Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial
Portuguese Journal of Stomatology, Dental Medicine and Maxillofacial Surgery
REV PORT ESTOMATOL MED DENT CIR MAXILOFAC. 2025;66(3):115-123

Original Research

Impact of coffee exposure on the color adjustment potential of universal-shade resin composites: an in vitro study

Berkant Sezer[1], *Tuğba Misilli*[2,*], *Mehmet Buldur*[2]

[1] *Department of Pediatric Dentistry, School of Dentistry, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye.*
[2] *Department of Restorative Dentistry, School of Dentistry, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye.*

ARTICLE INFO

Article history:
Received 1 April 2025
Accepted 29 July 2025
Available online 29 September 2025

Keywords:
Coffee
Color
Coloring agents
Composite dental resin
Dental materials

ABSTRACT

Objectives: This study aimed to evaluate the color adjustment potential (CAP) of a universal-shade composite resin applied to acrylic teeth of different shades under various storage conditions and over different time intervals.
Methods: A universal-shade composite (Omnichroma; Tokuyama, Tokyo, Japan) and acrylic molar teeth in three shades (A1, A2, D4) were used. Two types of samples were prepared: dual-shade (Class I restorations with 5-mm diameter and 2-mm depth in acrylic teeth) and single-shade (artificial tooth replicas). Specimens were stored in either distilled water or coffee. Color measurements were performed using a spectrophotometer at baseline, 1 day, 1 week, and 1 month. Color differences (ΔE_{00}) were calculated using the CIEDE2000 formula. ΔE_{00} values were analyzed with two-way ANOVA and Tukey's tests. CAP_{00} values were analyzed using the three-way ANOVA for intergroup comparisons and repeated measures ANOVA with Bonferroni tests to assess time-related effects.
Results: At baseline, the ΔE_{00} values were lowest in the A1 group for both sample types, followed by A2 and D4. After 1 month, coffee immersion led to significantly higher ΔE_{00} values than distilled water in all groups. CAP_{00} values significantly decreased between 1 week and 1 month in coffee-stored samples. All shade and storage subgroups showed a significant time-dependent increase in CAP_{00} ($p < 0.05$).
Conclusions: One-month storage in distilled water enhanced CAP in all groups. In turn, prolonged coffee exposure increased color differences and diminished the color harmony of restorations over time. (Rev Port Estomatol Med Dent Cir Maxilofac. 2025;66(3):115-123)

* Corresponding author.
E-mail address: dt.tugbay@outlook.com; tugbamisilli@comu.edu.tr (Tuğba Misilli).
http://doi.org/10.24873/j.rpemd.2025.09.1437
1646-2890/

Introduction

In the field of restorative dentistry, facilitating treatment processes has always been an important goal in the material development process. Significant progress has been made with innovations such as universal adhesive systems,[1] high-power light-curing units,[2] and bulk-fill composites.[3] A recent breakthrough has been the development of universal-shade (single-shade) composite resins. These resins can mimic any tooth shade with a single application, thus eliminating the complexity of applying multiple layers of various shades to mimic the natural tooth appearance during restoration procedures.[1,4]

Universal-shade composite resins were pioneered by Omnichroma (Tokuyama, Tokyo, Japan), and their key feature has earned a place in dental terminology as "chameleon effect." This effect is attributed to smart chromatic technology, which relies on structural color, through a phenomenon where specific wavelengths of light are reflected due to the interaction of light with the material's uniformly arranged nano-structured fillers. According to its manufacturer's information, Omnichroma does not contain pigments; it is produced using the sol-gel method with spherical SiO_2 and ZrO_2 particles of equal size and 260-nm diameters. This regular supra-nanostructure is responsible for developing structural color within the range from yellow to red.[4–6] Smooth, uniformly spaced, and arranged spherical fillers facilitate light transmission throughout the restoration, reflecting the color of the surrounding cavity and demonstrating superior color blending ability.[7] As a result, it claims to match all 16 VITA Classic shade guide colors from A1 to D4.

Color compatibility, interactions, and stability are critical factors for evaluating the clinical performance of composite resins.[8] The color matching and interaction properties of universal-shade composites have been addressed in many studies using instrumental and/or visual methods. Studies have shown that these composites are compatible with a wide range of shades in restoration applications on human teeth,[6,9] and they can also adapt to color changes after teeth whitening.[10] Color shifting has also been investigated by placing these universal-shade materials into cavities prepared in composite substrates with different shades, showing effective blending properties in this clinical scenario simulating restoration repair.[11,12]

Color stability or instability is associated with aging and discoloration after restoration application.[13,14] The various physicochemical conditions in the oral environment can alter the chemical structure of composite resins, and exposure to multiple beverages containing specific chromogens, especially throughout the day, leads to inevitable color changes in restorations.[15] Studies investigating how universal-shade resin composites respond to these external factors have shown that they exhibit similar discoloration potential compared to traditional composites.[16,17] On the other hand, as the optical properties of an aged composite resin restoration change, color matching can become even more complex.[18]

Color perception relies primarily on how light is reflected or transmitted by an object and is perceived visually. In dental practice, shade selection can be conducted through several approaches, including visual comparison using shade guides, spectrophotometry, colorimetry, and computer-assisted digital imaging analysis.[19,20] Although visual assessment remains the most common technique, it is subject to variability caused by factors such as ambient lighting conditions, observer fatigue, the clinician's experience, and even gender differences.[21,22] Digital color measurement devices may minimize these subjective influences by offering a more objective alternative due to reducing environmental and observer-related biases. Instruments like spectrophotometers and colorimeters have been widely employed to quantify natural tooth color, aiding in the accurate selection of composite resin shades.[23,24] Spectrophotometers, known for their precision and versatility in color science, operate by detecting the intensity of light reflected from a surface at narrow wavelength intervals across the visible spectrum (400–700 nm).[25] The VITA Easyshade spectrophotometer, for example, integrates components including a light source, optical dispersion elements, a measurement system, a sensor, and signal processing units to convert reflected light into analyzable data. The spectral information obtained must then be translated into clinically relevant shade values to facilitate dental color matching.[25,26]

Based on this information, the research question of this study is whether a restoration made with universal-shade composite resin, in the long term, loses or maintains its compatibility with the substrate material in terms of discoloration. This study aims to examine the color adjustment potential (CAP) of a universal-shade composite resin in Class I restorations prepared on acrylic teeth with different shades (A1, A2, and D4), following exposure to coloring agents (distilled water and coffee) for 24 hours, 1 week, and 1 month, to understand how well it preserves color stability and aesthetic appeal. The primary null hypothesis was that the shade of the substrate, the storage medium, and the immersion time would have no significant effect on the CAP_{00} value of the universal-shade composite resin. The secondary hypothesis was that no interaction would be observed between these variables.

Material and Methods

According to the results of AlHamdan et al.[16] and using a three-way analysis of variance (ANOVA), G*Power software (version 3.1, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) with $\alpha = 0.05$, power $(1-\beta) = 0.95$, effect size = 0.8465196, and common standard deviation of 0.46526874, the total sample size required was 27 (3*9). Therefore, the experiment was conducted with n = 10 for each subgroup.

This study used sixty left mandibular first molar (#36) acrylic teeth without root extensions, containing only crown morphology (provided by Tokuyama Dental, Japan). Circular cavities were prepared on the teeth's occlusal surfaces, with 2-mm depth (measured from the lingual groove) and 5-mm diameter. The measurements were determined using a Nordent Periodontal Probe N116 (Nordent Manufacturing, USA). The acrylic teeth were bilayered to mimic the optical behavior of natural teeth and to enhance the reliability of the color evaluations. Shades A1, A2, and D4 were selected to reflect a clinically relevant range of tooth shades: A2 is among the most frequently observed natural shades,[27] while A1 and D4 represent the lighter and darker ends of the shade spectrum commonly encountered in daily clinical practice within the VITA Classical scale.

A single layer of universal-shade composite resin Omnichroma was placed in all cavity preparations. The occlusal surface of the restoration was flattened to allow measurement with a spectrophotometer. The composite restorations were polymerized for 20 seconds using an LED light-curing unit (D-light Pro; GC Europe, Leuven, Belgium) with an average light intensity of 1400 mW/cm², according to the manufacturer's instructions. The light intensity of the device was checked with an integrated radiometer every three polymerizations. Subsequently, finishing and polishing were performed on the restoration surfaces using a two-step polishing system (Enhance & PoGo; Dentsply, Konstanz, Germany) with a slow-speed handpiece. The visual schematics of the restorations prepared in the acrylic teeth is shown in Figure 1a.

The restored acrylic teeth were divided into three groups of 20 teeth according to the three different tooth shades. Then, the teeth in each group were randomly divided into two subgroups (n = 10) to be stored in either distilled water or coffee (Figure 1b). To mimic dietary staining, a coffee solution containing 2 g of granulated coffee (Nescafé Gold; Nestlé, Vevey, Switzerland) was prepared by dissolving the powder in 200 ml of boiling water (at approximately 100°C) and allowed to steep for 1 minute. The specimens were immersed while the solution was still hot (at approximately 90–95°C), simulating intraoral exposure to freshly brewed coffee. Based on studies by Ertaş et al.,[28] which indicate that immersion in beverages for 24 hours corresponds to 1 month in vivo, in this study, the samples were stored in solutions for 30 days, simulating a clinical lifespan of 2.5 years. Throughout the study, the solutions were refreshed every 24 hours in the same way.[28]

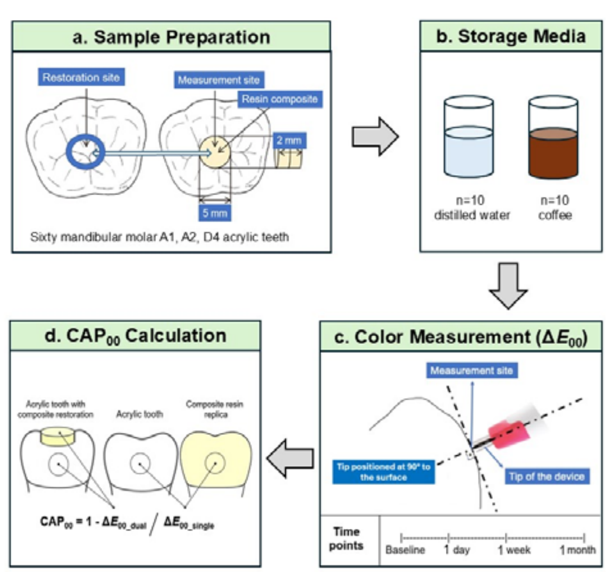

Figure 1. Step-wise experimental design

Color measurements were repeated immediately after the completion of restorations and then after 1 day, 1 week, and 1 month of immersion in distilled water or coffee. Samples removed from the solutions at all evaluation periods were rinsed under running water for 10 seconds, dried with blotting paper, and then left to air dry. Measurements were performed using an intraoral spectrophotometer (VITA Easyshade V; VITA Zahnfabrik, Bäd Säckingen, Germany) on a neutral gray background ($L^* \approx 50$), in accordance with standard protocols for reducing ambient light interference. The device features a measurement tip with a diameter of approximately 5 mm, which was positioned perpendicular to the measured surfaces during all evaluations. To obtain color parameters from acrylic teeth, the device probe was placed on the buccal surfaces of the teeth. To obtain color parameters of Omnichroma, the device probe was positioned perpendicular to the composite restorations on the occlusal surfaces of the resin teeth. Following the manufacturer's instructions, the device tip was positioned perpendicular to the measured area as illustrated in Figure 1c.

The average L*, a*, b* values of three repeated measurements were calculated for each restoration and acrylic tooth. After each of the three measurements, the device's calibration was checked. Then, using the Excel spreadsheet application, the color difference (ΔE_{00}) values between the acrylic teeth and the occlusal restorations were calculated with the formula below:[29]

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

Following the recommendations for dental research and in vivo instrumental color analysis, the K_L, K_C, and K_H parametric factors were adjusted to 2:1:1.[30] The color difference calculations at baseline, 1 day, 1 week, and 1 month were recorded as ΔE_{00_dual} values. Based on the literature, the 50:50% perceptibility (PT_{00}) and 50:50% acceptability (AT_{00}) thresholds were established at > 0.8 and ≤ 1.8, respectively, in line with previous CIEDE2000-based dental color research.[31]

The CAP_{00} index was used to calculate the CAP.[32] For this purpose, color difference values obtained from dual-shade (restored) samples (ΔE_{00_dual}) after exposure to distilled water/coffee solution at baseline, 1 day, 1 week, and 1 month, as well as color difference values obtained from single-shade samples (ΔE_{00_single}), were used. The single-shade samples consist of the acrylic tooth without cavity preparation and its replica made from composite resin. Thus, the color difference value ΔE_{00_single} corresponds to the color difference between these two individual samples. Moreover, a comparison was made with a reference ΔE_{00_single} value to track the time-dependent change in CAP. The color parameters of single-shade acrylic resin tooth samples were recorded from the flat buccal surfaces before preparation. For single-shade composite samples, Omnichroma resin replicas were made from silicone molds obtained from acrylic teeth (n = 10). The same procedures for polymerization and finishing/polishing were followed. Then, the averages of L*, a*, and b* measurements obtained from the buccal surfaces of single-shade acrylic and composite artificial teeth were used in the CIEDE2000 color difference formula to obtain a reference ΔE_{00_single} value for each shade of acrylic teeth (A1, A2, D4). The calculated reference ΔE_{00_single} values in distilled water and coffee, respectively, were 4.06 ± 0.84 and 4.36 ± 0.79 for A1, 10.75 ± 0.62 and 10.33 ± 0.65 for A2, and 12.39 ± 0.46 and 12.53 ± 0.57 for D4. CAP_{00} index values for each time period (baseline, 1 day, 1 week, 1 month) were then calculated using the following formula: $CAP_{00} = 1 - \Delta E_{00\_dual} / \Delta E_{00\_single}$. The distinction between dual and single-color measurement methods is visually presented in Figure 1d.

The data were analyzed using the statistical software program SPSS (version 23.0) (IBM; Chicago, IL, USA). According to the Shapiro-Wilk test, the data showed a normal distribution. For color-matching assessment, a two-way ANOVA with a post hoc Tukey's test was applied to the ΔE_{00} values obtained for each immersion time. CAP_{00} values were analyzed using three-way ANOVA for intergroup comparison, repeated measures ANOVA to determine the effect of immersion time, and, subsequently, Bonferroni tests. A p-value lower than 0.05 was considered statistically significant.

Results

According to the two-way ANOVA, only the substrate shade main factor had a statistically significant effect on the baseline color difference values (ΔE_{00}). The substrate shade and storage media main factors and the substrate shade*storage media interaction were also statistically significant at 1 day, 1 week, and 1 month ($p < 0.001$; Table 1). The color difference values for each time period are shown in Table 2. Accordingly, ΔE_{00} values obtained from single-shade and dual-shade samples before exposure to any solution were lowest in the A1 group, followed by the A2 and D4 groups, respectively. The highest ΔE_{00_dual} values after exposure to different solutions were observed in the D4 shade-distilled water subgroup at the 1-day and 1-week evaluations and in the D4 shade-coffee subgroup at the 1-month evaluation. The lowest ΔE_{00_dual} values were observed in the A1 shade-distilled water subgroup in all three evaluation points and in the A1 shade-coffee and A2 shade-coffee subgroups at the 1-week evaluation.

When considering each substrate shade in terms of different storage media, the A2 and D4 groups showed lower ΔE_{00_dual} values after 1 day and 1 week of exposure to coffee compared to distilled water. In the A1 group, however, storage in distilled water resulted in lower ΔE_{00_dual} values compared to coffee after 1 day, but statistically similar values were found after 1 week. After 1 month, storage in coffee resulted in significant-

Table 1. Effect of storage media and substrate shade on color matching values (ΔE_{00}) at each immersion time.

		Test statistics*	df	p-value
ΔE_{00_single}	Shade	835.417	2	**<0.001**
	Storage media	0.001	1	0.973
	Shade*storage media	1.650	2	0.202
Baseline	Shade	406.708	2	**<0.001**
	Storage media	3.200	1	0.079
	Shade*storage media	0.235	2	0.792
At 1 day	Shade	421.185	2	**<0.001**
	Storage media	48.691	1	**<0.001**
	Shade*storage media	106.387	2	**<0.001**
At 1 week	Shade	396.779	2	**<0.001**
	Storage media	236.851	1	**<0.001**
	Shade*storage media	49.976	2	**<0.001**
At 1 month	Shade	289.476	2	**<0.001**
	Storage media	612.685	1	**<0.001**
	Shade*storage media	17.902	2	**<0.001**

*Two-way analysis of variance, df: Degree of freedom. Bold values mean statistical significance.

Table 2. Mean ΔE_{00_single} and ΔE_{00_dual} values±standard deviations at baseline, 1 day, 1 week, and 1 month.

Shade	Storage media	ΔE_{00_single}	ΔE_{00_dual}			
			Baseline	1 day	1 week	1 month
A1	Distilled water	4.06±0.84	2.85±0.32	2.01±0.19 **e**	1.92±0.36 **c**	1.69±0.19 **d**
	Coffee	4.36±0.79	3.18±0.52	3.48±0.38 **c**	1.51±0.38 **c**	7.74±1.15 **b**
	Avg.	4.21±0.81 ‡	3.02±0.45 ‡	2.75±0.81 ‡	1.71±0.42 ‡	4.71±3.21 ‡
A2	Distilled water	10.75±0.62	6.14±0.91	3.96±0.27 **c**	3.85±0.37 **b**	4.07±0.43 **c**
	Coffee	10.33±0.65	6.33±0.96	2.82±0.47 **d**	1.58±0.36 **c**	9.01±1.06 **b**
	Avg.	10.54±0.66 δ	6.24±0.91 δ	3.39±0.69 δ	2.72±1.22 δ	6.54±2.65 δ
D4	Distilled water	12.39±0.46	9.31±0.61	8.30±0.73 **a**	8.35±1.11 **a**	7.85±0.71 **b**
	Coffee	12.53±0.57	9.81±0.82	5.37±0.61 **b**	4.44±0.25 **b**	16.57±1.78 **a**
	Avg.	12.46±0.51 ¥	9.56±0.75 ¥	6.84±1.64 ¥	6.40±2.16 ¥	12.21±4.66 ¥

Symbols (¥, δ, ‡) indicate significant differences between shades within each column ($p < 0.05$).
Letters (a,b,c,d,e) indicate significant differences between shade*storage media interactions within each column ($p < 0.05$).
Note: Symbols and letters are randomly assigned and serve purely for grouping purposes — they do not reflect ranking.

ly higher ΔE_{00_dual} values for all groups compared to distilled water.

The three-way ANOVA conducted to determine the effects of substrate shade ($F = 89.193$, $p < 0.001$), storage media ($F = 43.447$, $p < 0.001$), and immersion time ($F = 116.263$, $p < 0.001$) on the CAP_{00} value of Omnichroma revealed that all three main factors had statistically significant effects. The interaction between these factors was also significant ($p < 0.001$; Figures 2, 3, and 4). The time-dependent CAP_{00} graph for each shade-storage media subgroup during the experiment is shown in Figure 5. According to repeated measures ANOVA, time-dependent changes in CAP_{00} values were statistically significant for each shade-storage media subgroup ($p < 0.05$). Bonferroni tests revealed statistically significant differences between the 1-day and 1-month measurements for the A1 shade-distilled water subgroup ($p = 0.024$), between baseline and 1-month measurements for the D4 shade-distilled water subgroup ($p = 0.003$), and between baseline and 1-day ($p < 0.001$), 1-week ($p < 0.001$), and 1-month ($p = 0.001$) measurements for the A2 shade-distilled water subgroup. For the subgroups immersed in coffee solution, a statistically significant increase was observed between all immersion times except for baseline and 1-day measurements for the A1 shade-coffee subgroup ($p < 0.05$).

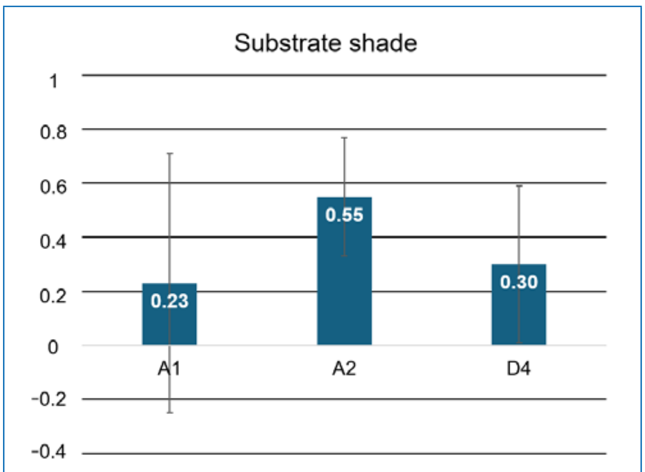

Figure 2. Results from a three-way ANOVA carried out to evaluate CAP_{00} according to substrate shade

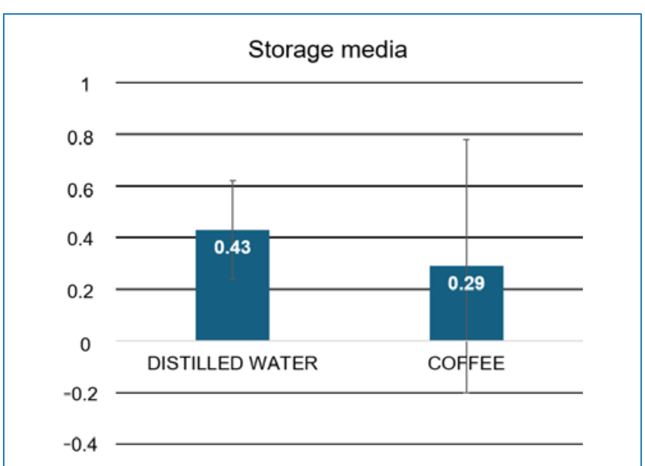

Figure 3. Results from a three-way ANOVA carried out to evaluate CAP_{00} according to storage media

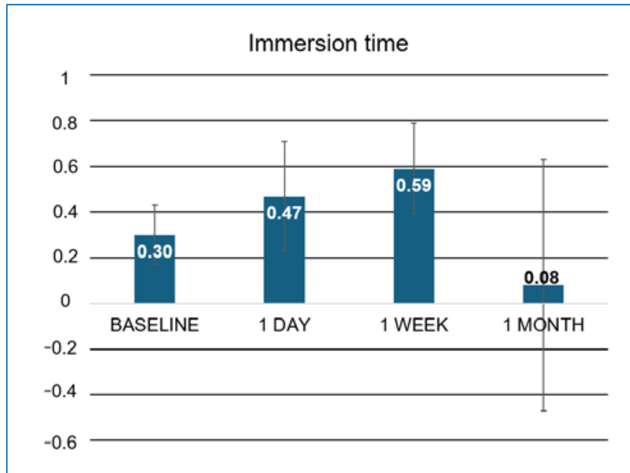

Figure 4. Results from a three-way ANOVA carried out to evaluate CAP_{00} according to immersion time

Discussion

This study used the CIEDE2000 color difference formula and the color adjustment potential (CAP_{00}) equation to analyze the potential color shift towards the substrate's color that resin composites undergo when exposed to colorants. Accordingly, the color matching with the substrate material after color changes over time in composite restorations was evaluated relative to the initial color difference values. Based on the significant changes observed in CAP_{00} values across different immersion media and time intervals, both the primary and secondary null hypotheses were rejected.

In all dual-shade samples, the CIEDE2000 color differences between the resin tooth and the restoration surface were initially considerably higher than the generally accepted acceptability threshold for ΔE_{00} ($AT_{00} \leq 1.8$), as reported in ISO/TR 28642:2016 and more recent perceptibility/acceptability consensus studies.[31,33] Omnichroma initially exhibited a lower color difference (ΔE_{00}) from the high-value VITA A1 substrate resin tooth and matched better than the low-value VITA D4 substrate shade. Similarly, Iyer et al.[34] reported that among universal-shade composites, Omnichroma exhibited better compatibility with lighter color shades (A2, B1, and B2) in resin teeth. Another study reported that the color-matching ability of a universal-shade resin composite (Omnichroma) was influenced by tooth color.[16] Forabosco et al.[10] reported a significant decrease in the color difference value of Omnichroma with brighter shades after bleaching in human teeth. The authors thus noted the advantage of universal color composites in simplifying the technique, shortening the process, and eliminating the need to replace existing restorations when bleaching occurs.[5]

The high ΔE values observed for the D4 group may not only reflect restoration-substrate mismatch but could also be par-

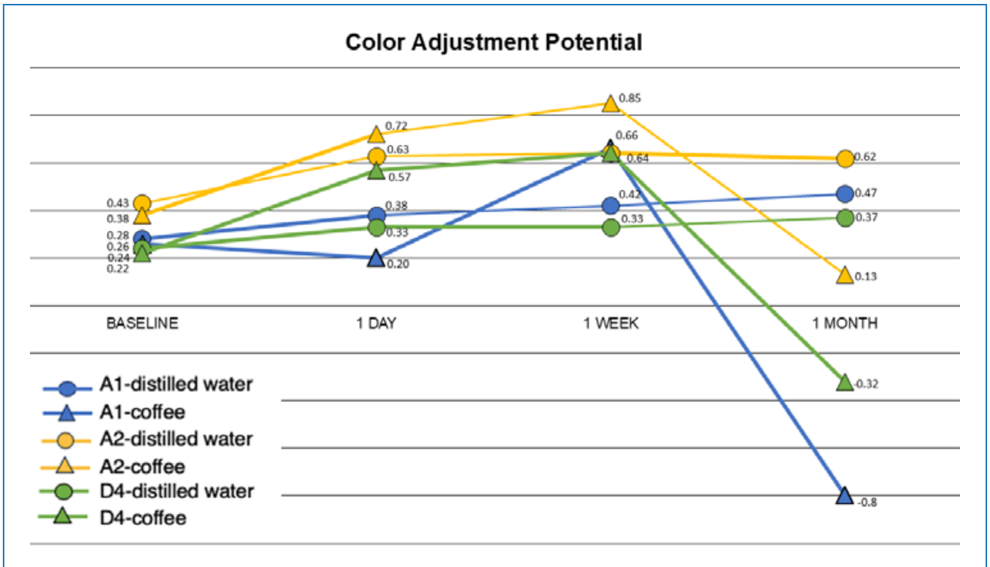

Figure 5. **Line graph of CAP_{00} measurements according to shade and solution during the storage time ($p = 0.029$ for A1-distilled water; $p < 0.001$ for A1-coffee, A2-distilled water, A2-coffee, and D4-coffee; $p = 0.003$ for D4-distilled water)**

tially due to the reduced measurement precision of spectrophotometers in darker and more chromatic shade areas. While specific data on D4 are scarce, the literature indicates that the peripheral regions of the VITA Classical shade scale—such as C and D groups—may pose greater challenges in accurate color measurement due to their higher chromaticity and lower frequency in calibration sets.[35]

Unfortunately, most materials exhibit color changes ranging from light cream to yellowish or light brown due to exposure to organic pigments found in food and beverages.[36] In clinical scenarios involving prolonged exposure to a coloring solution, it is important to examine how these new-generation composites with CAP interact with the substrate tissue. The coffee solution contains low-polarity yellow stain molecules, which potentially cause staining due to their affinity for the polymer network.[37] Researchers have stated that coffee provides pigments that are adsorbed and absorbed by the substrate composite resin, leading to discoloration on the material's surface and in deeper layers.[28,38] It is also believed that the high coffee temperature could facilitate the restoration's staining process.[39] Furthermore, previous studies have reported that Omnichroma exhibits color stability comparable to traditional composite resin in coffee.[16] In the current study, after 1 month, the coffee solution led to higher color difference values than the control environment across all shades, with the highest values observed in the D4 tone. Um and Ruyter[40] have noted that colorants in coffee adhere to the surface and then become fixed, thus making staining from coffee more pronounced. Lago et al.[41] emphasized that when staining occurs due to external factors, it happens synergistically with cumulative material degradation.

The CAP_{00} values, which evaluate the time-dependent color match between the universal-shade composite and the substrate, increased noticeably after 1 month compared to baseline in the distilled water environment, showing relatively consistent trends from 1 day on, as expected. Research indicates that most clinically significant color changes occur after the initial polymerization and within 24 hours. After 24 hours, the color change over 1 month remains negligible and does not significantly contribute to the total color change. The increase in color change observed within the first 24 hours is attributed to the change in optical properties of the resin during the post-irradiation polymerization reaction, which is known to occur following light activation of the composites and can last up to 24 hours.[42]

A CAP_{00} of 0.50 (corresponding to a 50% ΔE_{00} reduction in dual-shade samples compared to single-shade samples) is considered a threshold for effective blending.[12] The data from the current study show that the CAP_{00} values of samples immersed in distilled water approached the threshold value after 24 hours compared to baseline, but remained above the threshold only for A2-shade samples. In contrast, when examining the ΔE_{00_dual} values, the lowest color difference was observed in the A1 shade for all evaluation periods (1 day, 1 week, 1 month). This difference between the two parameters arises from the higher level of ΔE_{00_single} in the A2-shade samples. Although better color-matching results were obtained in the A1 shade from the beginning, it can be said that there is a higher CAP in the A2 shade. This suggests that different substrate shades may affect the blending capacities of these materials. Furthermore, considering a previous study that established a CAP (using the CIE L*a*b* color difference formula) value of 0.20 as the threshold for effective blending with denture tooth shade, only the values obtained in the coffee solution after 1 month fell below this threshold.[43] Additionally, in the same study, it was reported that instrumental (CAP-I) and visual (CAP-V) measurements performed on the A2 denture tooth yielded higher results for most of the tested resin composites, similar to the findings in the current study.

Many studies in the literature report conflicting results regarding color matching with Omnichroma and high ΔE_{00} values.[44,45] In the study by Vaizoğlu et al.,[46] significant changes were observed in the ΔE_{00} values after traditional composites repaired with universal resin composites were colored with coffee. In another study, Omnichroma was the composite that changed color the most, and repairing composites with the same resin yielded the best results.[47] Pereira-Sanchez et al.,[43] based on both instrumental and visual evaluations, stated that Omnichroma exhibited the greatest color mismatch in their study. The differences in the results from these studies can largely be attributed to the methods used.

When considering the CAP_{00} values of samples immersed in the coffee simulating the coloring environment, it is surprising that after 1 day, which simulates 1 month of exposure, all CAP_{00} values except for the A1 group (0.20) were above the threshold of 0.50. Previous studies evaluating the color stability of universal-shade composite, including Omnichroma, have reported that, although universal-shade composites exhibit some differences depending on the immersion environment, they have a high potential for color change.[17,48–52] Earlier studies on the CAP_{00} values of universal-shade composites focused on blending effects superior to other multi-shade composites, which are visually and instrumentally correlated[9,43] and positively affect the color and translucency attributes.[12] However, limited evidence is available regarding the degree of CAP when these composites are subjected to conditions simulating intraoral aging. One study found that increased storage time and resin thickness positively influenced CAP_{00} values of class V universal-shade composite restorations with different thicknesses (2 and 3 mm) in acrylic denture teeth immersed in distilled water for 24 hours and 1 month.[52] In the current study, similarly, the level of color matching increased over time in the control environment, while long-term exposure to a coloring environment had a negative impact. Another study that accounted for aging conditions (thermal aging for 10,000 cycles in distilled water) also found inadequate color-matching performance with high ΔE_{00} for universal-shade repair composites.[18] However, unlike our study, they applied aging conditions before the repair application of universal-shade composites and did not consider CAP_{00} values.

This study has certain limitations that should be acknowledged. The investigation was limited to a single universal-shade composite resin (Omnichroma), selected intentionally to maintain material standardization and focus on the intrinsic behavior of a widely used representative. While this enhances internal consistency, future research should explore other single-shade composites with varying formulations to broaden the scope of applicability. Moreover, only coffee was used as the staining agent, chosen due to its established and reproducible staining capacity reported in prior literature. However, evaluating the effects of beverages with different pH levels or using multiple staining agents would provide a more comprehensive understanding of real-life discoloration mechanisms. Simulated toothbrushing was not included in the protocol, as mechanical abrasion could interfere with surface integrity and introduce uncontrolled variables in color measurements. Likewise, salivary dilution and dynamic exposure to staining agents, which occur in the oral environment, were not replicated in order to preserve the conditions' standardization. Finally, the immersion was performed under static conditions without agitation, consistent with previous in vitro protocols aimed at isolating the effects of storage medium and time. The absence of fluid motion may underestimate the staining potential of beverages, yet this approach allowed for more controlled assessment of color changes. These methodological choices, while limiting clinical mimicry, were implemented to ensure experimental reproducibility and internal validity.

Although some variables, such as the inherent glossiness of acrylic resin teeth and the inability to simulate the complex dynamics of the oral environment, could not be controlled, several standardization techniques were applied to minimize their impact. These included using prefabricated teeth with identical surface morphology, a consistent finishing and polishing protocol, and standardized spectrophotometer positioning under controlled lighting. These measures aimed to reduce operator and environmental bias and ensure reliable comparisons.

This study provides valuable insights into the color compatibility and long-term color stability of universal-shade composite resins, specifically Omnichroma, in restorative dentistry. By simulating real-life staining agents, the research enhances understanding of how these materials perform over time, offering essential information to improve aesthetic outcomes and durability in clinical practice. These findings help inform decisions regarding the use of universal-shade composites in long-term dental restorations. Therefore, the clinical relevance of these findings should be emphasized, especially when selecting restorative materials for long-term aesthetic stability.

Conclusions

When comparing the initial ΔE_{00_single} and ΔE_{00_dual} values, the lowest values were observed in the A1 shade, followed by A2 and D4 shades, respectively. After 1 month, the ΔE_{00} values obtained in the coffee environment were significantly higher for all groups than those in distilled water. Except for the values obtained after 1-month exposure to the coffee solution, the CAP_{00} values were positive for all groups and increased over time. The shade of the substrate resin tooth resulted in different CAP_{00} values, with the A2 shade demonstrating the highest performance in both immersion environments.

One-month storage in distilled water enhanced CAP in all groups. However, prolonged coffee exposure increased color differences and diminished the color harmony of restorations over time.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

CRediT authorship contribution statement

Berkant Sezer: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Resources, Writing – review and editing. **Tuğba Misilli:** Methodology, Supervision, Formal analysis, Writing – original draft. **Mehmet Buldur:** Conceptualization, Methodology, Resources, Writing – review and editing.

ORCID

Berkant Sezer 0000-0001-9731-6156
Tuğba Misilli 0000-0003-0019-4872
Mehmet Buldur 0000-0001-9103-0069

REFERENCES

1. Perdigão J, Araujo E, Ramos RQ, Gomes G, Pizzolotto L. Adhesive dentistry: Current concepts and clinical considerations. J Esthet Restor Dent. 2021;33:51-68.
2. Jandt KD, Mills RW. A brief history of LED photopolymerization. Dent Mater. 2013;29:605-17.
3. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. J Dent. 2014;42:993-1000.
4. Ahmed MA, Jouhar R, Khurshid Z. Smart monochromatic composite: A literature review. Int J Dent. 2022;2022:2445394.
5. Furusawa K, Kobayashi S, Yamashita A, Tichy A, Hosaka K, Shimada Y, et al. Effect of filler load on structural coloration and color adjustment potential of resin composites. Dent Mater J. 2023;42:343-50.
6. Kobayashi S, Nakajima M, Furusawa K, Tichy A, Hosaka K, Tagami J. Color adjustment potential of single-shade resin composite to various-shade human teeth: Effect of structural color phenomenon. Dent Mater J. 2021;40:1033-40.
7. Ismail EH, Paravina RD. Color adjustment potential of resin composites: Optical illusion or physical reality, a comprehensive overview. J Esthet Restor Dent. 2022;34:42-54.
8. Trifkovic B, Powers JM, Paravina RD. Color adjustment potential of resin composites. Clin Oral Investig. 2018;22:1601-7.
9. Altınışık H, Özyurt E. Instrumental and visual evaluation of the color adjustment potential of different single-shade resin composites to human teeth of various shades. Clin Oral Investig. 2023;27:889-96.
10. Forabosco E, Consolo U, Mazzitelli C, Kaleci S, Generali L, Checchi V. Effect of bleaching on the color match of single-shade resin composites. J Oral Sci. 2023;65:232-6.
11. Chen F, Toida Y, Islam R, Alam A, Chowdhury AFMA, Yamauti M, et al. Evaluation of shade matching of a novel supra-nano filled esthetic resin composite employing structural color using simplified simulated clinical cavities. J Esthet Restor Dent. 2021;33:874-83.
12. Durand LB, Ruiz-López J, Perez BG, Ionescu AM, Carrillo-Pérez F, Ghinea R, et al. Color, lightness, chroma, hue, and translucency adjustment potential of resin composites using CIEDE2000 color difference formula. J Esthet Restor Dent. 2021;33:836-43.
13. Khazaal G, Daou M, Mahdi SS, Ahmed Z, Maalouf E, Batteni G, et al. In vitro evaluation of the color stability and surface roughness of a new composite flow. J Clin Exp Dent. 2023;15:e43-e50.
14. Chen S, Zhu J, Yu M, Jin C, Huang C. Effect of aging and bleaching on the color stability and surface roughness of a recently introduced single-shade composite resin. J Dent. 2024;143:104917.
15. Barutcigil Ç, Yıldız M. Intrinsic and extrinsic discoloration of dimethacrylate and silorane based composites. J Dent. 2012;40:e57-63.
16. AlHamdan EM, Bashiri A, Alnashmi F, Al-Saleh S, Al-shahrani K, Al-shahrani S, et al. Evaluation of smart chromatic technology for a single-shade dental polymer resin: an in vitro study. Appl Sci. 2021;11:10108.
17. Ahmed MA, Jouhar R, Vohra F. Effect of different pH beverages on the color stability of smart monochromatic composite. Appl Sci. 2022;12:4163.
18. Çalişkan A, Alagöz LG, Irmak Ö. Shade matching potential of one-shade resin composites used for restoration repair. Dent Mater J. 2023;42:158-66.
19. Hardan L, Bourgi R, Cuevas-Suárez CE, Lukomska-Szymanska M, Monjarás-Ávila AJ, Zarow M, et al. Novel Trends in Dental Color Match Using Different Shade Selection Methods: A Systematic Review and Meta-Analysis. Materials (Basel). 2022;15:468. https://doi.org/10.3390/ma15020468
20. Tabatabaian F, Beyabanaki E, Alirezaei P, Epakchi S. Visual and digital tooth shade selection methods, related effective factors and conditions, and their accuracy and precision: A literature review. J Esthet Restor Dent. 2021;33:1084-104.
21. Medeiros JA, Pecho OE, Pérez MM, Carrillo-Pérez F, Herrera LJ, Della Bona A. Influence of background color on color perception in dentistry. J Dent. 2021;108:103640.
22. Menini M, Rivolta L, Manauta J, Nuvina M, Kovacs-Vajna ZM, Pesce P. Dental Color-Matching Ability: Comparison between Visual Determination and Technology. Dent J (Basel). 2024;12:284.
23. Rashid F, Farook TH, Dudley J. Digital Shade Matching in Dentistry: A Systematic Review. Dent J (Basel). 2023;11:250.
24. Akl MA, Mansour DE, Zheng F. The Role of Intraoral Scanners in the Shade Matching Process: A Systematic Review. J Prosthodont. 2023;32:196-203.
25. Weyhrauch M, Igiel C, Pabst AM, Wentaschek S, Scheller H, Lehmann KM. Interdevice agreement of eight equivalent dental color measurement devices. Clin Oral Investig. 2015;19:2309-18.
26. Kim HK. Evaluation of the repeatability and matching accuracy between two identical intraoral spectrophotometers: an in vivo and in vitro study. J Adv Prosthodont. 2018;10:252-8.
27. Karaman T, Altintas E, Eser B, Yildirim T, Oztekin F, Bozoglan A. Spectrophotometric evaluation of anterior maxillary tooth color distribution according to age and gender. J Prosthodont. 2019;28:e96-e102.
28. Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. Dent Mater J. 2006;25:371-6.
29. Sharma G. The CIEDE2000 color-difference formula. Excel spreadsheet implementation of the CIEDE2000 color-difference formula (including test data). Available from: https://hajim.rochester.edu/ece/sites/gsharma/ciede2000/. Accessed 20 July, 2025.
30. Mdel MP, Ghinea R, Herrera LJ, Ionescu AM, Pomares H, Pulgar R, et al. Dental ceramics: a CIEDE2000 acceptability thresholds for lightness, chroma and hue differences. J Dent. 2011;39:e37-44.

31. Paravina RD, Pérez MM, Ghinea R. Acceptability and perceptibility thresholds in dentistry: A comprehensive review of clinical and research applications. J Esthet Restor Dent. 2019;31:103-12.
32. Paravina RD, Westland S, Johnston WM, Powers JM. Color adjustment potential of resin composites. J Dent Res. 2008;87:499-503.
33. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, et al. Color difference thresholds in dentistry. J Esthet Restor Dent. 2015;27:S1-9.
34. Iyer RS, Babani VR, Yaman P, Dennison J. Color match using instrumental and visual methods for single, group, and multi-shade composite resins. J Esthet Restor Dent. 2021;33:394-400.
35. Rashid F, Farook TH, Dudley J. Digital shade matching in dentistry: a systematic review. Dent J. 2023;11:250.
36. Gawriołek M, Gawriołek K, Eliasz W, Czarnecka B, Paszynska E, Sikorski M. How does the color of restorative material change during exposure to dietary liquids due to the acquisition of a discolored layer? Coatings. 2020;10:866.
37. Ardu S, Braut V, Gutemberg D, Krejci I, Dietschi D, Feilzer AJ. A long-term laboratory test on staining susceptibility of esthetic composite resin materials. Quintessence Int. 2010;41:695-702.
38. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent. 2005;33:389-98.
39. Ribeiro JS, Peralta SL, Salgado VE, Lund RG. In situ evaluation of color stability and hardness' decrease of resin-based composites. J Esthet Restor Dent. 2017;29:356-61.
40. Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. Quintessence Int. 1991;22:377-86.
41. Lago M, Mozzaquatro LR, Rodrigues C, Kaizer MR, Mallmann A, Jacques LB. Influence of bleaching agents on color and translucency of aged resin composites. J Esthet Restor Dent. 2017;29:368-77.
42. Sabatini C, Campillo M, Aref J. Color stability of ten resin-based restorative materials. J Esthet Restor Dent. 2012;24:185-99.
43. Sanchez NP, Powers JM, Paravina RD. Instrumental and visual evaluation of the color adjustment potential of resin composites. J Esthet Restor Dent. 2019;31:465-70.
44. de Abreu JLB, Sampaio CS, Jalkh EBB, Hirata R. Analysis of the color matching of universal resin composites in anterior restorations. J Esthet Restor Dent. 2021;33:269-76.
45. Rohym S, Tawfeek HEM, Kamh R. Effect of coffee on color stability and surface roughness of newly introduced single shade resin composite materials. BMC Oral Health. 2023;23:236.
46. Vaizoglu GA, Ulusoy N, Alagöz LG. Effect of coffee and polishing systems on the color change of a conventional resin composite repaired by universal resin composites: An in vitro study. Materials. 2023;16:6066.
47. Buldur M, Ayan G. Is It Possible for Single-shade Composites to Mimic the Color, Lightness, Chroma, and Hue of Other Single-shade Composites? An In Vitro Study. Oper Dent. 2024;49:691-703.
48. Ersöz B, Karaoğlanoğlu S, Oktay EA, Aydin N. Resistance of Single-shade Composites to Discoloration. Oper Dent. 2022;47:686-92.
49. Ebaya MM, Ali AI, El-Haliem HA, Mahmoud SH. Color stability and surface roughness of ormocer- versus methacrylate-based single shade composite in anterior restoration. BMC Oral Health. 2022;22:430.
50. El-Rashidy AA, Abdelraouf RM, Habib NA. Effect of two artificial aging protocols on color and gloss of single-shade versus multi-shade resin composites. BMC Oral Health. 2022;22:321.
51. Fidan M, Yağci Ö. Effect of aging and fiber-reinforcement on color stability, translucency, and microhardness of single-shade resin composites versus multi-shade resin composite. J Esthet Restor Dent. 2024;36:632-42.
52. Akgül S, Gündoğdu C, Bala O. Effects of storage time and restoration depth on instrumental color adjustment potential of universal resin composites. J Oral Sci. 2022;64:49-52.

Impacto da exposição ao café no potencial de ajuste de cor de compósitos de resina de tonalidade universal: um estudo *in vitro*

RESUMO

Objetivos: Este estudo teve como objetivo avaliar o potencial de ajuste de cor (CAP) de uma resina composta de cor universal aplicada a dentes artificiais de diferentes tonalidades, sob diferentes condições de armazenamento e em vários intervalos de tempo.
Métodos: Uma resina composta de cor universal (Omnichroma; Tokuyama, Tóquio, Japão) e dentes molares artificiais em três tonalidades (A1, A2, D4) foram utilizados. Dois tipos de amostras foram preparados: restaurações de tonalidade dupla (Classe I) e réplicas de dentes artificiais de tonalidade única. As amostras foram armazenadas em água destilada ou café. As medições de cor foram realizadas com um espectrofotômetro no momento inicial e ao fim de 1 dia, 1 semana e 1 mês. As diferenças de cor (ΔE_{00}) foram calculadas utilizando a fórmula CIEDE2000. Os valores de ΔE_{00} foram analisados com ANOVA de dois fatores e testes de Tukey. Os valores de CAP_{00} foram analisados com ANOVA de três fatores para comparações entre grupos e ANOVA de medidas repetidas com testes de Bonferroni para avaliar os efeitos ao longo do tempo.
Resultados: No momento inicial, os valores de ΔE_{00} foram mais baixos no grupo A1 para ambos os tipos de amostras, seguidos por A2 e D4. Após 1 mês, a imersão em café resultou em valores de ΔE_{00} significativamente superiores aos da água destilada em todos os grupos. Os valores de CAP_{00} diminuíram significativamente entre 1 semana e 1 mês nos grupos armazenados em café. Todos os subgrupos de tonalidade e armazenamento apresentaram um aumento significativo do CAP_{00} ao longo do tempo ($p < 0{,}05$).
Conclusões: O armazenamento por um mês em água destilada melhorou o CAP em todos os grupos. Por outro lado, uma exposição prolongada ao café aumentou as diferenças de cor e reduziu a harmonia estética das restaurações com o tempo. (Rev Port Estomatol Med Dent Cir Maxilofac. 2025;66(3):115-123)

Palavras-chave:
Café
Cor
Agentes corantes
Resina composta
Materiais dentários