F = 8.930, $p < 0.001$), coffee (F = 31.190, $p < 0.001$), cola (F = 12.146, $p < 0.001$), and water (F = 6.882, $p < 0.001$) had significant effects on the composites. Following 12 days of immersion, significant differences among solutions were observed in all composite groups, including G-ænial Injectable (F = 4.251, $p = 0.011$), 3 M Filtek Flowable (F = 19.423, $p < 0.001$), Stela Automix (F = 38.213, $p < 0.001$), and Stela Capsule (F = 16.284, $p < 0.001$). Regarding solutions, tea (F = 6.624, $p = 0.001$), coffee (F = 22.756, $p < 0.001$), and cola (F = 33.383, $p < 0.001$) caused statistically significant differences among composites, while water (F = 11.179, $p = 0.055$) did not have a significant effect.

At 6 days, the $\Delta E_{00}$ value was below the A.T. in all composite groups immersed in water (control group). In coffee and cola, $\Delta E_{00}$ was above the A.T. for all composites except G-ænial Injectable. Except for G-ænial Injectable ($p = 0.094$), all composite groups showed a statistically significant difference in $\Delta E_{00}$ values between the different solutions ($p < 0.001$), with the highest $\Delta E_{00}$ value observed in the coffee ($p < 0.05$). Statistical differences were also found between different composites in the same solutions ($p < 0.001$). Stela Capsule showed the greatest color change in all solutions ($p < 0.05$), while G-ænial Injectable and Filtek Bulk Fill Flowable showed similar and least color change in all solutions ($p > 0.05$). Stela Capsule also showed a similar color change in coffee and cola ($p = 0.986$).

At 12 days, $\Delta E_{00}$ was below A.T. for all water-immersed composite groups. In all solutions, $\Delta E_{00}$ was above A.T. for all composites except G-ænial Injectable. Statistical analysis showed significant differences in $\Delta E_{00}$ between solutions for each composite ($p < 0.05$). G-ænial Injectable was found to be the most color stable composite. While its color change was above the A.T. in coffee, it was the only composite that remained below A.T. in tea and cola, showing a similar color change in both solutions ($p = 0.999$). Filtek Bulk Fill Flowable showed significantly more discoloration than water in all staining solutions ($p < 0.05$). Statistically significant differences were found between the different composites in all solutions except water ($p = 0.055$). Stela Capsule and Stela Automix showed the greatest color change in coffee and

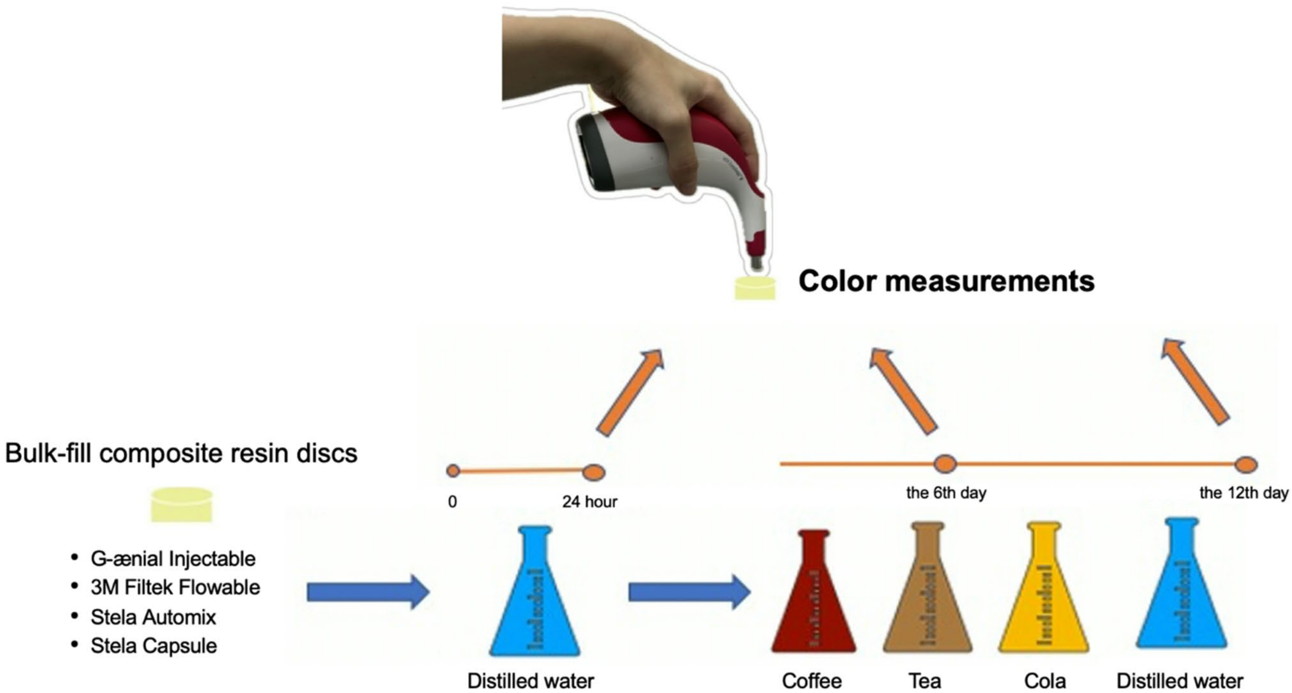


**Fig. 1** Diagram of Composite Specimen Immersion and Spectrophotometric Evaluation

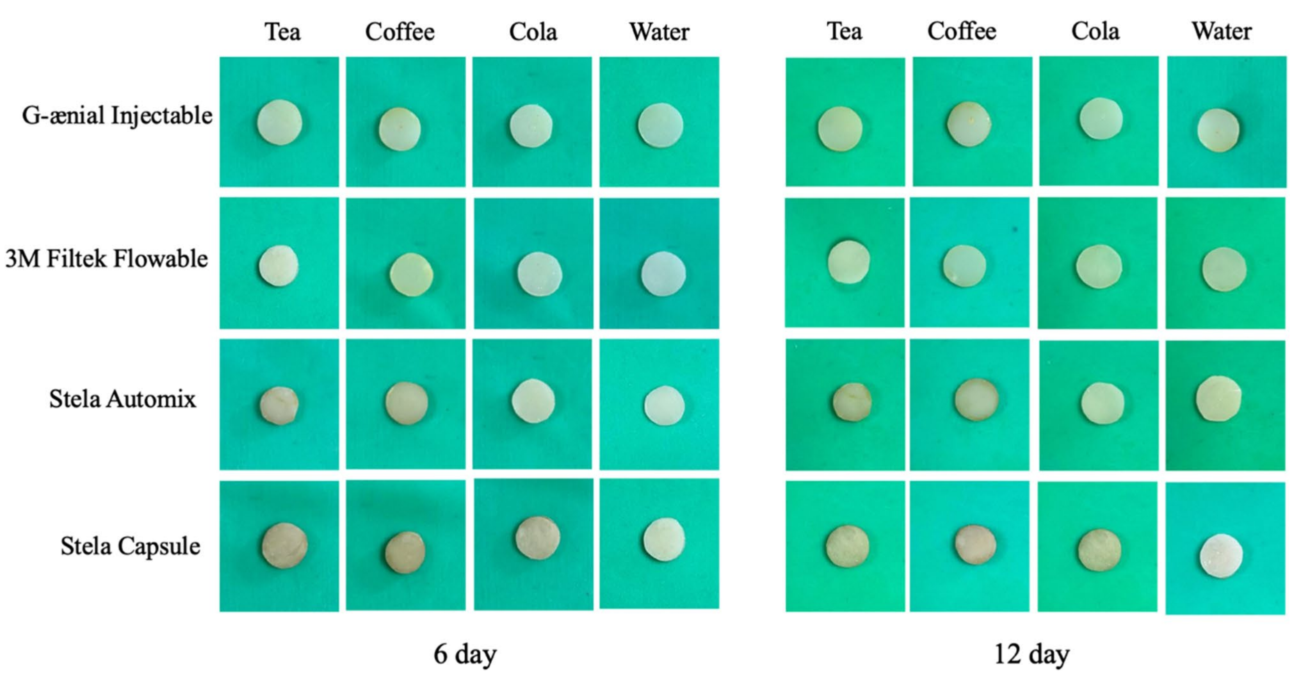


**Fig. 2** Images of Color Changes in Composites After 6 and 12 Days of Immersion

cola ($p < 0.05$) while G-ænial Injectable and Filtek Bulk Fill Flowable showed the least color change of all staining solutions ($p < 0.05$) (Figs. 1 and 2).

At 6 and 12 days, the time dependent color changes of all specimens in the different solutions are shown in Fig. 3. All composite groups tended to show greater discoloration with longer immersion times. In terms of color change over time, Filtek Bulk Fill Flowable and Stela Automix showed a statistically significant increase in all solutions ($p < 0.05$); G-ænial Injectable showed a significant increase in coffee and water; Stela Capsule showed a significant increase in tea.

The changes in ΔL, Δa and Δb values of the composite groups immersed in the different solutions are shown

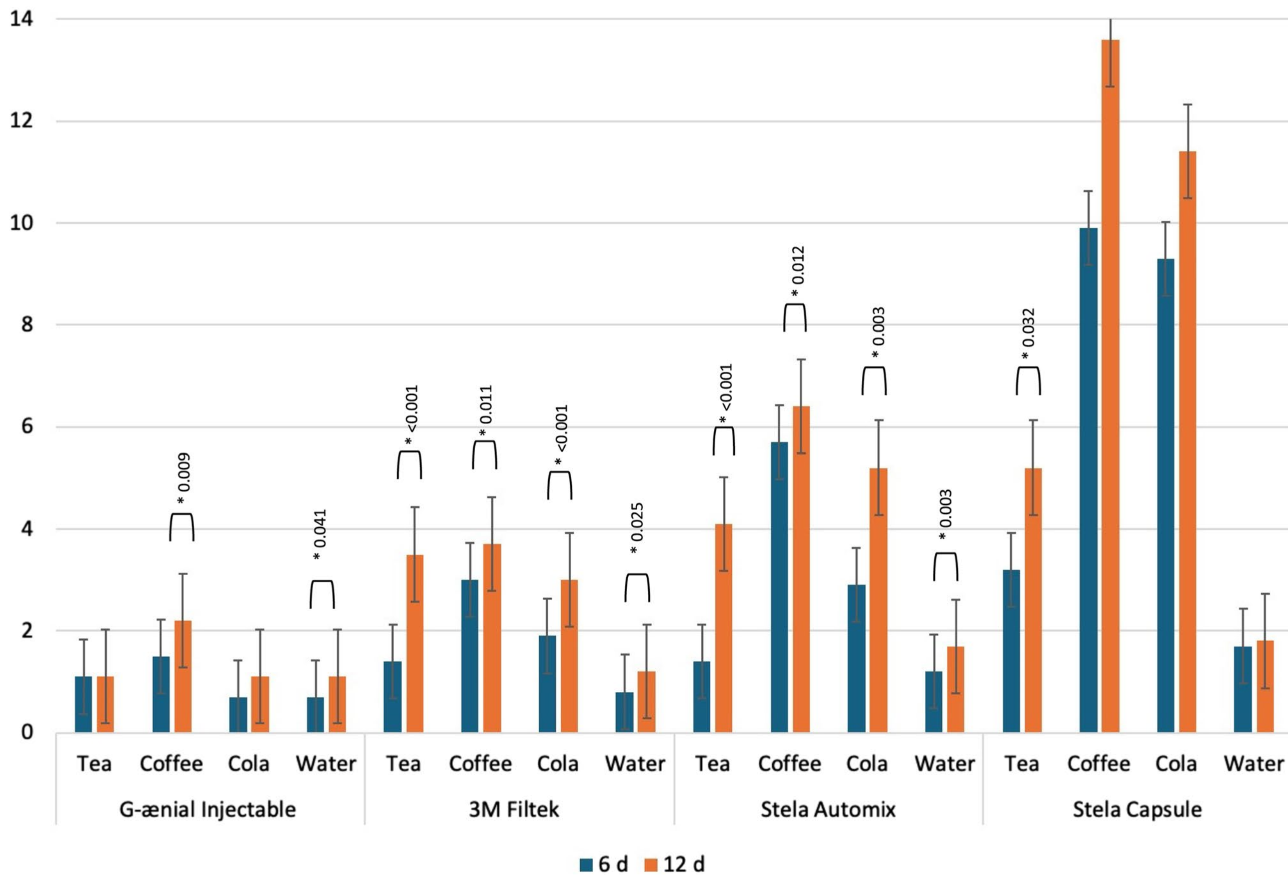


**Fig. 3** Time-dependent changes in $\Delta E_{00}$ values of the four composite groups after 6 and 12 days immersion in different solutions. * idicates statistically significant difference ($p < 0.05$)

in Figs. 4, 5 and 6. In general, no significant color change was observed in the Filtek Bulk Fill Flowable and G-ænial Injectable composites, while a decrease in ΔL values and an increase in Δa and Δb values were observed in the Stela self-cure bulk-fill composites. The changes in hue on the red-green axis (Δa) indicate that tea produces a redder color than the other solutions. It was also observed that the Stela Capsule showed a shift towards the red hue (+a) in all solutions.

## Discussion

The color stability of composites is a key factor in their clinical performance and patient satisfaction. In this study, we compared the color stability of a novel self-cure bulk-fill composite (Stela) to a light-cure bulk-fill and a conventional composite when exposed to common staining solitions. The results showed that both type of solution and the immersion time significantly affect color stability leading to recetion of the null hypothesis.

Instrumental color measurement was performed using spectrophotometry and the CIEDE2000 system which offers objective and sensitive detection of small color differences. CIEDE2000 is considered more accurate and reliable than the older CIELab system for evaluating color changes in dental materials [24, 25]. In this study, color changes ($\Delta E_{00}$) were calculated relative to baseline and a threshold of 1.8 was used to determine cilinical perceptibility [23]. Although all composites immersed in water remained below the A.T. even after 12 days, indicating inherent color stability, the statistically significant differences observed at day 6 diminished by day 12, yet the *p*-value ($p = 0.055$) still approached the significance threshold, suggesting a potential trend that warrants cautious interpretation. However, immersion in coffee and cola caused $\Delta E_{00}$ values exceed 1.8 for the bulk-fill composites as early as day 6. Tea had more moderate staining effect, generally producing clinically perceptible changes only after 12 days. Immersion durations were based on data from Ertaş et al. [26], who reported an average daily coffee consumption of 3.2 cups, each lasting around 15 min. Accordingly, 6 days of immersion simulated approximately 6 months of clinical exposure, and 12 days represented about 1 year. This approach allowed the long-term effects of staining beverages to be evaluated in a standardized in vitro setting.

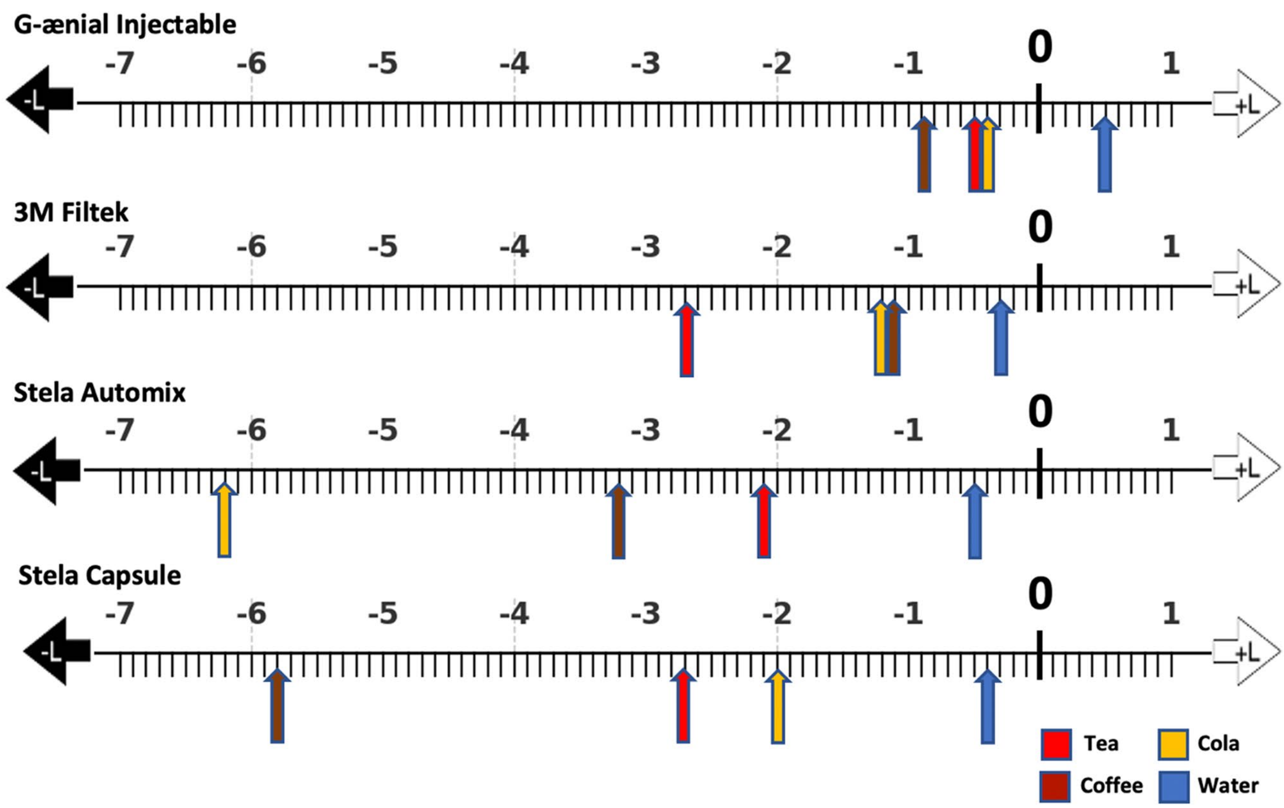


**Fig. 4** Changes in lightness (ΔL) of the composites after 6 and 12 days of immersion

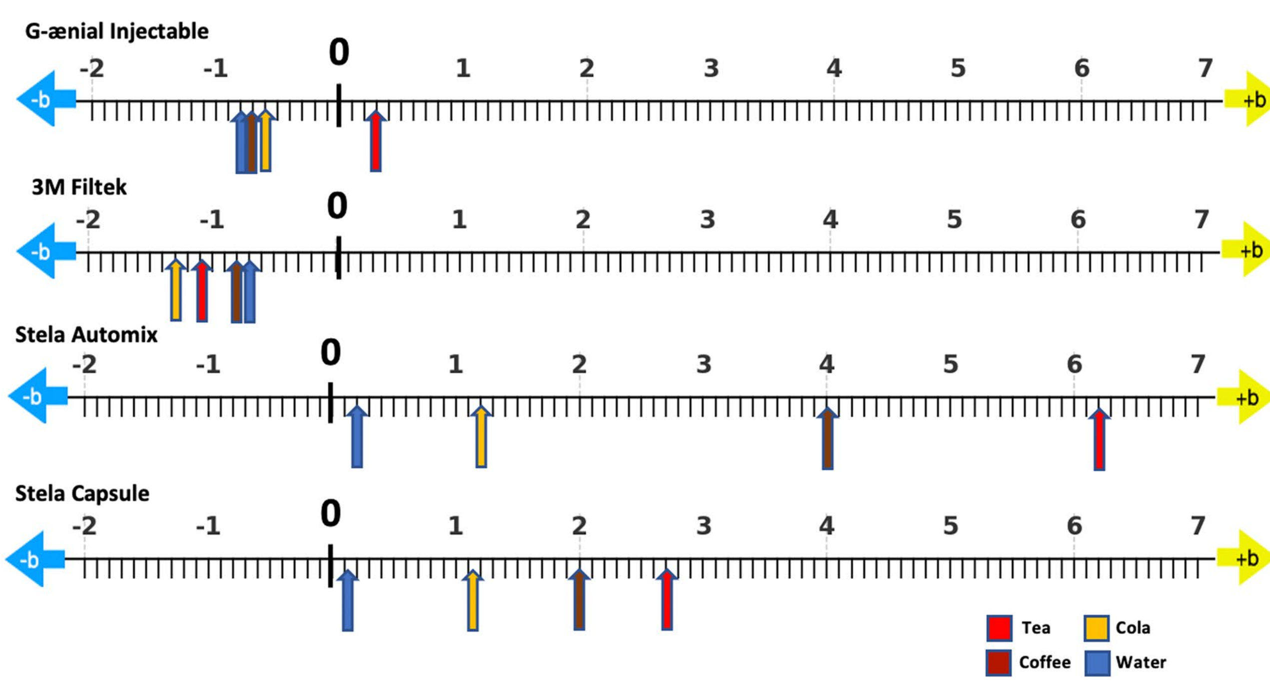


**Fig. 5** Changes in hue across the yellow-blue axis (Δb) of the composites after 6 and 12 days of immersion

Coffee, tea, and cola are widely consumed and known for causing extrinsic staining. The staining potential of each beverage is linked to its chemical characteristics. Coffee contains low-polarity polyphenolic pigments that can penetrate the organic matrix of composites, causing deep discoloration. Tea contains more polar yellow tannins, which generally cause only superficial staining that can be removed by brushing [27]. Cola lacks strong

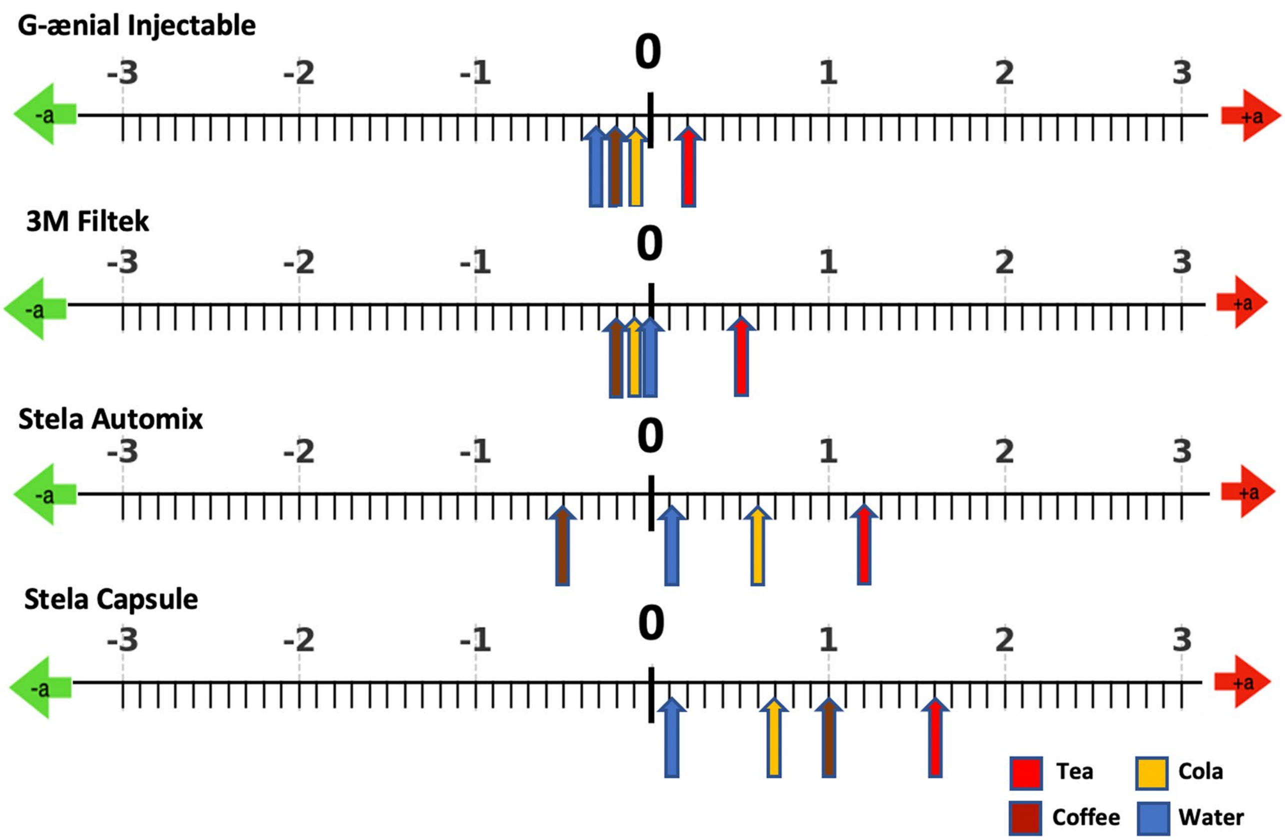


**Fig. 6** Changes in hue across the red-green axis (Δa) of the composites after 6 and 12 days of immersion

pigments but contains phosphoric and citric acids, which may erode the surface and increase roughness, facilitating stain accumulation [26, 28]. In this study, coffee caused the highest $\Delta E_{00}$ values across all composites, followed by cola and then tea, consistent with prior reports [8, 29].

A notable finding was the difference in color stability among the composite types. The self-cure bulk-fill composites (Stela Automix and Capsule) showed significantly more discoloration than the light-cure composites (Filtek Bulk Fill Flowable and G-ænial Injectable). For example, on day 12 in coffee, Stela Capsule reached a $\Delta E_{00}$ of 13.6, while G-ænial remained at 2.2. Stela Automix had the second highest values across all solutions. G-ænial Injectable, a highly filled conventional composite, had the least color change, followed by Filtek Bulk Fill Flowable. The superior stability of these light-cure composites may be attributed to their resin matrix and photoinitiator, which include Bis-EMA and conventional monomers. In contrast, self-cure systems like Stela may produce more by-products or contain reisdual accelerators that contribute intrinsic discoloration, as also observed in some dual-cure systems [10, 14].

Although Stela Automix and Capsule share similar chemistry, differences in filler content and size may explain the slight variations in their staining behavior. Stela Capsule contains 76.8 wt% filler, like with larger particles, whereas Stela Automix has 61.2 wt% and smaller particles. Larger particles can increase surface roughness and promote staining by creating microvoids that trap pigments [28]. Our findings support an inverse relationship between filler particle size and color stability. Discoloration increased in the following order: G-ænial Injectable (nanofilled), Filtek Bulk Fill Flowable (microhybrid), Stela Automix, and Stela Capsule. This supports rejection of the second and third null hypotheses regarding the influence of composite type and commercial form.

Another possible factor is the Stela Primer, which contains 10-MDP and other monomers to enhance bonding and curing. Residual primer or its reaction products might affect the polymer matrix or increase water absorption, potentially impacting shade stability. Although the primer was applied uniformly, no direct data exist on how it influences discoloration. Further research is warranted to clarify this interaction, but clinicians should apply the primer carefully and avoid excess.

Surface finish is another important variable influencing staining. Rougher surfaces tend to absorb more pigment [30]. In this study, all specimens were polished using a standardized aluminum oxide disc, known for producing smooth finishes [31]. This minimized surface roughness as a confounding factor, allowing intrinsic material differences to be the primary cause of discoloration. It is important to note that in clinical conditions, surface wear or inadequate polishing can still lead to increased roughness and staining. Therefore, proper finishing and polishing techniques are essential for long-term esthetic outcomes [30].

Shade selection may also influence color stability. Darker or more opaque shades may better mask discoloration, while universal shades may show more perceptible changes [32]. In this study, universal-shade Stela and A2-shade Filtek and G-ænial Injectable composites were tested. In general, composites in universal shade composites exhibited greater color changes on staining than conventional multi-shade composites [33]. Consistent with this, Stela showed less color stability compared to the G-ænial Injectable and Filtek Bulk Fill Flowable. This suggests that the absence of certain pigments in the universal shades may make them more susceptible to discoloration, supporting the idea that shade formulation affets stain resistance. Clinicians should be aware that while universal shade composites offer esthetic versatility, they should be evaluated for color stability, especially in patients with a high consumption of staining foods or beverages.

This study was conducted under in vitro conditions, which inherently limit its clinical relevance. The use of flat composite disks does not fully replicate the anatomy and function of intraoral restorations. Although the 6- and 12-day immersion periods were accelerated compared to typical oral exposure, they offer useful insight into staining susceptibility. This study included only three staining solutions, whereas other agents like red wine, curry, and nicotine, which differ in pigment content, pH, and erosive potential, may also impact composite color stability.

Moreover, oral factors factors such as temperature changes, enzymatic activity, salivary pellicle formation, toothbrush abrasion, and pH changes were not simulated, all of which may influence stain retention or removal.

Primer application on Stela composites was standardized, but its thickness was not measured, potentially causing minor variability. Likewise, surface roughness after polishing was not quantitatively assessed; although a uniform polishing protocol was followed, slight differences may have occurred. Future studies could include profilometric or SEM analyses to evaluate surface characteristics more precisely.

Additionally, restorations may roughen over timedue to wear, affecting long-term color stability. Since color was assessed over a relatively short period, extended aging studies are necessary to reveal long-term discoloration trends, including intrinsic yellowing.

Given the increased discoloration observed in self-cure bulk-fill composites, their use in highly esthetic areas should be approached with caution. These materials may be better suited for posterior restorations where esthetic demands are lower. Regular maintenance and dietary guidance, along with effective finishing and polishing protocols, may help preserve color stability by reducing surface roughness and pigment adherence.

## Conclusion

Within the limitations of this in vitro study, the type of composite, the immersion time, and the immersion solution all had significant effects on color stability. After 6 and 12 days of immersion, the highest color changes ($\Delta E_{00}$) were observed in specimens immersed in coffee, while the lowest changes were observed in those immersed in water. Among the materials tested, the light-cure composites containing Bis-GMA/Bis-EMA in their resin matrix showed the greatest color stability. In contrast, the self-cure bulk-fill composites, which containing UDMA/GDMA and using chemical curing showed more pronounced color changes. Notably, despite expectations of improved performance, the Stela composites exhibited lower color stability in staining solutions compared to the conventional materials. These results suggest that filler characteristics, including particle size and loading, may have a greater influence on color stability than resin matrix composition alone, as composites with larger filler particles, such as Stela, tended to exhibit greater discoloration. In addition, the different commercial forms of the self-cure bulk-fill composite showed some variation in performance, likely due to formulation differences, suggesting that product form may influence results.

#### Abbreviations

| | |
|---|---|
| UDMA | Urethane dimethacrylate |
| GDMA | Glycerol dimethacrylate |
| LED | Light-emitting diode |
| mW/cm$^2$ | Milliwatt per square centimeter |
| mm | Millimeter |
| rpm | Revolutions per minute |
| °C | Degree Celsius |
| mL | Milliliter |
| g | Gram |
| A.T. | Acceptability threshold |
| wt% | Percentage by weight |
| MDP | 10-methacryloyloxydecyl dihydrogen phosphate |
| SEM | Scanning electron microscope |
| Bis-GMA | Bisphenol-A glycidyl dimethacrylate |
| Bis-EMA | Bisphenol-A diglycidyl methacrylate ethoxylated |

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Not applicable.

#### Authors' contributions
B.Ç. contributed to the study design, experimental phase, data collection and analysis, and manuscript writing; İ.A.Ş. contributed to the experimental phase and data collection; V.A. and E.S. contributed to manuscript writing and review; and all authors read and approved the final manuscript.

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**Data availability**
The datasets generated during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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