Research Article

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Color match evaluation using instrumental method for three single-shade resin composites before and after in-office bleaching

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Abstract: The aim of this study is to evaluate the effect of an office bleaching agent on the color of various single-shade resin composites. Three single-shade resin composites were tested in this study. Thirty disk-shaped specimens were prepared with a diameter of 10 mm and a height of 1 mm, and they were divided into three groups ($n = 10$). After color measurements, 40% hydrogen peroxide containing bleaching agent gel was applied to all the specimens. Baseline and final color measurements were performed using a clinical spectrophotometer. Statistical analyses were performed. All bleached specimens had clinically incomprehensible color changes ($\Delta E < 3.3$). Comparisons for single-shade composites revealed no statistically significant color difference between groups. With the limitation of this study in mind, color changes in single-shade resin-composites after office bleaching were found to be clinically acceptable. It may be appropriate to use single-shade composites that shorten the in-chair clinical time by facilitating shade selection.

Keywords: blending, Chameleon effect, single-shade universal composite, office bleaching, color matching

1 Introduction

An increased level of social awareness has increased the demand for aesthetics and color harmony in restorative dental treatments. Resin composites are widely used for direct restorations on anterior and posterior teeth because of their aesthetic and mechanical properties [1]. However, the major problems regarding resin composites are polymerization shrinkage, water absorption, abrasion, microleakage, secondary caries, and color stabilization [2]. Resin composites that shorten chair time and minimize technical sensitivity are highly desirable among clinicians. Color selection for composite restorations is difficult due to environmental and operator-dependent variables. Thus, the trend of simplifying color change has led to the introduction of universal-shade composites [3]. The advantage of universal-shade composites is their enhanced color-adjustment potential, which refers to the interaction between perceptual and physical components [4].

Vital tooth bleaching is one of the most commonly performed aesthetic dentistry treatments, as it is a non-invasive, effective, and easy way to lighten discolored teeth. Society's interest in tooth whitening has increased recently. As compared to restorative treatment options, teeth whitening is one of the most conservative methods. The mechanism of tooth whitening is based on the redox reaction, in which the free oxygen released after the hydrogen peroxide (HP) decomposes creates chromatic discoloration in the dental tissues [5,6]. One major reason to replace anterior restorations is problems in color stability [7]. The discoloration of resin composites with bleaching agents has been related to the oxidation of surface pigments and amine compounds. The amount of conversion of resin matrix into the polymer matrix and the ratio of resin matrix in the composite can lead to color variation between different resin composites. Organic matrix compounds, which are less resistant to acidic contents in bleaching agents, can be colored more; this leads to differences in color changes in composite restorations [8].

Pre-existing resin composite restorations are exposed to bleaching agents during whitening. Therefore, the effect of whitening agents on resin composites, which are required to have properties similar to those of dental tissues, is gaining importance. Adverse effects on the part of bleaching associated with the surface morphology and chemical, physical, and aesthetic properties of resin composites have been

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reported, while other studies have found no such changes [9–14]. With this contradictory picture, it is important to evaluate newly developed materials. Forty percent HP gel was used in this study. According to the researchers, the concentration of HP decreases during clinical application [15].

The most commercially used bleaching materials are HP and carbamide peroxide (CP). CP decomposes into HP and urea in the oral environment. Due to the components of HP, which are free radicals, reactive oxygen, and anions, HP is a potent oxidizing agent [16]. HP-based agents, which can cause the deterioration of restorations' physical and chemical properties, are most likely to come into contact with restorative materials during tooth bleaching. If there is a perceptible change in the color of the restoration after bleaching, the interaction of composite restorations with whitening preparations may be of practical importance [17].

Universal shade concepts were created by modifying formulations for resin composites. Some studies have been performed concerning the optical properties of single-shade resin composite materials. Although both manufacturers and independent researchers have, in this way, obtained some data on the mechanical stability of single-shade resin composite materials, there are still many areas to be investigated [18–20].

Spectrophotometers are widely used for color measurement in dentistry [21]. A previous study reported that VITA Easyshade's accuracy in terms of shade measurement was 92.6% *in vitro* [22]. Accordingly, VITA Easyshade was used to measure the color of specimens before and after the bleaching procedure. The CIE $L^*a^*b^*$ color system was chosen to measure color changes in this study. While a ΔE value equal to 1 corresponded to the value clinically detectable, ΔE values greater than 3.3 were considered clinically unacceptable [8].

When a bleaching agent is applied to single-shade composites, the combined effect of the color change in composite occurs due to both the bleaching agent and the blending effect, which will occur due to the lightening of the tooth color. Thus, this study aims to investigate the effect of an office bleaching agent on the color change in various single-shade resin composites. The null hypothesis is that the in-office bleaching procedure will not change the color of single-shade composites.

2 Methods

2.1 Specimen preparation

The single-shade resin composites used in this study were the Vittra Unique (FGM, Joinville, SC, Brazil), Omnichroma (Tokuyama, Tokyo, Japan), and OptiShade (Kerr Corporation, CA, USA), as shown in Table 1. Thirty disc-shaped specimens were prepared in a polytetrafluoroethylene mold with a diameter of 10 mm and a height of 1 mm (n = 10). Single-shade composites were placed in the mold and covered with mylar strips (Hawe Stopstrip, KerrHawe, Bioggio, Switzerland) on the top and bottom surfaces of the mold and pressed between two glass slides. The resin was polymerized with a visible blue LED light device (Ultradent Products, Inc, South Jordan, USA) for 20 s. Before each polymerization process, a radiometer was used to measure the light intensity of the curing unit (Model 100, Demetron/Kerr, Danbury, ABD). The disc-shaped specimens were placed in an incubator (FN 500, Nüve, Turkey) for 24 h in distilled water at 37°C and polished with medium, fine, and superfine aluminum oxide discs (Optidisc Kerr Corporation, 1717 W. Collins Ave., Orange, CA 92867 USA).

2.2 Color measurements

Baseline color measurements were performed with a clinical spectrophotometer (Vita Easyshade V, VITA Zahnfabrik,

Table 1: Materials used in the study

Resin composite	Manufacturer	Type	Organic matrix	Inorganic filler
Vittra unique	FGM, Joinville, SC, Brazil	Nanohybrid	UDMA, TEGDMA	Active ingredients: photoinitiator composition (APS), co-initiators, stabilizer, and silane. Inactive ingredients: The nanospheres of a complex of silica-zirconia
Omnichroma	Tokuyama, Tokyo, Japan	Supra-nano spherical	UDMA, TEGDMA	260 nm spherical SiO_2–ZrO_2
OptiShade	Kerr Corporation, CA, USA	Nanohybrid	Bis-EMA, Bis-GMA, TEGDMA	Barium glass, silica, ytterbium trifluoride

Abbreviations: Bis-GMA = Bisphenol A-glycidyl methacrylate, TEGDMA = triethylene glycol Di methacrylate, UDMA = urethane dimethacrylate, Bis-EMA = bisphenol A ethoxylated dimethacrylate. The data were provided by the manufacturers.

Bad Sackingen, Germany) in a custom-made viewing booth with D65 illumination (Master TL-D 90 De Luxe 18 W/965 1SL, Philips, Eindhoven, Holland). The detector was perpendicular to the sample surface, the background was white, and measurements were taken in a room with daylight; the spectrophotometer was calibrated for each measurement. “Single tooth” mode was selected on the spectrophotometer, and the probe was placed in the center of the specimen. Three consecutive measurements were made for each specimen, and the mean L^*, a^*, and b^* values were recorded. The CIELAB color system was used to evaluate the measurements of luminosity (L^*), red-green coordinate (a^*), and yellow-blue coordinate (b^*).

2.3 Bleaching protocols

The specimens were divided into three groups based on the single-shade composites ($n = 10$). After the initial color measurements, 40% HP gel (Opalescence Boost 40% Ultradent Products INC, South Jordan, Utah, USA) was applied to all specimens. The bleaching agent was applied in two cycles of 20 min each according to the manufacturer’s instructions. After the first application was finished, the gel was wiped with cotton pellets, and the gel was applied for the second time. Specimens were cleaned under running water for 1 min and dried after the bleaching procedure. Before and after the bleaching protocol cycles, all samples were immersed in distilled water and stored in an oven at 37°C (Star Dental 320S; İstanbul, Türkiye). The CIE $L^*a^*b^*$ values were recorded for each specimen, as previously described, after the bleaching treatment. The color change is calculated by before and after bleaching values, which are the ΔL, Δa, and Δb values. The following formula represents the total color change: $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. A flowchart (Figure 1) summarizes the methodology used.

2.4 Statistical analysis

Statistical analyses were performed using SPSS Statistics software Version 22.0 (IBM, SPSS Inc., Chicago, IL, USA). The suitability of the parameters to the normal distribution was evaluated with Kolmogorov–Smirnov and Shapiro–Wilk tests. While evaluating the study data, the Kruskal–Wallis test was used for intergroup comparisons of parameters and descriptive statistical methods (minimum, maximum, mean value, standard deviation, and median). $P = 0.05$ was considered the level of statistical significance.

3 Results

The ΔE values of the Omnichroma group ranged from 0.36 to 1.39, with a mean value of 0.89 ± 0.27 and a median value

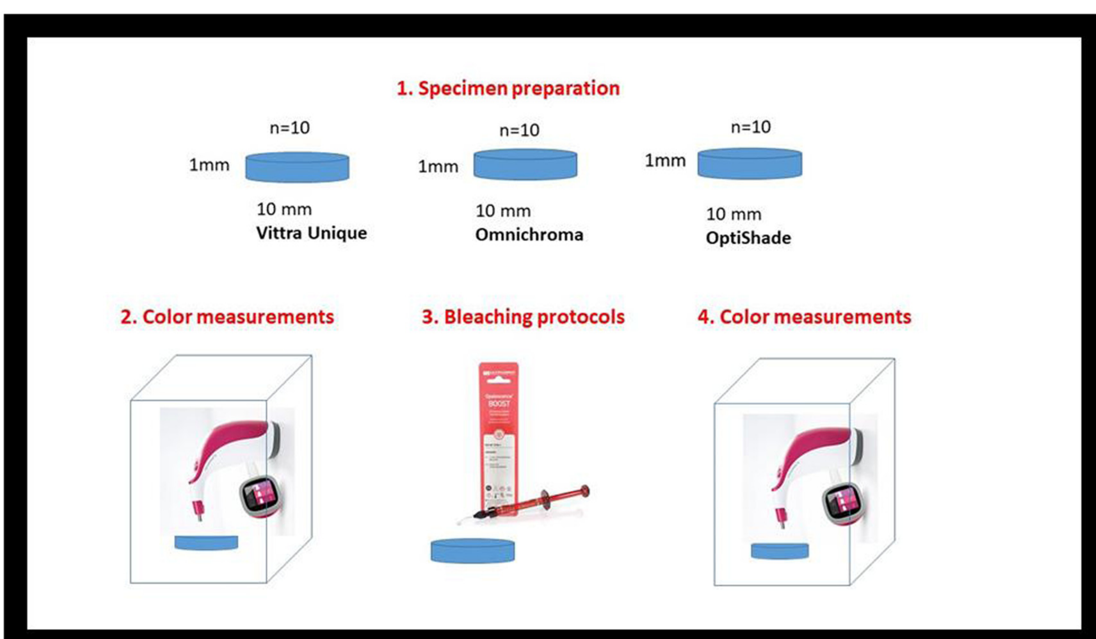

Figure 1: Flowchart summarizing the methodology.

of 0.88. The ΔE values of the OptiShade group ranged between 0.26 and 1.49, with a mean value of 0.74 ± 0.42 and a median value of 0.62. The ΔE values of the Vittra Unique group ranged from 0.12 to 2.67, with a mean value of 0.75 ± 0.75 and a median value of 0.51. All bleached specimens had clinically incomprehensible color changes ($\Delta E < 3.3$). The ΔE values for the various composites are represented in Figure 2. The standard deviations and minimum, maximum, and median values for mean color differences (ΔE) are displayed in Table 2. Comparisons between Vittra Unique, Omnichroma, and OptiShade revealed no statistically significant color differences between groups. The results of the Kruskal–Wallis test are given in Table 2. Although it was not statistically significant, the Omnichroma had the most color change, and the Vittra Unique had the least color change among the groups.

4 Discussion

This study aimed to examine the color change in newly developed single-shade composites after an office bleaching procedure. According to the results of the present study, the null hypothesis was accepted because there were no significant differences in color change between the resin composites after being subjected to the bleaching protocols.

Spectrophotometers are widely used for color measurement in dentistry [21]. A previous study reported that VITA Easyshade's accuracy of shade measurement was 92.6% *in vitro* [22]. Accordingly, VITA Easyshade was used to measure the color of specimens before and after the bleaching procedure. The CIE $L^*a^*b^*$ color system was chosen to measure color changes in this study. While a ΔE value equal to 1 corresponded to the value that was clinically detectable, a ΔE value greater than 3.3 was considered clinically unacceptable [8]. ΔE values were less than 3.3 in all groups in the present study.

The color change due to bleaching depends on the matrix structure of the resin composites, its volume, and the type of filler particles [15,21–23]. The role of HP in the bleaching mechanism is based on the release of free radicals that bind to organic molecules and other substances in the composite's organic component, causing the polymer chains and carbon bonds to break [17].

Restorative materials aim to imitate natural dental tissues. Single-shade resin composites have been introduced because they have light-scattering properties similar to the enamel and dentin [19]. The color match of the restoration is more successful when the composite reflects the color of the tooth tissue to which it is applied [24].

The mechanism of color changes caused by bleaching in restorative materials is still unclear [25]. Free prehydroxyl (HO_2^-) radicals formed by the degradation of H_2O_2 can induce the oxidative cleavage of polymer chains. Moreover, free radicals are combined to form oxygen and water, which speeds up the hydrolytic degradation of resin composites and, thus, affects color changes [25]. According to previous studies, the composites with higher resin content are expected to break down more and may undergo more color change, as well as those with higher filler content being more resistant to bleaching agents [23,25,26]. The high filler content can explain the translucence of single-shade composites. It has been shown that the higher the filler ratio, the higher the translucency value and, accordingly, the greater the blending effect [27,28]. Single-shade resin composites can assimilate the color of teeth or surrounding structures and improve color uniformity. Known as the "chameleon effect," this phenomenon is commonly used in conjunction with the blending effect [27]. Bleaching agents have peroxides that cause surface roughness and degradation of the organic matrix complex of resin composites [29]. Bleaching materials eliminate the external discoloration on the tooth, but composite restorations do not whiten in the same way as the tooth structure does [29].

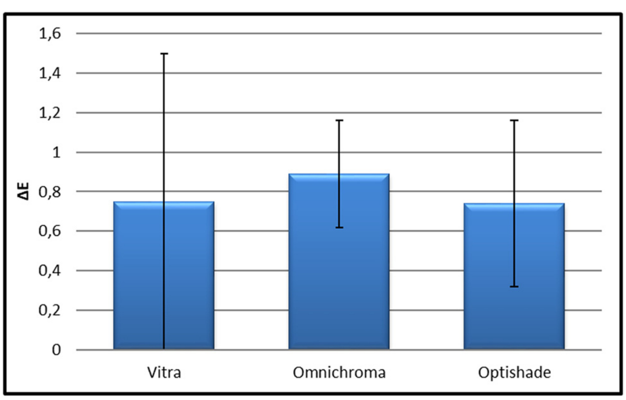

Figure 2: ΔE values for different composites.

Table 2: Results of all interactions among the groups in terms of ΔE values

	ΔE		
	Min–max	**Ort ± SS**	**Median**
Vittra unique	0.12–2.67	0.75 ± 0.75	0.51
Omnichroma	0.36–1.39	0.89 ± 0.27	0.88
OptiShade	0.26–1.49	0.74 ± 0.42	0.62
P		0.205	

Kruskal–Wallis test.

Considering all this, the blending or the chameleon effect may have been less affected by the bleaching agents, and thus, single-shade composites reflected the white background. HP, as used in this study, releases free oxygen during ionization; thus, the discolored pigments oxidized on the tooth enamel, and the organic materials are broken down [30]. Because single-shade composites have a blending effect, the color they reflect may lighten as the tooth tissue underneath becomes whiter, but we believe that the thickness of the composite layer may have an effect on the blending effect. As the thickness of the composite layer increases, it will most likely reflect the color of the tooth tissue whitening from below. Consequently, the color change was found to be limited in the present study. Moreover, because the thickness of the translucent specimens was 1 mm, they were more likely to reflect the underlying white background during color measurement.

Omnichroma is a uniformly sized 260 nm spherical filler containing a single-shade composite that does not contain pigments, according to the manufacturer. The color properties of the material are based on the surrounding structural properties and intelligent chromatic technology that controls the optical properties of the resin composite. This type of filler leads to a structural color phenomenon. In previous studies, statistically significant differences in ΔE values were observed [31,32], indicating a lighter shade [31]. According to another study, Omnichroma had the highest ΔE value in the photographic evaluation, which was confirmed by our research, while it had the highest color match in visual analysis [3]. Although not statistically significant, Omnichroma had the lowest color match and highest ΔE values in this study.

According to the manufacturer, the main filler of OptiShade is spherical silica and zirconia particles shaped from a molecular suspension. OptiShade has an average filler ratio of 50 nm [19,33]. Adaptive response technology, which is also included in OptiShade, contains a two-component member of the filler system. First, the zirconia and silica nanoparticles are arranged so as to reveal unique optical properties [33]. In particular, OptiShade exhibits light diffusion properties similar to natural enamel. While enamel reflects light more diffusely at lower wavelengths, it reflects specularly at longer wavelengths [33]. To mimic this property, the zirconia/silica particles work together, resulting in a much more harmonious restoration, or the "chameleon effect." Lower ΔE values that were not statistically significant were obtained with OptiShade as compared to Omnichroma in the present study. This may be due to the difference between the average particle sizes contained in the OptiShade. Smaller average particle size provides better polishability and a smoother surface.

Vittra Unique has been shown to have the lowest ΔE values based on a post-curing color match [34]. These findings are consistent with this study. Vittra Unique had the lowest ΔE values, as compared to Omnichroma and OptiShade, in this study, though this difference was not statistically significant. It may have performed better in terms of color change because it uses the advanced polymerization system (APS) [35]. The APS technology, as a more transparent photoinitiator in Vittra Unique, may have resulted in the lowest ΔE values. It is also free of bisphenol A-glycidyl methacrylate (Bis-GMA) but contains urethane dimethacrylate (UDMA) and a smaller amount of camphorquinone, according to the manufacturer. Previous studies have found less color change, which is consistent with this study's findings [36,37]. This system's application improves composites' properties by increasing the degree of conversion while increasing the aesthetic quality of the profile [35].

Composites containing Bis-GMA monomer show less color difference according to the rigid network formation as compared to triethylene glycol Di methacrylate (TEGDMA), as well as more color difference than UDMA and bisphenol A ethoxylated dimethacrylate (Bis-EMA) [32]. Similar to the previous findings, Omnichroma containing TEGDMA showed the highest ΔE values, although this was not statistically significant in this study [3,32]. Although Vittra Unique also contains TEGDMA and UDMA, like Omnichroma, the results may depend on Vittra Unique's filler content and APS technology.

Although they were not statistically significant, the different ΔE values obtained in this study may be attributed to single-shade composites' inorganic and organic contents, different filler sizes, and different color reflection systems [38]. Structural color and composite translucency are affected by the refractive indexes of the organic matrix and filler content [38,39]. According to the manufacturer, Vittra Unique's color-adjustment ability is due to the material's translucency, which is especially increased after polymerization [38]. During the polymerization of the monomers, the refractive index of the organic matrix increases, reducing the disharmony with the inorganic fillers [38]. The lowest ΔE observed for Vittra Unique in this study can be associated with these factors above.

This study had certain limitations. In order to perform clinically successful color evaluations, it is necessary to mask the background or measure the color of the resin composite surrounded by natural dental tissues. Moreover, this is an *in vitro* study measuring the color match of single-shade composites before and after bleaching agent application. In clinical use, discoloration can reveal differences between the fluids in the mouth and the food eaten. Further studies are needed to assess universal shade composites' physical and optical properties and surface roughness. Based on the results of this *in vitro* study, it would be beneficial to conduct clinical studies examining the effects of coloring foods after bleaching.

5 Conclusion

With the limitation of this study in mind, color changes in single-shade resin composites after office bleaching were found to be acceptable. All bleached specimens had clinically incomprehensible color changes ($\Delta E < 3.3$). Although not statistically significant, the color change for Omnichroma was greater than those of Vittra Unique and OptiShade. Vittra Unique and OptiShade had similar color-change results. The effect of the bleaching agent on all single-shade composites tested in this study was found to be clinically acceptable.

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Data availability statement: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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