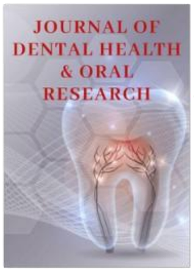


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# Shade Matching and Color Stability of Chameleon Effect Composites in Class V Restorations: An *In-Vitro* Colorimetric Study after Cola Immersion

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## Abstract

In dentistry, restorations must fulfill both functional requirements and visual harmony. Composite resins have become the material of choice for reproducing the natural shape and color of teeth. The aim of this study was to evaluate the shade matching and color stability of two chameleon effect composite resins: Omnichroma® (Tokuyama Dental, Tokyo, Japan) and Charisma Diamond ONE (Kulzer, Hanau, Germany) in Class V restorations after exposure to an acidic cola solution.

Ten freshly extracted molars were selected, each prepared with two standardized Class V cavities (3 × 3 × 2 mm) on the buccal surface using a round bur (FG 001/014) and standardized with a resin pattern key (GC, Tokyo, Japan) and periodontal probe (PCP-UNC 15, Hu-Friedy, Chicago, IL, USA). The teeth were randomly divided into two groups according to the composite used. Restorations were placed following etching with 37% phosphoric acid and application of the corresponding adhesive system (Palfique Bond (Tokuyama Dental, Tokyo, Japan) or Gluma Bond (Heraeus Kulzer, GmbH, Hanau, Germany), followed by LED light curing. All restorations were polished with Diacomp Plus Twist® (EVE Technik, Pforzheim, Germany). Shade matching was assessed using the Optishade® colorimeter (Smile Line SA, Saint-Imier, Switzerland) before (T0) and after (T1) immersion in a cola solution for one week at 37 °C. L, a*, b* values and color differences (ΔE) were recorded, with a perceptibility threshold of 3.3. Data were analyzed with IBM SPSS Statistics version 22. A p-value $\leq 0.05$ was considered significant.

No significant difference in ΔE values was observed between the composites and tooth structure, either before or after immersion ($p > 0.05$). Similarly, no significant difference was found between the two composites ($p > 0.05$).

These findings suggest that both chameleon effect composites demonstrated satisfactory shade compatibility and color stability even after exposure to a coloring solution. However, further in vivo studies are needed to assess their long-term performance in clinical settings.

**Keywords:** Aging; Color; Coloring Agents; Composite Resins; Esthetics

## Introduction

Esthetics play a crucial role in dentistry, particularly in restorative treatments. Despite the historical use of various filling materials, composite resins have demonstrated superior performance in both functional and esthetic domains, which explains their widespread use in contemporary restorations [1,2]. When first introduced, composites were available in only four shades.

They have now expanded to include up to 32 shades, enabling more precise color matching with natural dentition [3]. Despite this advancement, selecting the correct shade remains a difficult task [4]. Factors like lighting conditions, composite brand and the clinician's experience can all influence shade selection [5]. To simplify this process, single-shade composites, also called chameleon-effect composites, have been developed. These materials can adapt to the surrounding tooth color, mimicking natural enamel and dentin. This means one composite shade can match a variety of tooth colors [6]. However, the performance of single-shade composites depends on several variables [2,7]. One key factor is the size of the restoration, which can negatively impact the material's blending ability [2,7]. Additional factors influencing shade matching include the material's translucency and the color discrepancy between the restoration and adjacent teeth [7,8]. Nevertheless, the dental industry continues to advance, with numerous brands introducing single-shade composites [7,8]. These innovations are designed to improve efficiency and optimize esthetic outcomes in restorative dentistry [6].

For example, Omnichroma® (Tokuyama Dental, Tokyo, Japan) is a nanofilled universal composite widely used in restorative procedures [2]. It operates according to "smart chromatic technology," which reflects on the optical properties of the composite [9,10]. It has a great ability to adjust to the tooth and adjacent shades by reducing the use of multiple types of composite. This composite does not contain pigments and its optical properties rely on structural color [2,9]. Due to its properties, this type can modulate the various wavelengths to obtain a specific wavelength for the colorimetric space of the tooth [9,10]. This composite is composed of a mixture of Silicon Dioxide ($SiO_2$) and Zirconium Dioxide ($ZrO_2$) fillers [9]. These fillers are distributed in a way that facilitates the transmission of light through the material and the reflection of the color of the cavity, which can enhance the chameleon effect. Furthermore, the structural color (ranging from red to yellow to match neighboring teeth) is achieved through the uniform shape and size of these fillers: spherical particles of 260 nm [11]. Also, after polymerization, the refractive index of the monomers increases from 1.47 to 1.52, confirming an increase in translucency [11].

Another example, Charisma Diamond ONE introduced by Kulzer Dental (Kulzer, Hanau, Germany) [12] is also a nanohybrid universal composite, corresponding to the 16 classic VITA shades [12]. It consists of a unique Tricyclodecane (TCD) matrix and nano-hybrid fillers offering improved esthetics, durability and handling [12]. This composite is based on the concept of "light adaptation", meaning that the restoration acquires its shade by absorbing the wavelengths reflected from the surrounding tooth structure [9].

Therefore, the aim of this study was to evaluate the performance of two single-shade composites in Class V restorations, specifically comparing Omnichroma® and Charisma Diamond ONE. The study assessed their shade stability following continuous exposure to a cola beverage over one week, providing guidance for material selection. The null hypothesis was that the single-shade composites included in this study would not exhibit identical esthetic characteristics and would not match the original tooth color before and after immersion in a carbonated cola solution for one week.

## Materials and Methods

*Sample Preparation*

This study was approved by the Ethics Committee at Saint-Joseph University of Beirut, Lebanon (Tfemd/2024/44). Two composites with chameleon-effect were used: Omnichroma® (Tokuyama Dental, Japan) and Charisma Diamond ONE (Kulzer, Hanau, Germany) (Table 1).

| Composites | Type | Fabricant | Composition |
|---|---|---|---|
| Omnichroma® | Nanofilled | Tokuyama, Tokyo, Japan | Matrix: triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA), butylhydroxytoluene and UV absorber, Mequinol.<br>Uniformely sized spherical charge system: silicon dioxide ($SiO_2$), zirconium dioxide ($ZrO_2$) (68% by volume; 79% by weight; 0.2–0.4 μm) |

| | | | |
|---|---|---|---|
| Charisma Diamond One | Nanohybrid | Kulzer, Hanau, Germany | Organic matrix of advanced tricyclodecane and UDMA, bisphenol-free -A free (containing 64% by volume filler, 5 nm–20 μm), barium aluminum fluoride glass, highly dispersed nanoparticles and fluorescent, metal oxide and organic pigments. |
| Gluma Bond | Universal Bonding | Kulzer, Hanau, Germany | 4-META acid, monomer methacrylate, acetone,10-Methacryloyloxydecyl Dihydrogen Phosphate (MDP), water. |
| Palfique bond | Universal Bonding | Tokuyama, Tokyo, Japan | Phosphoric Monomer Acid, bisphenol A-glycidyl methacrylate (Bis-GMA), triethylene glycol dimethacrylate (TEGDMA), 2-hydroxyethyl methacrylate (HEMA), Camphorquinone, Alcohol and Purified Water. |

**Table 1:** Composites and bonding agents: types, manufacturers and compositions.

Ten freshly extracted molars, each with two Class V cavities, were included based on a statistical power analysis. The teeth were randomly assigned to two groups: one restored with Omnichroma® (Tokuyama Dental, Tokyo, Japan) and the other with Charisma Diamond ONE (Kulzer, Hanau, Germany). Shade matching in both groups was evaluated using Optishade (Smile Line SA, Saint-Imier, Switzerland) before and after immersion in a cola solution. All teeth were washed and stored in distilled water at 37°C for one week.

On the buccal surface of each extracted molar, two standardized Class V cavities (3 × 3 × 2 mm) were prepared by the same operator to minimize bias (Fig. 1). The cavities were created using a small diamond round bur (FG 001/014) under water irrigation for 5 s and their dimensions were verified with a periodontal probe (PCP-UNC 15, Hu-Friedy, Chicago, IL, USA). To ensure standardization, a resin template (GC, Tokyo, Japan) fabricated from a control cavity was inserted into all preparations.

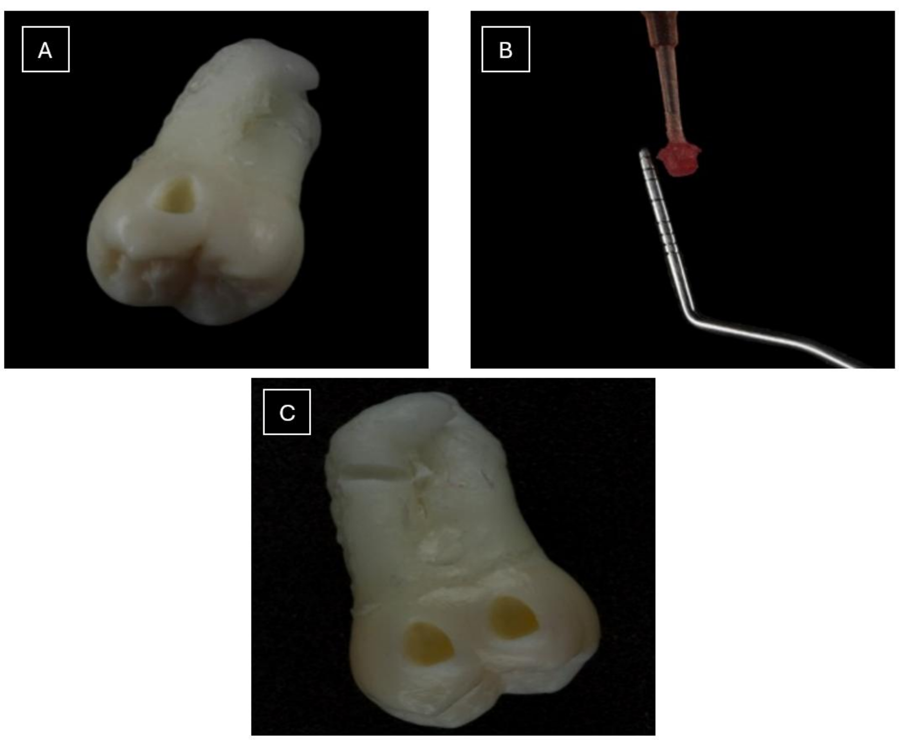


**Figure 1: (**A) Class V cavity prepared according to the selecting standards (3x3x2mm) / (B) A resin pattern key used to standardize the cavities / (C) Two Class V cavities prepared according to the same standards using the resin pattern key.

On the palatal/lingual surfaces, trimming was performed using a plaster trimmer to achieve a smooth, flat surface. The roots of the teeth were sectioned with a diamond disk (Dfs-Diamon-Germany). After cavity preparation, the same obturation technique was applied on all teeth (Fig. 2).

**Figure 2:** The filling of the cavities with Omnichroma® on the left and Charisma Diamond One on the right.

Charm-Etch Phosphoric acid (37%) (37(LV) DENTKIST, Inc, 1412004 Korea) was applied to enamel for 30 s and to dentin for 15 s. Then the phosphoric acid was rinsed for 30 s with distilled water. In Group 1, Palfique Bond (Tokuyama, Tokyo, Japan) was applied, while Gluma Bond (Kulzer, Hanau, Germany) was used in Group 2, both using a microbrush followed by 5 s of air blowing. Polymerization was done with a DTE Lux VI® LED light (Woodpecker, China) in progressive mode, reaching 1600 mW/cm² over 20 s in order to pass from the pre-gel to the post-gel phase. Final polishing was performed with Diacomp Plus Twist® discs (Eve, Pforzheim, Germany). Color assessment was performed using the Optishade (Smile Line SA, Saint-Imier, Switzerland) device (Fig. 3), a digital colorimeter designed to measure the color and appearance of teeth and restorations. It operates exclusively with the "OptiShade®" app, available on the iPhone or iPad App Store.

**Figure 3:** Optishade Smile Line, Switzerland.

To record the results, specific points were chosen: one at the center of each restoration and another on the tooth surface between the two cavities (Fig. 4). The device measures color parameters using the CIELAB system, providing L*, a* and b* values, where L* indicates lightness, a* represents the red-green chromatic axis and b* corresponds to the yellow-blue axis. The device also calculates the color difference (ΔE) between the two points. Measurements were repeated twice for each tooth, with data displayed by the OptiShade® system.

$$\Delta E_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

The performance of each composite was assessed by calculating ΔE between the tooth and the composites and comparing it to a perceptibility threshold of ΔE = 3.3.

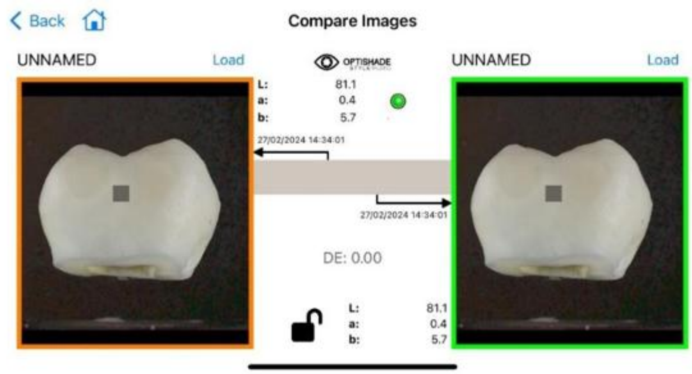


**Figure 4:** Color evaluation using the OPTISHADE® by calculating ΔE.

*Color Change Assessment*

To assess color variations, samples from each group were immersed in a carbonated cola solution (Coca-Cola) and stored in an incubator at 37°C for one week. The solution was replaced after three days to prevent bacterial or yeast contamination. After seven days, the samples were removed, rinsed with distilled water for 5 min and air-dried. A second color measurement was then performed using Optishade®. Color variations were determined by comparing the initial measurements with those taken after immersion, based on L, a and b* values and ΔE calculations. Shade measurements were recorded at two time points: T0, immediately after filling the cavities on the same tooth with both composites before immersion and T1, after one week of immersion in the cola solution

*Statistical Analysis*

Statistical analysis was performed using IBM SPSS Statistics version 22. Descriptive statistics were calculated and data normality determined the appropriate tests. The Wilcoxon Signed Rank Test was used for Omnichroma® before immersion and the One-Sample T Test for Omnichroma® after immersion and Charisma Diamond ONE Shade group. Comparisons between composites before immersion were made with the Mann–Whitney U Test and after immersion with the Independent Samples T Test. Intragroup comparisons used either the Wilcoxon Signed Rank Test or Paired Samples T Test. A p-value ≤ 0.05 was considered significant.

## Results

This study included 20 Class V cavities on 10 teeth, divided into two groups: one restored with Omnichroma® and the other with Charisma Diamond ONE. The grouped bar chart shows that immersion in the cola solution slightly increased the ΔE values for both composites, with Charisma Diamond ONE exhibiting a slightly higher change (Fig. 5, Table 2).

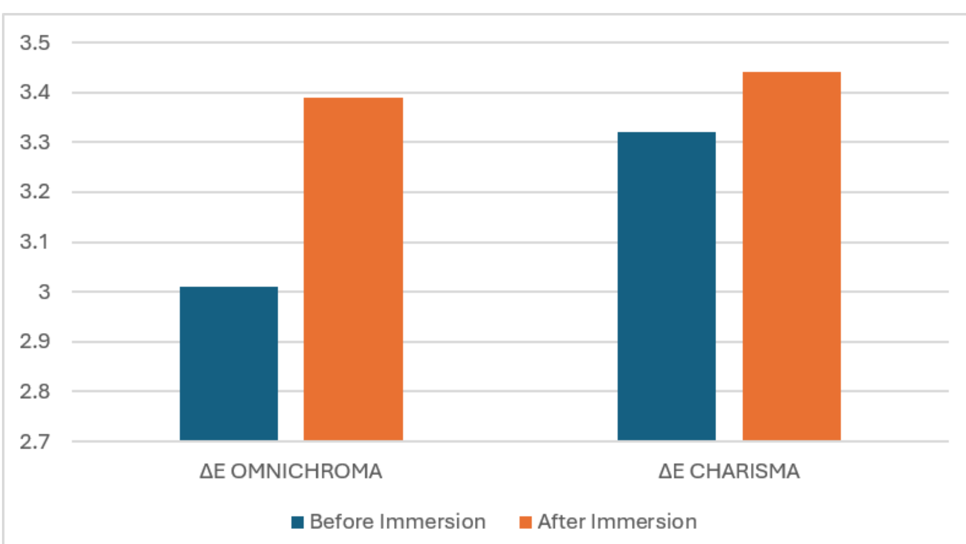


**Figure 5:** Histogram showing the mean ΔE values of Omnichroma® and Charisma composites, before and after immersion.

| Normality Test | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Composite | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| **Before immersion** | Charisma | .165 | 10 | .200 | .948 | 10 | .639 |
| | Omnichroma® | .276 | 10 | .029 | .818 | 10 | .024 |
| **After immersion** | Charisma | .237 | 10 | .118 | .894 | 10 | .190 |
| | Omnichroma® | .181 | 10 | .200 | .905 | 10 | .248 |

**Table 2:** Values of the normality test.

Based on the Shapiro–Wilk test, normality was observed in all groups except for the Omnichroma® reference group, which showed a non-normal distribution (Table 2). To compare values before and after immersion, a one-sample one-tailed t-test was used for groups with normally distributed data, assessing whether the mean ΔE after immersion significantly differed from the perceptibility threshold of 3.3. For non-normally distributed data, the one-tailed Wilcoxon Signed Rank Test was applied to evaluate differences in the median. In both cases, a two-tailed approach was used to detect significant increases or decreases relative to the 3.3 threshold, with the significance level set at 0.05 (Table 3).

| Comparison of delta E in each group at 3.3 | Test used | P-value | 95% Confidence Interval (CI) |
|---|---|---|---|
| **Omnichroma® before immersion** | One-Sample Wilcoxon Signed Rank Test | 0.445* | - |
| **Omnichroma® after immersion** | One sample T-test | 0.741* | (-1.17 ;1.36) |
| **Charisma before immersion** | One sample T-test | 0.92* | (-0.57; -0.62) |
| **Charisma after immersion** | One sample T-test | 0.74* | (-0.83 ;1.13) |

**Table 3:** Results comparing the composites with the teeth before and after immersion. * No statistically significant difference between the baseline value and 3.3.

To compare the two groups at baseline and after immersion, the Mann–Whitney U test was used when normality was not assumed and the independent t-test was applied when normality was confirmed. Levene's test for equality of variances yielded a p-value of 0.22, indicating equal variances ($p > 0.05$) (Table 4). All tests were two-tailed with a significance level of 0.05.

| Group | Mean deltaE | Test | P-value | Interpretation |
|---|---|---|---|---|
| Omnichroma® before immersion **Vs** charisma before immersion | 3.01<br>3.32 | Mann-whitney U test (2 samples) | 0.247 | There is no significant difference between Omnichroma®and Charisma before immersion. |
| Omnichroma® after immersion **Vs** charisma after immersion | 3.39<br>3.44 | Independent samples T test | 0.94<br>IC 95%<br>(-1.54;1.44) | There is no significant difference between Omnichroma®and Charisma after immersion. |

**Table 4:** Results comparing the composites to each other before and after immersion. Bivariate Analysis to check if there is a significant difference between before and after immersion within each group.

For non-normal distributions, the Wilcoxon signed-rank test was used for paired samples, while for normally distributed variables, the paired t-test was used. The tests were performed bilaterally with a significance level of 0.05 (Table 5).

| Group | Mean | Test | P-value |
|---|---|---|---|
| Omnichroma® before immersion<br>Vs<br>Omnichroma® after immersion | 3.01<br><br>3.39 | Wilcoxon Test | 0.799* |
| Charisma before immersion<br>Vs<br>Charisma after immersion | 3.32<br><br>3.44 | Paired Samples T-test. | 0.762* |

**Table 5:** Results comparing each composite before and after immersion. * No difference in delta E between before and after immersion.

**Discussion**

This study evaluated the color matching of single-shade (monochrome) composites in Class V restorations and assessed their color stability after one week of exposure to an acidic cola solution. Based on the results, the null hypothesis was rejected.

Color matching is crucial for the success of composite restorations, influencing both professional and patient acceptance. Monochrome composites simplify color selection and save clinical time, improving dental material efficiency without compromising esthetic results [13]. In this study, color determination was performed using the Optishade® colorimeter, a device that removes subjective errors and detects slight ΔE on flat surfaces [14,15]. Studies by Ruyter IE, et al., Demir A, et al., and Aylin CI, et al., have shown that a ΔE value above 3.3 is perceptible to the human eye and clinically unacceptable. This threshold was used in this study to evaluate the shade-matching performance of the composites [16-18].

The composites tested in this study, Omnichroma® and Charisma Diamond One, both showed ΔE values before immersion (3.01 and 3.32, respectively), which were below the perceptibility threshold, indicating good color matching and simplified shade selection. Notably, Omnichroma® had a slightly lower mean ΔE, suggesting a potentially superior chameleon effect compared to Charisma Diamond One. The results of this study align with previous research, demonstrating the satisfactory chameleon effect of Omnichroma® [9,19]. However, a previous study by Al-Hadithi AM, et al., reported a color mismatch between Omnichroma® and the tooth, in contrast to the findings of the present study. This discrepancy may be attributed to the use of artificial teeth as substrates and variations in the measurement devices employed [20].

Omnichroma® is a resin-based composite material composed of fillers with a uniform supra-nanospherical size (260 nm), along with rounded composite fillers. Unlike traditional composites that use added pigments, Omnichroma® contains no pigments, which may contribute to its improved color stability [18]. Its unique optical properties, driven by structural color and smart chromatic technology, enable it to reflect wavelengths that match natural tooth shades, resulting in effective shade matching with minimal perceptible color changes [18]. Omnichroma® is made from Urethane Dimethacrylate (UDMA), a hydrophobic monomer that boosts water stability, protecting the material from degradation and color changes [21].

The Charisma Diamond One composite also demonstrates a satisfactory chameleon effect, aligning with Zhu J, et al., findings that it can match various tooth shades, simplifying shade selection and enhancing clinical efficiency, particularly for posterior restorations, due to its high translucency [22].

Formulated with TCD, a monomer that reduces polymerization shrinkage and maintains low viscosity, Charisma Diamond One also benefits from TCD's resistance to hydrolytic degradation, which may contribute to its color stability [22]. However, Fidan M, et al., reported a color mismatch between Charisma Diamond One and natural tooth shades, possibly due to its pigment-containing formulation. Additionally, the presence of filler particles may lead to weaker cross-linking between the polymer matrix and fillers, contributing to color changes [23].

In the comparison between Omnichroma® and Charisma Diamond One before immersion, no significant difference was found, supporting Rosa, et al., findings that both composites have strong color adjustment potential [24].

Cola solution was used because it is a staining agent and is consumed frequently in daily life. According to Ebaya, et al., cola causes the greatest color change in teeth and restorations. Being a yellow-brown soft drink, the staining is caused by ammonia-sulfite caramel. It also has a bleaching effect that affects adsorption and material solubility [25].

In this study, no significant difference was found between the composite groups before and after immersion in the cola solution. This opposes the results of Reddy, et al., Ozkanoglu, et al., and Ebaya, et al., who reported that *in-vitro* staining affects the color match of aesthetic restorations and that cola's staining intensity is greater than that of other staining agents [26]. However, these results align with those of Mundim F, et al., who showed that cola does not seem to significantly contribute to composite discoloration, despite containing phosphoric acid. Acids behave differently in promoting the dissolution and erosion of materials. Additionally, the presence of phosphate ions in Coca-Cola may suppress dissolution, as it has been shown that these ions reduce the dissolution rate of calcium phosphate from teeth. Bagheri et al. also revealed that cola does not produce as much discoloration [14].

Both Omnichroma® and Charisma Diamond One showed no significant difference in color before and after immersion, consistent with findings by Alshehri A, et al., and E Ozera, et al. [26,27]. This stability may be attributed to the presence of TEGDMA and UDMA, which enhance water stability and reduce water absorption, making the materials less prone to color changes from dye stains [28].

However, the results of this study contradict the findings of Ebaya, et al., who reported color changes in these composites after immersion in acidic cola solution [24]. Their study showed that methacrylate-based composites (as in the case of Omnichroma® and Charisma) are prone to color changes after immersion in various staining agents [25]. Cavity depth is a factor that can influence shade-matching outcomes, which may account for the discrepancies between studies. The findings of this research align with those of Mohamed Sanad, et al., who concluded that variations in cavity depth had no significant impact on the color-matching ability of the resin composite materials. Consequently, the cavity depth was standardized across all restorations in this study to control for this variable [29].

This study has several limitations. First, the sample size was relatively small due to challenges in obtaining healthy, intact and freshly extracted molars. Second, accurately reproducing all clinical conditions in an *in-vitro* setting is inherently difficult, which may limit the generalizability of the findings to real-world scenarios. The study duration was also limited to one week, restricting the assessment to a single staining agent and preventing long-term evaluation. Additionally, multiple factors influence shade matching in clinical practice, including tooth morphology, the color of adjacent teeth and the optical effects of surrounding soft tissues. This study also employed a single standardized cavity type, whereas cavity size and location influence the thickness of the composite layer and, consequently, its optical properties.

Future research should address these limitations by including larger sample sizes and incorporating a wider range of tooth types and cavity designs. Long-term *in-vivo* studies are necessary to evaluate the color stability and clinical performance of single-shade composites under dynamic oral conditions, including exposure to various staining agents, pH fluctuations and mechanical wear. Moreover, future investigations could explore additional parameters such as surface roughness, translucency and the interaction of composites with different adhesive systems. Evaluating these composites in diverse clinical scenarios will provide a more comprehensive understanding of their optical behavior and performance, ultimately guiding optimal material selection and improving restorative outcomes.

**Conclusion**

Within the limitations of the present study, the following conclusion can be drawn:

1. Omnichroma® and Charisma Diamond One single-shade composites have demonstrated their ability to maintain a certain shade correspondence with the tooth structure, even after immersion in colored solutions.
2. Further clinical studies are needed to better understand the optical properties of these composites and optimize their clinical performance.

**Conflict of Interest**

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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The authors have no acknowledgments to declare.

**Data Availability Statement**
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

**Ethical Statement**
The project did not meet the definition of human subject research under the preview of the IRB according to federal regulations and therefore was exempt.

**Informed Consent Statement**
Informed consent was obtained from all participants included in the study.

**Authors' Contributions**
All authors contributed equally to this paper.

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