Received date: 28 November 2024 / **Accept date:** 19 February 2025

DOİ: 10.61139/ijdor.1592596

Evaluation of Color-Matching Ability of Different Single-Shade Composites in Repair of Aesthetic Composite Resins

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Abstract

Aim: The aim of the study was to evaluate the color-matching ability of four different single-shade composite resins used to repair of two multi-shade aesthetic composite resins after thermal aging.
Materials and Methods: A total of 100 disc-shaped samples, 50 from each of two aesthetic composites [GC Kalore (GC), A2 and Filtek™ Ultimate (FU), A2 body] were prepared with a height of 4 mm and a diameter of 10 mm. After initial surface preparation, the samples were aged through 5,000 thermal cycles. Subsequently, the surfaces were treated again using Sof- Lex discs and stored in distilled water at 37 ºC for 24 hours. Initial color parameters (L_1, a_1, b_1, C_1, h_1) were measured using a clinical spectrophotometer. The samples in each group were then randomly divided into five groups (n = 10 each) and numbered. Cavities of 2 mm depth and 6 mm diameter were prepared on the sample surfaces. After acid etching for 30 seconds, a two-step total-etch adhesive (Adper Single Bond 2) was applied, and the cavities were filled with four different single-shade composite resins (Omnichroma, Vittra APS Unique, Charisma Topaz One and Olident ONEshade). Control groups were restored with FU and GC. After polymerization procedure, the samples were again subjected to surface treatment with the disc polishing system and stored in distilled water at 37 ºC for 24 hours. Final color parameters (L_2, a_2, b_2, C_2, h_2) were measured, and the color change (ΔE_{00}) was calculated using the CIEDE2000 formula. The data were analyzed using two-way ANOVA and post-hoc Tukey tests.
Results: The ΔE_{00} values varied significantly depending on the single-shade composite used ($p<0.05$). The ΔE_{00} values of the control samples were 0.95 for GC and 1.20 for FU. Among the single-shade composites, the ΔE_{00} values ranged from 3.30 and 11.21. Olident ONEshade showed better color compatibility with lower ΔE_{00} values compared to other single-shade composites. The Vittra APS Unique group exhibited the highest ΔE_{00} values.
Conclusion: The color-matching ability of single-shade composites in the repair of aesthetic composites were variable. Additionally, all ΔE_{00} values for the single-shade composites exceeded the clinical perceptibility and acceptability thresholds, except for the control groups.

Research Article (HRU Int J Dent Oral Res 2025; 5(1):12-19)

Keywords: Color-matching, single-shade composite, dental esthetic, dental restoration repair.

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Introduction

In recent years, composite resin restorative materials have become widely preferred by dentists for restoring teeth to meet individuals' aesthetic expectations (1). Since their introduction to the market, resin composites have undergone continuous development (2). While early research primarily focused on improving physical properties such as polishability, wear resistance, and reducing polymerization shrinkage, manufacturers have recently placed greater emphasis on enhancing the aesthetic and optical properties of resin composites (3, 4). Resin-based restorative materials are commonly used because they easily match the color of natural teeth and meet patients' aesthetic expectations (5). The color-related properties of resin composites directly affect their aesthetic performance (6). For a successful aesthetic outcome, it is crucial for the resin composite used to achieve a seamless color match with the surrounding dental hard tissues (7).

Due to the polychromatic nature of teeth and the different optical properties of enamel and dentin, manufacturers have introduced various enamel and dentin resin composite shades with distinct optical characteristics to replicate natural teeth (2). Most resin composites on the market are available in shades ranging from A1 to D4, encompassing a total of 16 tones based on the Vita Classic shade guide (2). To achieve optimal color-matching and an aesthetically pleasing appearance in composite resin restorations, the layering technique, which involves using composites of different colors and opacities in various layers, has been employed for a long time (8). Since the optical properties of composites used in this technique vary significantly, clinicians should have sufficient knowledge about the materials used to predict the final shade of the restoration (9). The availability of multiple enamel and dentin shades complicates shade selection and matching, requiring a long learning curve for practitioners for each composite system (10).

With the introduction of nanotechnology into dentistry, manufacturers have begun offering single-shade resin composites instead of more complex shade systems (11). Composed of nanomers (nanofillers) and nanoclusters (12), these resin composites are noted for their "chameleon effect," achieving more effective color-matching with dental tissues (13). The concept of single-shade or "one-shade" resin composites has been developed to aesthetically mimic any color using a single nominal shade. These resin composites, formulated based on an extended color-matching approach, appear to blend seamlessly with adjacent teeth (9). The perceived color of a material is determined by the wavelengths of light reflected from its surface (14). In aesthetic restorative materials such as ceramics and resin-based composites, these wavelengths result from pigments incorporated into their composition (11). However, recent technological advancements have introduced single-shade resin composites with no added pigments, relying entirely on structural coloration for their optical properties a concept referred to as "smart chromatic technology" (11). This technology enables resin-based composites to respond to specific light wavelengths and accurately reflect a particular wavelength within the range of natural tooth colors (15).

Dynamic changes in oral pH and temperature caused by dietary habits, salivary composition, and aging can lead to degradation of resin composites during their clinical use (16). These changes may result in discoloration, wear, cracks, or fractures (17). In such cases, dentists may opt to repair a restoration instead of entirely replacing it, as full removal may not always be necessary. Repairing composite restorations is a minimally invasive approach that minimizes impact on the pulp and surrounding dental hard tissues (18). Existing resin composite restorations can be repaired by applying a new layer of resin composite (19). However, the altered optical properties of aged resin composites make achieving color harmony even more challenging (20, 21). In that regard, single-shade resin composites can offer a simpler restorative process and greater convenience for clinicians (2).

There is limited information regarding the color-matching ability of single-shade composites used in the repair of resin composite materials (11). Therefore, this study aimed to evaluate the color-matching ability of single-shade resin composites in the repair of different resin composite materials. The null hypothesis of this study posits that the color changes of aesthetic composites repaired with single-shade composites will be comparable and clinically acceptable.

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Materials and Methods

This study was conducted at the Department of Restorative Dentistry, Faculty of Dentistry, Erciyes University. Six different composite resins were used in this study, including two multi-shade aesthetic composite resins: Filtek Ultimate (A2 Body, 3M ESPE, USA) and GC Kalore (A2, GC Corporation, Tokyo, Japan), as well as four single-shade composite resins: Charisma Topaz One (Kulzer, Germany), ONEshade (Olident, Poland), Omnichroma (Tokuyama, Japan) and Vittra APS UNIQUE (FGM Dental, Brazil). The composition and detailed information of these materials are provided in Table 1. Sample size was determined using G*Power software (G*Power v.3.0.10, Franz Faul, Universitat Kiel, Germany) with an effect size of f = 0.4, a = 0.05 and power of the test p=0.86552 was found. (N=100)

Table 1. Detailed information about the materials used in the study

Composite Resins	Filler Type	Composition	Manufacturer
Kalore, A2 (multi-shade)	Nanohybrid	UDMA, DX-511(UDMA), Bis-EMA, lanthanide fluoride, strontium glass, barium glass, Fluoroaluminosilicate glass, silicon dioxide	GC Dental, Tokyo, Japan
Filtek Ultimate, A2 Body (multi-shade)	Nanofilled	Bis-GMA, UDMA, Bis-EMA, PEGDMA, TEGDMA, Zirconia, Silica	3M ESPE, St. Paul, MN, ABD
Omnichroma (single-shade)	Spherical Nanofilled	UDMA, TEGDMA, uniform sized supra-nano spherical filler (260 nm spherical SiO_2-ZrO_2) and composite fillers	Tokuyama Dental, Tokyo, Japan
Charisma Diamond One (single-shade)	Nanohybrid	advanced TCD matrix, BPA-free, and BrF B_2O_3-F-Al_2O_3-SiO_2, silica, TiO_2, fluorescent pigments, metallic oxide pigments, organic pigments,	Kulzer, Hanau, Germany
ONEshade (single-shade)	Microhybrid	UDMA, Bis-GMA, BDDMA, SiO_2, glass particles	Olident, Poland
Vittra APS UNIQUE (single-shade)	Nanohybrid	UDMA, TEGDMA, advanced polymerization system(APS) composition, co-initiators, silane, boron-aluminum-silicate glass	FGM Dental, Joinville, Brazil

Abbreviations: BDDMA:1,4-Butanediol Dimethacrylate; Bis-EMA: Ethoxylated bisphenol A glycol dimethacrylate; Bis-GMA: Bisphenol A-diglycidyl methacrylate; Bis-MEPP: bisphenol-A ethoxylate dimethacrylate; BPA: Bisphenol A; PEGDMA: Polyethylene glycol dimethacrylate; TCD: Tricyclodecane; TEGDMA: Triethylene glycol dimethacrylate; UDMA: Urethane dimethacrylate.

To prepare the samples, plastic molds measuring 10 mm in diameter and 4 mm in depth were used. A total of 100 samples, 50 from each of the aesthetic composites (Filtek Ultimate and GC Kalore), were fabricated in 2- mm-thick layers. These layers were cured at a light intensity of 1000 mW/cm² using a Valo light-curing unit (Ultradent, USA). After each 5 samples, the light intensity of the light-curing unit was checked using a radiometer. The surfaces of the samples were standardized by polishing with 600-grit and 1000-grit sandpaper by same operator (SB). Following surface preparation, the samples underwent thermal aging with 5,000 thermal cycles between +5°C and +55°C, with a dwell time of 30 seconds and a transfer time of 5 seconds.

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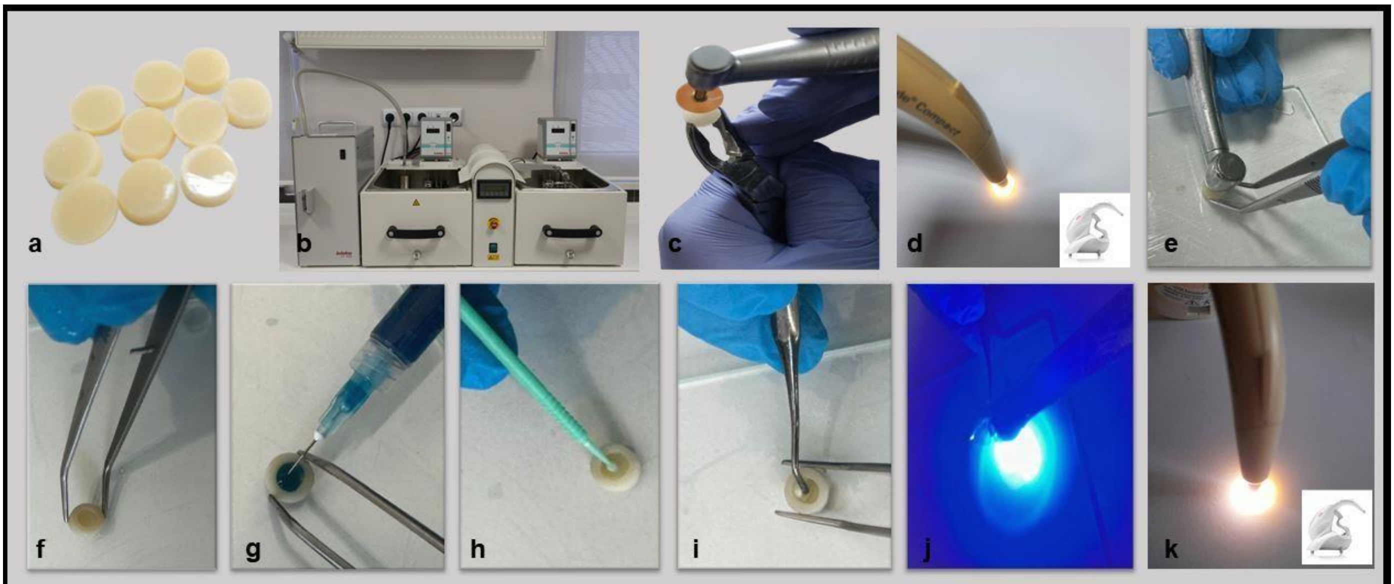
DOİ: 10.61139/ijdor.1592596

After thermal cycling, the surfaces of the samples were polished using a disc polishing system (Sof-Lex, 3M ESPE, USA) and subsequently stored in distilled water at 37°C for 24 hours. The initial color parameters of the composite samples were measured three times using a clinical spectrophotometer (Vita Easyshade Compact, Vita Zahnfabrik, Germany) by one operator (SB), based on the CIE L*a*b* color scale, and the average values of L_1, a_1, b_1, C_1, and h_1 were noted. Color measurements were made using a white background under standard conditions, and the device was calibrated at regular intervals using the calibration block on it, taking into account the manufacturer's instructions.

The samples in two groups were then randomly divided into five subgroups (n = 10) using table of random number and the samples were numbered 1 to 10 for each subgroup. Cavities measuring 6 mm in diameter and 2 mm in depth were prepared on the samples. The cavities were etched with acid for 30 seconds and treated with a 5th generation two-step etch rinse adhesive (Adper Single Bond 2, 3M ESPE, USA). Subsequently, the cavities were restored with the control materials (Filtek Ultimate or GC Kalore) or one of the four single-shade composite resins (Omnichroma, Vittra APS Unique, Charisma Topaz One, and Olident ONEshade) and cured 20 sec at a light intensity of 1000 mW/cm² using a Valo light-curing unit. After polymerization, the samples were polished again using the disc polishing system and stored in distilled water at 37°C for 24 hours. Final color measurements were performed three times, and the average values of L_2, a_2, b_2, C_2, and h_2 values were recorded. The images of the stages of the study were presented in Figure 1. Color changes (ΔE_{00}) were calculated using the CIEDE2000 formula (22).

The values were calculated using a formula defined in the Microsoft Excel program. Statistical analyses were performed using two-way ANOVA and Tukey's multiple comparison test. The level of significance was set at 0.05 (α=0.05).



a: prepared samples; **b:** thermal aging; **c:** surface treatment; **d:** 1st color measurement; **e:** cavity preparation
f: cavity; **g:** acid etching; **h:** application of adhesive; **i:** repairing procedure; **j:** polymerization; **k:** 2nd color measurement

Figure 1. Images of the stages of the study.

HRÜ Uluslararası Diş Hekimliği ve Oral Araştırmalar Dergisi
HRU International Journal of Dentistry and Oral Research
Received date: 28 November 2024 / **Accept date:** 19 February 2025
DOİ: 10.61139/ijdor.1592596

Results

The statistical analysis of color change values revealed that the color changes (ΔE_{2-1}) observed in the repaired aesthetic composite resins were significantly influenced by the type of single-shade composite used ($p \leq 0.001$). The lowest values were found in the control group ($p<0.001$). The color changes (ΔE_{2-1}) values are presented in Table 2.

Table 2. ΔE00 values for the study groups

Groups	Kalore	Filtek Ultimate	p values
Control group (KAL-KAL) & (FU-FU)	0.95 ± 0.12 ^{A}	1.20 ± 0.16 ^{A}	0.0756
Omnichroma	7.66 ± 0.38 ^{B}	7.15 ± 0.39 ^{BX}	0.0620
Vittra APS UNIQUE	10.34 ± 0.49 ^{C}	11.21 ± 0.25 ^{D}	<0.001
Charisma Topaz One	6.69 ± 0.29 ^{EX}	6.41 ± 0.28 ^{E}	0.0693
ONEshade	3.68 ± 0.62 ^{F}	3.30 ± 0.22 ^{F}	0.318
p-values	< 0.001	< 0.001	

*Groups with the same superscript capital letters are statistically similar.

Among the single-shade composites, Olident ONEshade demonstrated better color compatibility by exhibiting the lowest color change values. Conversely, the greatest color change values were observed in the Vittra APS Unique group. Except for Vittra APS Unique, the other single-shade composites showed statistically similar color change values for repairing both aesthetic composites ($p>0.05$).

Examining the ΔL, ΔC and Δh values, the lowest values were again found in the control group (Tables 3-5). The highest ΔL and ΔC values were observed in the groups where both composite types were repaired with Vittra APS Unique. The highest Δh value was recorded for the repair of the Kalore composite resin using Omnichroma. While there was no statistically significant difference in the ΔL, ΔC, and Δh values among the control groups, the ΔC values in the repairs performed with ONEshade and the Δh values in the repairs performed with Vittra APS Unique for both aesthetic composites were statistically similar among the single-shade groups ($p>0.05$). The ΔL, ΔC, and Δh values for the other single-shade composites varied significantly depending on the repaired composite resin.

Tablo 3. ΔL values for the study groups

	Kalore	Filtek Ultimate	p-values
Control group (KAL-KAL) & (FU-FU)	0.25 ± 0.06 ^{A}	0.32 ± 0.10 ^{A}	0.0671
Omnichroma	4.46 ± 0.70 ^{B}	1.53 ± 0.25 ^{C}	<0.001
Vittra APS Unique	6.11 ± 0.31 ^{D}	2.34 ± 0.80 ^{E}	<0.001
Charisma Topaz One	5.68 ± 0.55 ^{D}	0.40 ± 0.24 ^{A}	<0.001
ONEshade	2.09 ± 0.52 ^{E}	1.14 ± 0.22 ^{F}	<0.001
p-values	<0.001	<0.001	

*Groups with the same superscript capital letters are statistically similar.

Table 4. ΔC values for the study groups

	Kalore	Filtek Ultimate	p-values
Control group (KAL-KAL) & (FU-FU)	2.34 ± 0.19 ^{A}	2.24 ± 0.14 ^{A}	0.112
Omnichroma	8.19 ± 0.66 ^{B}	10.95 ± 0.58 ^{C}	<0.001
Vittra APS Unique	14.51 ± 0.92 ^{D}	18.07 ± 0.78 ^{E}	<0.001
Charisma Topaz One	9.08 ± 0.27 ^{F}	11.33 ± 0.57 ^{C}	<0.001
ONEshade	6.06 ± 0.83 ^{G}	6.11 ± 0.18 ^{G}	0.231
p-values	<0.001	<0.001	

*Groups with the same superscript capital letters are statistically similar.

Tablo 5. Δh values for the measurements

	Kalore	Filtek Ultimate	p values
Control group (KAL-KAL) & (FU-FU)	2.34 ± 0.19 ^{A}	2.24 ± 0.14 ^{A}	0.092
Omnichroma	23.06 ± 1.28 ^{B}	15.44 ± 1.16 ^{C}	<0.001
Vittra APS Unique	17.18 ± 1.74 ^{D}	19.19 ± 1.33 ^{D}	0.064
Charisma Topaz One	7.67 ± 0.96 ^{E}	3.44 ± 0.31 ^{F}	<0.001
ONEshade	3.07 ± 0.25 ^{F}	1.63 ± 0.10 ^{G}	<0.001
p-values	<0.001	<0.001	

*Groups with the same superscript capital letters are statistically similar.

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Discussion

This study evaluated the color-matching capability of four different single-shade resin composites used for the repair of two aesthetic composite resin materials. Resin-based composite materials, due to their variations in filler particle type, size, and shape, as well as differences in monomer formulations, can exhibit differing optical properties even when labeled with the same color code. These discrepancies can result in varied aesthetic outcomes (23). While color assessment of restorations can be performed visually or using devices, environmental lighting conditions can influence visual assessments. However, device-based measurements are considered more reliable as they provide objective and quantitative data (24). In this study, the Vita Easy Shade Compact dental spectrophotometer was used. Since this device has its own light source to illuminate the tooth surface being measured, the results are unaffected by ambient lighting conditions, as evidenced by various studies (25, 26).

In the literature, there are differing views on the acceptability and perceptibility thresholds of color changes in dental restorations (27). Paravina et al. (28) recently reported that the perceptibility threshold is $\Delta E_{00} = 0.8$, while the acceptability threshold is $\Delta E_{00} = 1.8$. The results of this study demonstrated that the ΔE_{00} values for aesthetic composites repaired with single-shade composites -excluding the control groups- were all above the acceptability threshold (>1.8), with values varying depending on the single-shade composite used. As a result, the null hypothesis was rejected.

The number of studies investigating the color-matching ability of single-shade resin composites for the repair of resin-based materials is limited. In a study by Çalışkan et al. (2), the color compatibility of two different single-shade resin composites was evaluated for the repair of various resin-based materials and ceramic resin hybrid CAD/CAM blocks. Their findings indicated that the color-matching performance of single-shade composites was not clinically acceptable for either early or post-thermal-cycle repairs. The use of multi-shade systems for repairs of materials with the same multi-shade system yielded clinically acceptable ΔE_{00} values (2). Consistently, in our study, while the ΔE_{00} values of aesthetic composites repaired with single-shade composites exceeded the acceptability threshold, the control groups repaired with the same composite material displayed clinically acceptable ΔE_{00} values.

In a study by Buldur et al. (29), the color compatibility of three different composite resin materials (Omnichroma, ZenChroma, and Charisma Topaz One) was evaluated after repair using identical or different single-shade composites, following aging in coffee solution and distilled water. The evaluation focused on color change parameters (ΔE_{00}, ΔL_{00}, ΔC_{00} and ΔH_{00}). Significant differences were found in the mean ΔE_{00} measurements among the three composite resins across all timepoints ($p<0.05$). Similarly, for each study group, the mean ΔE_{00} measurements for each composite resin over time also showed statistically significant differences ($p<0.05$) (29). In the distilled water-aged groups, initial measurements of the materials repaired with the same material were within acceptable ΔE_{00} thresholds. In the coffee solution-aged groups, the final measurements for the materials repaired with the identical material were also within acceptable ΔE_{00} limits (29).The single-shade composites used in the present study are materials with high translucency properties. Differences in color change values depending on the repair composite used may be due to differences in the content of the material and its translucency properties. During the preparation of the samples, it was observed that the composites had different translucency. In fact, due to their different translucency, color matching abilities may have varied. In clinical conditions, the surface of the composite to be repaired should be prepared and adhesive application should be made before repair. Therefore, adhesive application was made to the surface in a standard manner in all groups. The adhesive applied to the interface may affect the color parameters in the color measurement. This may also affect the color change values due to differences in translucency.

As with all in vitro studies, this study has certain limitations. Restorations in the oral environment are exposed to various factors, such as fluctuating temperatures, masticatory forces, and organic acids produced by bacteria. Additionally, intraoral restorations typically have a convex surface rather than the flat surfaces created in in vitro studies. These differences in surface geometry affect light reflection, thereby directly

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influencing aesthetic parameters. The inability to fully simulate these conditions in in vitro settings constitutes a limitation of this study. With ongoing advancements in the physical, mechanical, and optical properties of single-shade composite materials, there is a growing need for more in vivo and in vitro studies that can better reflect intraoral dynamics to evaluate the color-matching capabilities of these materials when used to repair aesthetic composite resins.

Conclusion

Within the limitations of this study, the degree of color compatibility varied depending on the single-shade composite materials used for repairing aesthetic composites. The color-matching performance of single-shade resin composites utilized for delayed repair of different resin-based materials was not clinically acceptable. The observed color change values, except for the control group, exceeded the clinically acceptable threshold. Clinicians should consider this information when performing repairs using single-shade resin composites.

Acknowledgments
This study was presented as an oral presentation at the Gaziantep University 1st International Dentistry Congress held in Gaziantep/Türkiye between 25-27 October 2024.
Author contributions: SB and VK. conceived the ideas; VK. developed the theory and performed the computations; S.B conducted the method of study; SB and VK collected the data; VK and HB analyzed the data; and all authors discussed the results and contributed to the final manuscript and led the writing.
Conflict of Interest: The authors declare that they have no conflict of interest.
Ethical approval: This article does not contain any studies with human participants oranimals performed by any of the authors.

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Received date: 28 November 2024 / **Accept date:** 19 February 2025
DOİ: 10.61139/ijdor.1592596

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