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# The Visual and Instrumental Analyses of Different Single-Shade Resin Composites

# Análisis visual e instrumental de diferentes resinas compuestas omnicromáticas

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ABSTRACT: The purpose of this study was to evaluate the color adaptation of single-shade resin composites applied to different tooth shades. A total of 108 class III preparations (n=6) were performed on the acrylic denture maxillary incisors (2mm depth and 2mm height). 5 single-shade resin composites (Vittra APS Unique, Omnichroma, ZenChroma, Clearfil Majesty ES-2 Universal, Charisma Topaz One) and 1 multishade resin composite (Estelite Asteria) were placed in the cavities and polished. I performed visual and instrumental color analyses. The CIEDE2000 formula was used to assess the shade differences (ΔE) between teeth and restorations. The obtained ΔE values were recorded and statistically analyzed. For the instrumental analysis, ZenChroma in A1 shade groups showed statistically significant higher differences ($p<0.05$). Among all tested materials, A3 shade groups showed lower ΔE values ($p<0.05$). For the visual analysis, there were no significant differences between materials and scores in A1 and A3 shade groups ($p>0.05$). There were statistically significant differences between the materials and the scores in A2 shade groups ($p<0.05$). As a result of this study, it was concluded that, making esthetic restorations with single-shade resin composites promises proper color adaptation, but their properties still need improvement. Single-shade resin composites can reduce chair-time and technical sensitivity with good color matching.

KEYWORDS: Color; Color matching; CIEDE2000; Blending effect; Single-shade resin composites; Smile Lite MDP.

RESUMEN: El objetivo de este estudio fue evaluar la adaptación del color de resinas compuestas omnicromáticas. Se realizaron un total de 108 preparaciones de clase III (n=6) en los incisivos superiores de prótesis acrílicas (2mm de profundidad y 2mm de altura). Se colocaron cinco resinas compuestas omnicromáticas (Vittra APS Unique, Omnichroma, ZenChroma, Clearfil Majesty ES-2 Universal, Charisma Topaz One), además de una resina multitono (Estelite Asteria) en las cavidades y se pulieron. Se realizó el análisis de color visual e instrumental. Se utilizó la fórmula CIEDE2000 para evaluar las diferencias de tono (ΔE) entre dientes y restauraciones. Los valores de ΔE obtenidos se registraron y analizaron estadísticamente. Para el análisis instrumental, ZenChroma en los grupos de color A1 mostró diferencias mayores estadísticamente significativas ($p<0,05$). Entre todos los materiales probados, los grupos de tonos A3 mostraron valores de ΔE más bajos ($p<0.05$). Para el análisis visual, no hubo diferencias significativas entre materiales y puntuaciones en los grupos de color A1 y A3 ($p>0,05$). Hubo diferencias estadísticamente significativas entre los materiales y las puntuaciones en los grupos de color A2 ($p<0,05$). Como resultado de este estudio, se concluyó que la realización de restauraciones estéticas con resinas compuestas omnicromáticas promueve una adecuada adaptación del color, pero aún necesitan mejorar sus propiedades. Las resinas compuetas omnicromáticas pueden reducir el tiempo de atención clínica y la sensibilidad técnica con una adecuada combinación de colores.

PALABRAS CLAVE: Color; CIEDE2000; Resinas compuestas omnicromáticas; Sonrisa Lite MDP.

## INTRODUCTION

Achieving a perfect color match between natural teeth and restorations is of paramount importance to the patient and is a key factor in the acceptability of the restorations. The increasing aesthetic demands of patients have accelerated the development of restorative materials that mimic the optical properties of natural teeth (1,2). With the development of adhesive technology, resin composites, which are one of the most used materials to meet this aesthetic expectation, have increased their use in dentistry due to their being conservative, having a relatively low cost, good mechanical properties, and aesthetic outcomes (3). Achieving the best results for dental restorations is very important since they would have the same appearance as natural teeth, and, moreover, they would be able to maintain this natural appearance over time (4).

Color selection is a subjective procedure. It can be affected by environmental factors and can also differ between dentists due to their experiences, age, etc. The polychromatic structure of natural teeth is one of the factors that makes color selection difficult. Inadequate color matching of composite restorations with adjacent teeth or the surrounding tooth structure can cause unsatisfactory aesthetic results. The way to overcome this problem is to use the layering method along with the right color selection (5). In this method; by using composites in different opacities and chromas in each layer, the optical properties of natural tooth color are tried to be imitated (6). This variety of colors in natural teeth has led manufacturers to produce composite systems containing various shades of color, often using the Vita Classical Shade Guide (Vita Zahnfabrik) as a reference (7). Numerous enamel and dentin shades have been developed with different translucencies and opacities. However, the multitude of color options not only complicates the color selection procedure but also increases the cost and the chair-time. Therefore, it has recently been suggested by companies that by adding improved color properties to universal resin composites, sufficient aesthetic results can be obtained with fewer color options and even a single-color option in some products. These resin composites and restorative techniques, which provide simplified clinical procedures, have also reduced the chair-time, as they have eliminated the color selection step. These materials are frequently preferred by dentists because they minimize technical sensitivity (8,9).

A great deal of laboratory and clinical research has been conducted to understand the optical behavior of resin composites and their interaction with dental tissues. These studies aimed to accurately measure color and determine the color match between restorations and healthy tooth structure. Therefore, different methods are suggested in the literature for the evaluation of color matching (10-12).

Two main techniques are generally preferred for color analysis: the visual technique using tooth-shaped color scales and the instrumental technique using color measuring devices. The visual technique is subjective and depends on factors such as the lighting conditions, the observer's perception of color, translucency, and the optical properties of the material being examined (13). In the instrumental technique, the color can be measured quantitatively with devices such as colorimeters, spectrophotometers, and digital cameras.

There are three coordinates: L*, the luminosity of the object, a*, the chroma in the green-red axis saturations, and b*, the chroma in the blue-yellow axis saturations. Each color has a specific numerical value that describes its objective characteristics and helps in color communication. CIELAB ($\Delta E_{ab}$) or CIEDE2000 formula ($\Delta E_{00}$) over L*, a*, and b* values are used to calculate the color changes. The CIEDE2000 ($\Delta E_{00}$) color change formula was developed by the International Commission on Illumination (CIE, Commission Internationale de l'Eclairage), and all variables are considered equally. It has been developed to detect an acceptable and perceptible color change more appropriately and accurately by making modifications to the factors that affect the perception of the eye more dominantly in order to eliminate the deficiencies in the CIELab ($\Delta E^*_{ab}$) system (14,15).

This study has aimed to evaluate the color adaptation of single-shade resin composites applied to different tooth shades. The null hypothesis is:

There is no significant difference between the color adaptation of the single-shade resin composites.

## MATERIALS AND METHODS

### SAMPLE PREPARATION

Natural human teeth have different opacities with different thicknesses of the enamel and dentin tissues. To standardize the study, acrylic denture teeth (Ivostar; Ivoclar Vivadent Ltd. São Paulo, Brazil) with three different Vita Classical Shades (A1, A2, and A3) were used in this study. A total of 108 class III preparations (n=6) were performed on the acrylic denture maxillary incisors. Mesial and distal preparations were performed by a single operator using #1014 diamond burs

(2mm in height and 2mm in depth). Cavities were prepared on the buccal surfaces in the middle of the incisor-gingival height of the teeth, and then cavities were cleaned using an air syringe. A universal adhesive (Scotchbond Universal, 3M ESPE, USA) was applied to the cavities for 10 sec with a micro-brush applicator, dried with a gentle airflow for at least 10 sec, and polymerized with an LED light-curing device (Valo, Valo, Ultradent).

5 single-shade and 1 multishade resin composites were used as a single layer and have been given respectively; Vittra APS Unique (code: VU; FGM Dental, Joinville, SC, Brazil), Omnichroma (code: O; Tokuyama Dental Corporation, Tokyo, Japan), ZenChroma (code: ZC; President Dental GmbH, Allershausen, Germany), Clearfil Majesty ES-2 Universal (code: CMU; Kuraray Noritake, Osaka, Japan), Charisma Topaz One (code: CTO; Kulzer, Hanau, Germany), and Estelite Asteria (code: EA; Tokuyama Dental Corporation, Tokyo, Japan). Tested resin composite materials are shown in Table 1.

Materials were placed into the cavities according to the manufacturer's instructions and then polymerized for 20 sec using a LED light-curing device. In the control EA group: the color of the materials was chosen to be the same color as the acrylic denture incisors (A1B for A1 colored teeth; A2B for A2 colored teeth; A3B for A3 colored teeth). A radiometer (Bluephase Meter II, Ivoclar Vivadent) was used to measure the output intensity of the light curing unit before usage in each group. The restorations were dry polished with Soflex XT (3M ESPE, USA) finishing and polishing discs (coarse to fine) using a low-speed handpiece at 5000rpm with 10 strokes. To complete the polymerization, restorations were kept in distilled water for 24 hours before color measurement.

**Table 1**. Resin composite materials evaluated in this study.

| Group | Brand Name | Filler Type | Composition | Manufacturer | Shades |
|---|---|---|---|---|---|
| VU | Vittra APS Unique | Nano-hybrid | Methacrylate monomer, photoinitiator composition (APS) 72 to 80wt %, (52 to 60vol %) | FGM Dental, Joinville, SC, Brazil | Single-shade |
| O | Omnichroma | Supra-nano filled | UDMA, TEG-DMA, uniform sized supra-nano spherical filler (260nm spherical SiO2-$ZrO_2$) 79wt %, (68vol %) | Tokuyama Dental Corporation, Tokyo, Japan | Single-shade |
| ZC | ZenChroma | Micro-hybrid | Glass powder, UDMA, silicon dioxide, Bis-GMA, tetramethylene dimethacry late 75wt %, (53vol %) inorganic filler (0.005-3.0µm) | President Dental GmbH, Allershausen, Germany | Single-shade |
| CMU | Clearfil Majesty ES-2 Universal | Nano-hybrid | Silanated barium glass filler, pre-polymerized organic filler, BIS-GMA, hydrophobic aromatic dimethacrylate, di-Camphorquinone 78wt %, (40vol %) inorganic filler (0.37-1.5µm) | Kuraray Noritake, Osaka, Japan | Single-shade |
| CTO | Charisma Topaz One | Nano-hybrid | UDMA, TCD-DI-HEA, TEGDMA 81wt %, (64vol %) | Kulzer, Hanau, Germany | Single-shade |
| EA | Estelite Asteria | Nano-hybrid | Matrix: Bisphenol A, Bis-GMA, Bis-MPEPP, TEGDMA, UDMA 82wt %, 71vol % Uniform supranano spherical silica- zirconia fillers (200nm) | Tokuyama Dental Corporation, Tokyo, Japan | A1B, A2B, A3B |

UDMA: urethane dimethacrylate. TEGDMA: triethyleneglycol dimethacrylate. $SiO_2$: Silicone oxide. $ZrO_2$: Zirconium oxide.
Bis-GMA: bisphenol-A-diglycidyl methacrylate. TCD-DI-HEA: Bis-(acryloyloxymethyl)tricyclo [5.2.1.0.sup.2,6] decane.
Bis-MPEPP: bisphenol A polyethoxy methacrylate.

### COLOR ANALYSIS: PHOTOGRAPHIC

The photographs were obtained by a combination of a smartphone (iPhone 11, Apple Inc., California, USA) and a mobile dental photography device (Smile Lite MDP, Smile Line, St-Imier, Switzerland). All photographs were taken using the SILKYPIX Shot Camera (Ichikawa Soft Laboratory, Japan) application with the white balance set to 5500 K, at a 25cm distance with an x2 camera zoom, in the same room with the standardized light source using a black background. Color measurements were conducted at three different points for each restoration and tooth 0.5mm away from the composite-tooth junction (Figure 1). L, a, and b values were obtained from photographs using Digital Color Meter v5.22 (Macbook, Apple Inc., California, USA) and recorded (Figure 2). The average values were calculated.

The following CIEDE2000 formula was used to assess the shade differences (ΔE) between teeth and restorations (16-18):

$$\Delta E00= \sqrt{(\Delta L^*/(K_L S_L)^2+(\Delta C^*/(K_C S_C)^2+(\Delta H^*/(K_H S_H)^2+R_T (\Delta C^*/(K_C S_C)+(\Delta H^*/(K_H S_H)}$$

The parameter coefficients KL, KC, and KH are correction terms for variation under experimental conditions and were all set to 1.0 in this study.

### COLOR ANALYSIS: VISUAL

At the beginning of the visual color analysis, Kappa values were calculated to test the intra- and inter-examiner reproducibility. The Kappa values were high (0.779) and showed powerful intra- and inter-examiner agreement.

The visual color analysis scored as; 0: perfect match, 1: very good match, 2: not a good match, 3: obvious mismatch, 4: major mismatch. Examiners who have the same experience and specialty scored the restorations in 3 seconds. Data were recorded and statistically analyzed.

The obtained data were analyzed with the SPSS 22 software. As a result of the normality analysis of the data obtained in this study, the ANOVA and/or T test were preferred for the comparisons between groups for the normally distributed variables. In addition, the non-parametric Kruskall-Wallis H test and Mann-Whitney U test were preferred for the non-normally distributed variables.

## RESULTS

### INSTRUMENTAL EVALUATION

The mean ΔE values and ± standard deviations for instrumental analysis of color matching evaluation have been detailed in Table 2.

When materials were evaluated among themselves, only the ZC group in A1 shade groups showed statistically significant higher differences ($p<0.05$).

In A2 and A3 shade groups, there were no significant differences between materials ($p>0.05$). VU, CTO, and CMU groups in the A3 shade groups showed lower ΔE values than in the A1 and A2 shade groups ($p>0.05$). O group in the A1 shade groups showed higher ΔE values than the A2 and A3 shade groups ($p>0.05$). In the control EA group, there were no significant differences between the ΔE values in A1, A2, and A3 ($p>0.05$).

A3 shade groups showed lower ΔE values ($p<0.05$) among all tested materials. EA and O groups showed statistically significant lower ΔE values when compared to the ZC group ($p<0.05$) (Figure 3).

## VISUAL EVALUATION

A total of 108 class III restorations were scored from "0" to "4" by 2 evaluators. The sum of the data given by the two evaluators is graphically shown in Figure 4. Scores of "3: obvious mismatch" and "4: major mismatch" were not given to any of the samples.

There were significant differences between the shade groups (A1-A2-A3) in terms of material and scores ($p<0.05$). When compared to the other groups, a higher percentage of "0" scores were observed in VU groups (11.1%), while "1" scores were higher in CMU (88.9%), O (88.9%), and EA groups (88.9%) ($p<0.05$).

There were no significant differences between materials and scores in the A1 and A3 shade groups ($p>0.05$). There were statistically significant differences between the materials and the scores in the A2 shade groups ($p<0.05$). The highest "0" score was seen in the VU group (33.3%), and the highest "1" score was observed in the O (91.7%) and EA (91.7%) groups.


**Figure 1**. Representative image of class III preparations, and color acquisition. Two different color measurements were performed: 0.5mm away from the tooth/restoration margin for each restoration and tooth.

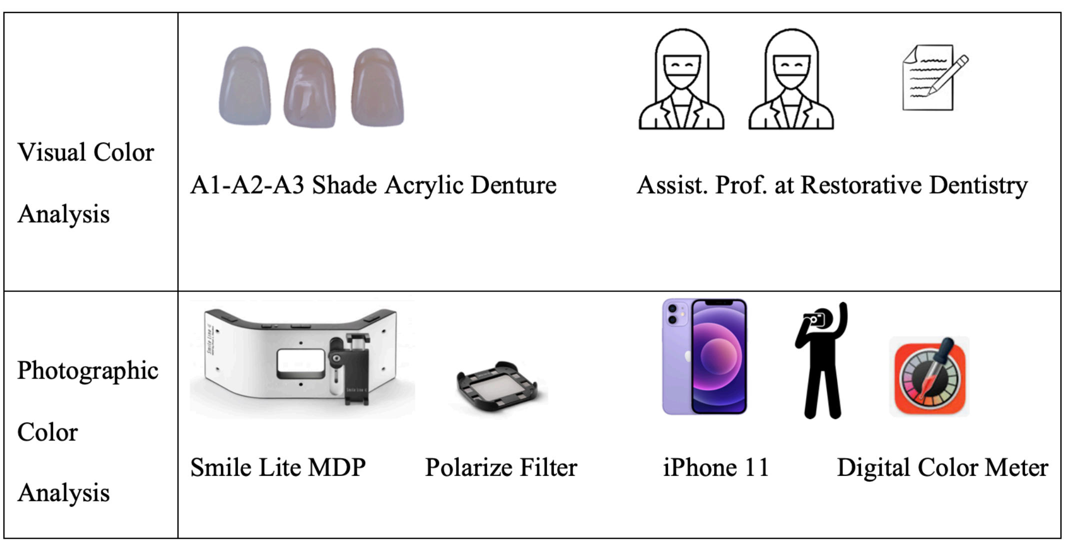



**Figure 2**. Color analysis procedures.

**Table 2**. Mean color differences ($\Delta E_{00}$) and standard deviations of tested materials.

| Groups | A1 shade groups | A2 shade groups | A3 shade groups |
|---|---|---|---|
| VU | 2.0837± 0.4617 $^{Aa}$ | 1.9251± 0.8073 $^{Aa}$ | 1.3647± 0.8299 $^{Aa}$ |
| O | 2.2300± 0.5277 $^{Aa}$ | 1.5346± 0.5277 $^{Aa}$ | 1.1133± 0.8163 $^{Aa}$ |
| ZC | 3.0882± 0.4484 $^{Bb}$ | 1.7986± 0.6454 $^{Aa}$ | 1.8133± 0.4315 $^{Aa}$ |
| CMU | 2.4777± 0.9483 $^{Aa}$ | 2.1730± 0.5995 $^{Aa}$ | 1.4019± 0.5348 $^{Aa}$ |
| CTO | 1.7795± 0.4699 $^{Aa}$ | 2.0430± 0.6309 $^{Aa}$ | 1.3837± 0.5784 $^{Aa}$ |
| EA | 1.6250± 0.4936 $^{Aa}$ | 1.4198± 1.5467 $^{Aa}$ | 1.1899± 0.9605 $^{Aa}$ |

$^{ab}$Different lowercase letters indicate statistically significant differences in the row.
$^{AB}$Different uppercase letters indicate statistically significant differences in the colum.

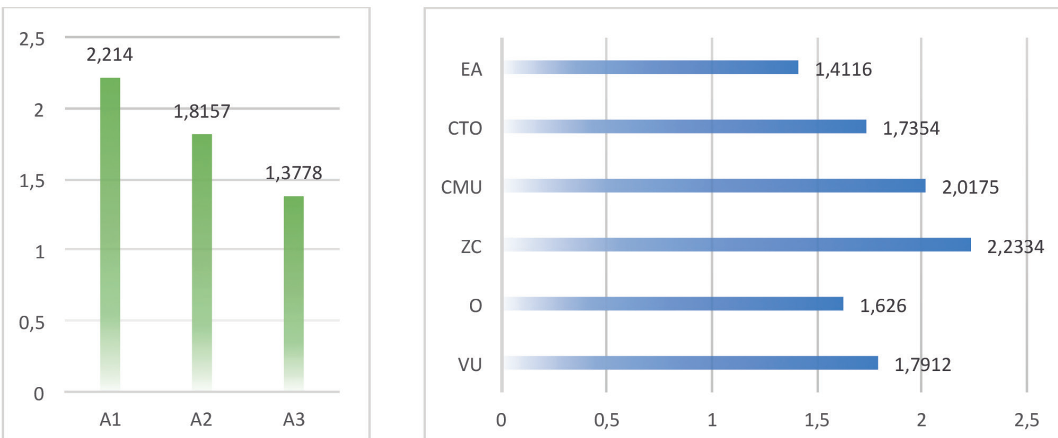
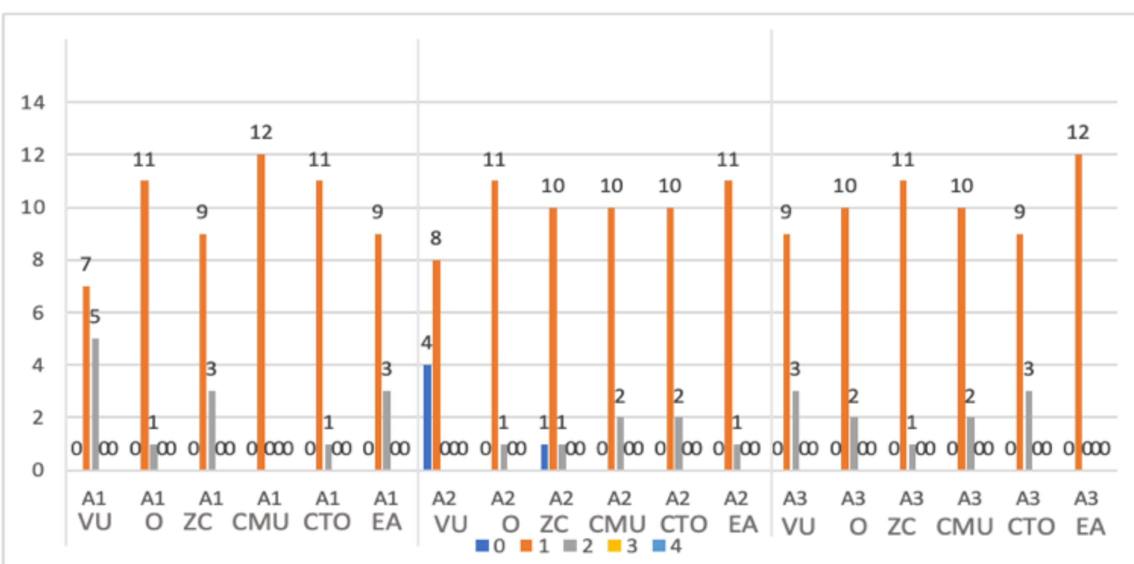



**Figure 3**. ΔE values between different shades and different materials.




0: perfect match; 1: very good match; 2: not a good match; 3: obvious mismatch; 4: major mismatch.

**Figure 4**. Number of scores as 0 to 4 for materials between shade groups.

## DISCUSSION

Color matching of restorations in clinical conditions is the most important step for aesthetic results. Especially in anterior teeth, optimum aesthetic results are obtained by imitating the optical properties of enamel and dentin with the relevant colors of resin composites. The existing optical mismatch between restorative materials and dental tissues necessitates a more diverse approach to material composition and selection for highly challenging aesthetic restorations (19).

Color selection is usually accomplished using color guides such as the VITA Classic Shade Guide system based on tone and chroma, the value-based VITA 3D-MASTER, or customized color guides for a particular resin composite. In clinical conditions, every tooth has different hues, chromas, and values; this is called a polychromatic structure (19). Successful esthetic composite restorations depend on the color of teeth, as well as on translucency and opacity, and the filler type and composition of materials can affect color adaptation (20). In this current study, acrylic maxillary incisors were used to provide standardization, since the enamel and dentin thicknesses are not the same in human teeth. These different thicknesses may affect the outcome of the restorations.

Today, digital photographs are widely used for color detection using different software. In addition, digital cameras are easily accessible and cheaper than other devices. Since everyone has a smartphone, the idea of mobile dental photography (MDP) was born, and Smile Lite (Smile Line, Switzerland) was developed. This system provides ideal light conditions (5,500K=daylight) and a polarizing filter in one device (21). The polarizing filter eliminates glare and improves the visualization of details and areas of transparency in tooth structures. In addition, it is an uncolored filter that decreases oblique reflections from glossy surfaces and can therefore darken and saturate the perceived color by eliminating unnecessary reflections (22). In this study, Smile Lite was used for photographic color analysis. The obtained photographs were measured with a digital color meter, and ΔE values were calculated with the CIEDE2000 formula, which is more sensitive than the CIELAB formula in measuring color differences.

To achieve a better correlation with visual analysis, currently, ISO (International Standards Organization) and CIE jointly recommend using the CIEDE2000 color difference formula for the total color difference calculation, which is based on CIELAB color space (23).

The “Blending effect” is a very complicated phenomenon. The chameleon effect, or blending effect, describes the ability of the material to achieve a color similar to the surrounding tissues. Thanks to this effect, it is aimed to make restorations by using fewer various materials and providing appropriate colors (9). Achieving a good color match is not just about the material, the size of the restoration is also an important factor (24). Class III restorations were made to evaluate the blending effect in the present study. Mesial or distal dental tissue did not surround the resin composites. It is considered that such restorations may affect the blending effect of the materials.

One study reported that the detectability threshold value of ΔE values was ≤0.8 and the acceptability threshold value was>0.8-<1.8 in the CIEDE 2000 system (25). Based on these ΔE values, almost all the materials tested in the A3 shade groups showed acceptable results. These results suggested that resin composites may have a higher color adaptive capacity in darker-color dental tissues.

Although there are a few differences, the instrumental and visual color analysis data in this study support each other. The results of the visual analysis showed that the resin composites were clinically acceptable. No "obvious mismatch" or "major mismatch" was given to any of the resin composites.

There are six materials, which were evaluated in this study. All tested materials have a %75-82 by weight filler composition, also materials are nanohybrids except one. According to the manufacturers, a single-shade resin composite, ZC, has micro-hybrid filler content. In addition, the results of the instrumental analysis showed that ΔE values of ZC in A1 shade groups were significantly higher among the tested materials. This difference may be due to the different filler contents.

The ΔE values of this study showed that the color adaptation of single-shade resin composites was no better than the tested multishade resin composites. Analysis of the instrumental evaluation showed that the tested multishade resin composites had the highest color-adapted capacity among the other materials, but this was not the case for all shades. As a single-shade resin composite, O showed lower ΔE values in A3 shade groups than EA.

In recent years, Omnichroma has been evaluated in many studies (8, 26, 27), but there are only limited studies evaluating the color adaptation of other single-shade resin composites. This study is unique because five commercially available single-shade resin composites were evaluated. According to the manufacturers, these materials have different properties to achieve excellent color matches, such as the Advanced Polymerization System (APS), Adaptive Light Matching (ALM), and Light Diffusion Technology (LDT). Further studies are needed to understand these features.

## CONCLUSION

Within the limitations of this in vitro study, it was concluded that:

"Making aesthetic restorations with single-shade resin composites promises proper color adaptation, but their properties still need improvement."

## CONFLICT OF INTEREST

The authors declare no competing interests.

## AUTHOR CONTRIBUTION STATEMENT

Conceptualization and design: Ö.E. and D.K
Literature review: Ö.E. and D.K
Methodology and validation: Ö.E .and D.K.
Formal analysis: Ö.E.
Investigation and data collection: D.K
Resources: Ö.E and D.K
Data analysis and interpretation: D.K
Writing-review and editing: Ö.E and D.K
Supervision: Ö.E.
Project administration: Ö.E and D.K

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