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Color variation of composite resins in relation to the Vita Classical shade guide: colorimetric analysis

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Aim: The aim of this study was to verify the color variation between different composite resins and the Vita Classical Shade Guide. **Methods:** Two-millimeter thickness samples were made (n = 6) from eight commercial brands of composite resin (shade A2): Charisma (Kulzer), Forma (Ultradent), Harmonize (Kerr), Luna (SDI), Opallis (FGM), Oppus Bulk Fill (FGM), Vittra (FGM) and Filtek Z250 XT (3M ESPE). Specimens were stored in distilled water for 7 days and then polished. Color measurements of samples and A2 shade of the Vita Classical Shade Guide were performed using the Vita Easy Shade Advance 4.0 spectrophotometer on a black background. Color variations were calculated using the CIEDE2000 formula, considering values ≥0.81 being noticeable by the human eye and ≥1.77 being clinically unacceptable. Results were statistically analyzed with a 5% significance level. **Results:** Color variation (ΔE) of composite (E_1) compared to the Vita Classical Shade Guide (E_0) was greater than clinically acceptable for all the materials evaluated in this study. Forma (ΔE=2.08 ± sd=0.47) and Filtek Z250 XT (2.50 ± 0.20) had the smallest amount of color variation values found in the results. Harmonize (3.32 ± 0.63) presented values similar to Filtek Z250 XT, but it was worse than Forma. Vittra (3.51 ± 0.28), Charisma (3.80 ± 0.20), Opallis (4.24 ± 0.30) and Luna (5.67 ± 0.20) did not differ among each other and presented higher color variation than Forma, Filtek Z350XT and Harmonize. Oppus Bulk Fill (13.94 ± 1.12) was the composite with the greatest color variation. **Conclusions:** The findings in this study show that attention should be taken when using the Vita Color Shade Guide for composite shade selection.

Keywords: Composite resins. Color. Spectrophotometry.

Introduction

The tooth's crown is composed of enamel, dentin and pulp; and the way light relates to each one of these histological tissues results in the color of the tooth's structure. Due to enamel low thickness and high translucency, dentin has a great influence on overall color composition of tooth[1,2]. These intrinsic factors are influenced by the deposition of pigments on enamel surface, thus, modifying light absorption and reflection until it reaches the observer's eye, which makes teeth a polychromatic structure[3].

The increased demand for cosmetic dentistry is associated to an increase in number of brands and types of restorative materials available on the market[4]. Composite resins are made up of four basic components: inorganic filler, organic matrix, a bonding agent and an accelerator-initiator system. These components vary in some properties, such as viscosity, size, shape and quantity of filler particles, as well as optical properties. The use of different shades and opacities of composite resin, applied to the restoration with different increments' thicknesses – a stratification technique - is responsible for mimicking lost tooth structure regarding optical characteristics[5].

A proper composite shade selection should be used in direct restorations to avoid errors in tooth color reproduction, which would likely lead to treatment failure due to patient dissatisfaction[6]. At the time of shade selection, the dentist must take into consideration the patient's age, appropriate dental office's lightness, tooth wetness and restoration's esthetic demand[7]. Thus, to assist the professional on shade selection, different methods might be used, such as color scales, colorimeters, digital images, photographs, and a spectrophotometer[8,9].

In 1976, the Commission Internationale de l'Eclairage (CIE) created the color space diagrams, defined by parameters or coordinates, called CIE L*a*b*. These coordinates represent value or lightness (L*), greenish-red content (a*) and bluish-yellow content (b*) of color. An update on this diagram was the CIE L*C*h*, where the coordinates represent lightness (L*), saturation (C*) and hue (h*). The CIEDE2000 formula is considered the most sophisticated, as it corrects the non-uniformity of the CIE L*a*b* space. In the CIEDE2000 formula, specific adjustments were carried out, replacing differences in lightness (ΔL*), saturation (ΔC*) and hue (ΔH*) by SL, SC and Sh coordinates, respectively. These three-dimensional arrangements are based on the theory of opposite colors, where two colors cannot be green and red at the same time, nor blue and yellow. The total color variation between an analyzed and a standardized sample is defined as ΔE in all these systems[10].

The color selection technique commonly used in dental practices is the visual naked-eye shade scale comparison to teeth and dental materials, which is a subjective method, influenced by the materials used, gender, light and the ability of the observer. Methods using electronic devices such as a spectrophotometer, which is more accurate for color matching, can be an excellent tool during this clinical stage, reducing subjectivity[9]. This device works by emitting a light on the analyzed surface and reading its reflection. The results appear on the device's display and the reading values are given in Commission Internationale de l'Eclairage systems (CIE L*a*b* and CIE L*C*h*), as well as in Vita Classical and Vita 3D Master notations. However, this instrument has a high cost, which justifies why the visual method is the most used one yet[9,11].

Regardless of wide clinical use of the visual method, shades of composite resins present a color difference in comparison to the Vita Classical Shade Guide, which makes it difficult to properly select materials for esthetic restorations, even when the layering technique is used[12]. Alongside this color difference between Shade Guides and composite resins, the final restoration color is influenced by the oral cavity blackness, which serves as the background to the restoration[13].

Therefore, it is essential to know the difference in shades presented by the color palette in comparison to composite resins. Thus, the aim of the present study is to quantify, using a spectrophotometer, the color variation between different composite resins and their corresponding color on the Vita Classical Shade Guide. The null hypothesis tested is that there is no correlation between the colors of composite resins and their corresponding color on the Vita Classical Shade Guide.

Methods

The composite resins used in the present study are described in Table 1. For standard control, the Vitta Classical A2 color palette was used.

Table 1. Information on composite resins used

Composite resin / Manufacturer	Color	Classification / Composition	Batch	Polymerization time
Charisma / Kulzer (São Paulo, SP, Brazil)	A2	Microhybrid / Bis-GMA (58% filler particles), fluorinated aluminum barium glass (0.02–2 µm), highly dispersed silicon dioxide (0.02–0.07 µm)	K010734	20 seconds
Forma / Ultradent (Indaiatuba, SP, Brazil)	EA2	Nanohybrid / Bis-GMA, TEGDMA, Bis-EMA, UDMA, zirconia/silica and barium glass.	D05MV	20 seconds
Harmonize / Kerr (Joinville, SC, Brazil)	A2E	Nanohybrid / UDMA, Bis-EMA, mixture of methacrylates and dimethacrylates; silica zirconia and pigments	7217964	20 seconds
Luna / SDI (São Paulo, SP, Brazil)	EA2	Nanohybrid / UDMA, Bis-EMA, TEGDMA, charge of glass strontium particles	16127	20 seconds
Opallis / FGM (Joinville, SC, Brazil)	EA2	Nanohybrid / Bis-GMA, Bis-EMA, UDMA, TEGDMA, silanized barium aluminum silicate glass and silicon dioxide nanoparticles, camphorquinone, accelerators, stabilizers and pigments	270617	20 seconds
Oppus Bulk Fill / FGM (Joinville, SC, Brazil)	A2	Microhybrid / Urethanedimethacrylic monomers, stabilizers, photoinitiators, coinitiators, silanized silica, stabilizers and pigments	110918	20 seconds
Vittra / FGM (Joinville, SC, Brazil)	EA2	Nanohybrid / Mixture of methacrylate monomers, photoinitiator composition (APS), coinitiators, stabilizers, silane, zirconia filler, silica and pigments	081217	20 seconds
Filtek Z250 XT / 3M ESPE (Sumaré, SP, Brazil)	A2	Microhybrid / Bis-GMA, TEGDMA, Bisphenol A, polyethylene glycol diether dimethacrylate, UDMA, treated silanized ceramic, silane treated silica.	2007200115	20 seconds

Sample Preparation

A single operator made 48 samples of 8 different brands of composite resins, (6 specimens per group) using a steel matrix composed of different layers of discs that were overlaid on each other while placing the uncured composite resin. The resulting sample takes a form of an inverted conical cylinder with 4mm top diameter, 3mm base diameter and a 2mm thickness (Figure 1). Each sample was photocured (Optilight LD Max, 600 mW/cm^2 - Gnatus - Ribeirão Preto, SP, Brazil) according to the manufacturer's recommendations (Table 1).

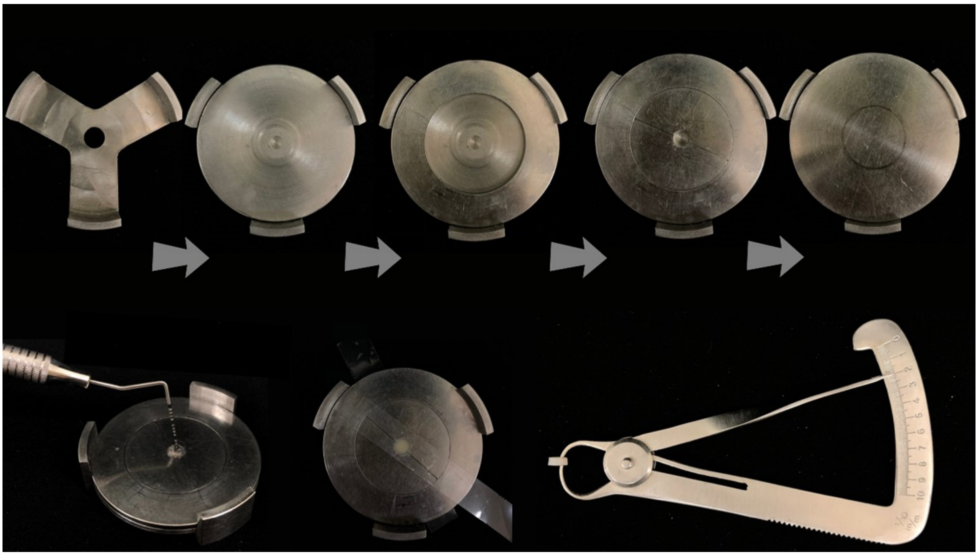

Figure 1. Sequence of the matrix assembly

Samples were stored in distilled water for 7 days at room temperature and, afterwards, the finishing and polishing procedure was carried out with a low-speed handpiece, using a four granulation (coarse, medium, fine and extra fine) aluminum oxide discs system (Diamond Pro, FGM, Joinville, SC, Brazil). Each disc was applied for 10 seconds, intermittently for each granulation, in all samples.

Color measurements

Color measurements of the samples were assessed by individually positioning each one on a black background[14]. A spectrophotometer Vita EasyShade® Advance 4.0 (VITA Zahnfabrik, Bad Sackingen, Germany) was used to measure all specimen's data, calibrating the device at each measurement, and obtaining the color values, using CIE L*a*b* and CIE L*C*h systems. The measurement of the Vitta Classical A2 color was performed using a customized transparent acrylic matrix with a perforation located in the central region of the palette (Figure 2).

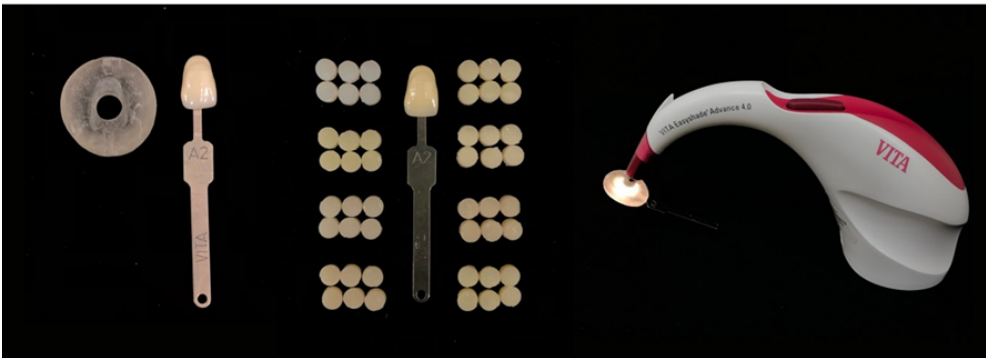

Figure 2. Color measurement of specimens and Vita Classical A2 palette.

The color variation (ΔE) of the specimens in comparison to the Vita Classical Shade Guide was determined using CIEDE2000, using the following formula:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + RT\left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2\right] 1/2$$

In this formula, ΔE_{00} is the color variation in CIEDE2000, ΔL, ΔC and Δh are the differences in lightness, chroma and hue for a pair of samples. RT is the rotation function, which is responsible for the interaction between chroma and hue differences in the blue region. The parametric factors KL, KC, KH (1:1:1) are correction terms for experimental conditions, and SL, SC, SH are the weighting coefficients and adjust the total color difference for variation in the location of the color difference pair at coordinates L, a, b[15].

Statistical analysis

The ΔE results between composite resins and their corresponding color on the Vita Classical Shade Guide were submitted to the Shapiro Wilk and Levene's test to verify the normality and homoscedasticity of the data, respectively. Then, the data was evaluated by one-way ANOVA. To identify differences among groups, the Tukey test was used. All statistical tests were considered at a significance level of 5% ($p \leq 0.05$).

Results

According to CIEDE2000, when compared to Vita Classical Shade Guide, all materials studied presented a color variation (ΔE) higher than the perceptibility (≥0.81) and acceptability (≥1.77) values. Therefore, all materials have a color difference considered clinically unacceptable when compared to their corresponding color in the shade guide.

Assessing the tested materials individually, the composite resin Forma (Ultradent) had the most similar color to its corresponding shade in Vita Classical Shade Guide (ΔE = 2.08), while the composite resin Oppus Bulk Fill (FGM) had the greatest color variation (ΔE = 13.94). Composite resins showed color variation among specimens from the same syringe. Oppus Bulk Fill (FGM) composite resin showed the highest ΔE, varying from 12.86 to 15.74, alongside high standard deviation (sd = 1.12). On the other hand, Luna (SDI), Opallis (FGM) and Filtek Z250 XT (3M ESPE) composite resins showed a more stable color behavior among its own samples, presenting the lowest standard deviation (sd = 0.20), as shown in Table 2.

Table 2. Mean and standard deviation of color variation (ΔE) of composite resins in relation to the Vita Classical shade guide.

Material	Mean ± standard deviation
Forma (Ultradent)	2,08 ± 0,47 A
Filtek Z250 XT (3M ESPE)	2,50 ± 0,20 AB
Harmonize (Kerr)	3,32 ± 0,63 BC
Vittra (FGM)	3,51 ± 0,28 C
Opallis (FGM)	3,80 ± 0,20 C
Charisma (Kulzer)	4,20 ± 0,30 C
Luna (SDI)	5,67 ± 0,20 D
Oppus Bulk Fill (FGM)	13,94 ± 1,12 E

Different letters indicate statistical differences (One-way ANOVA/Tukey test)

Discussion

The null hypothesis, that the evaluated composite resins do not present similarity in color with their corresponding shade in the Vita Classical Shade Guide, was confirmed.

In addition to creating a universal language about color, it is necessary to facilitate its understanding for clinicians. Several studies still use the CIE L * a * b * and CIE L * c * h * formulas, however it is the CIEDE2000 formula that best represents color differences perceived by the human eye, being considered an ideal equation to measure color difference regarding clinical interpretation[16].

A survey carried out in seven large research centers established the perceptibility and acceptability values for color variations (ΔE), which in the CIE L*a*b* system is 1.22 and 2.66 while in the CIEDE2000 is 0.81 and 1.77 respectively[14]. As these parameters are usually influenced by the background color, in the present study the samples colorimetric analyzes were performed on a black background, which would better simulate the bottom of the oral cavity[14,17].

The ability to reproduce the exact color of natural teeth using restorative materials is one of the most challenging goals in clinical dentistry. Visual analysis, according to composite resin manufacturers, must be carried out in natural daylight. It is also recommended to hold the shade guide at approximately 25 to 30 cm away from the observer's eye and to choose shade quickly, accepting the first decision, since eyes start to get tired after 5 to 7 seconds of shade selecting. There are studies showing that females have greater visual accuracy when compared to males[18]. Due to these difficulties, the use of objectives methods for shade selection, such as the spectrophotometer, could provide an easier and more precise procedure.

It is known that the composition of each material provides different optical characteristics for them. Regarding the resin matrix, Azzopard et al.[19] evaluated matrices based on Bis-GMA, TEGDMA and UDMA and measured the total and diffuse transmittance values through a spectrophotometer and the color difference was evaluated using the CIE Lab system. The authors concluded that there was no statistical difference among transmittance values when the matrices were tested separately. However, the association between a large amount of Bis-GMA and silica, resulted in a significant increase in the material's translucency. In the present study, the composites Forma and Filtek Z250 XT, which statistically showed the best results, have the interaction of these two materials in their composition, which may have favored the colorimetric performance.

In addition, the characteristics of the filler particles (size, quantity and distribution) can also affect the final color of the material, as they influence the color reproduction due to the refractive index between the particles and the resin matrix[20,21]. In the present study, there was no direct association between filler particle size and color compatibility with the Vita Classical Shade Guide. Lim et al.[22] mention that the pigment is another factor that interferes with the properties of composite resins, but there seems to be no standardization by manufacturers in terms of both the shade and the intensity of the color of these pigments.

Corroborating the results of the present study, Miranda et al.[23] reported that composite resins did not match the shade informed by the manufacturer when evaluated by objective analysis. They compared spectrophotometry and visual evaluation of composite resins by dividing them into patterns from lighter to darker and showed that, for both enamel and dentin resins, the resulting shade matching are poor when compared to the reference scale.

As dental enamel presents greater translucency, composite resins designed to replace enamel naturally have greater translucency as well. The same phenomenon applies to dentin regarding opacity. This approach on composite shade design can help to reproduce the optical characteristics of teeth's polychromatic nature. However, there will be A2 shaded composite for dentin, with greater opacity, and for enamel, with greater translucency, resulting in an obvious mismatching to shade guides. These more translucent composites are known to present greater tonal variation[24]. Thus, the use of shade guides presents an extra layer of complication when one considers opacity besides the traditional hue and chroma presented on shade codes[17].

The inconsistency of shade matching of different composite resins compared to Vita Classical Shade Guide makes the restorative procedure more difficult. Therefore, several manufacturers have launched universal single shade composites on the market that promise to mimic the dental substrate. The purpose of these is to promote greater color compatibility between the restorative material and the remaining tooth structure. However, even though the resins used in the present study are not compatible with the Vita Classical Shade Guide, the study by de

Abreu et al.[25] demonstrated that this problem cannot be solved with the use of monochromatic composite resins, as the authors concluded that multicolored composite resins showed greater color matching than resins composed of an "universal" single shade.

The present study has some limitations, such as the use of a single palette in the shade guide and a single formula for analyzing color variation. Furthermore, only one batch of composite resin were analyzed and only 2 mm thickness was evaluated. However, the results of the present study are of great clinical significance because color selection is an extremely important step during restorative treatment. Even with the incorporation of different color variation formulas, the level of agreement between visual and instrumental color decisions and matching may not be 100% effective. Despite developments in the assessment of color differences, this is still a process that depends largely on visual perception[15].

Therefore, it is necessary to know the colorimetric characteristics of each material to minimize the errors caused by the color mismatch between the material and its reference color in the shade guide. As an alternative to reduce this clinical difficulty, an International Organization for Standardization (ISO) for standardizing the color of composite resin composition could reduce color match errors between restorative materials and the remaining tooth or other teeth during restorative treatment.

Conclusion

Within the limitations of the present study, it can be concluded that in the CIEDE2000 analysis, all materials evaluated presented a color variation greater than what is considered clinically acceptable. Thus, all materials studied showed a large color variation in comparison to the Vita Classical shade guide.

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Data availability

Datasets related to this article will be available upon request to the corresponding author.

Conflict of Interests

The authors declare no competing interests with regards to the authorship and/or publication of this article.

Ethics Approval

Not applicable.

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