UNIVERSIDADE FEDERAL DE SERGIPE
CENTRO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE
DEPARTAMENTO DE ODONTOLOGIA

O PAPEL DA DISTÂNCIA DA INTERFACE E DO SUBSTRATO SUBJACENTE NO POTENCIAL DE AJUSTE DE COR DE COMPÓSITOS DE TONALIDADE ÚNICA

ARACAJU

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GABRIELLA DE JESUS SANTOS LIVI

O PAPEL DA DISTÂNCIA DA INTERFACE E DO SUBSTRATO SUBJACENTE NO POTENCIAL DE AJUSTE DE COR DE COMPÓSITOS DE TONALIDADE ÚNICA

Trabalho de conclusão de Curso apresentado ao Departamento de Odontologia da Universidade Federal de Sergipe como requisito à obtenção do grau de Cirurgiã-dentista.

Orientador(a): Profª. Drª. Rosa Maria Viana de Bragança Garçez

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SUMÁRIO

RESUMO

Este estudo avaliou como a distância entre a interface e o substrato subjacente afetam o potencial de ajuste de cor (CAP) de dois compósitos de tonalidade única. Espécimes em forma de cilindro foram criados usando Vittra APS Unique (VU), Charisma Diamond One (DO) e um compósito sombreado (A3). Alguns espécimes de cor única foram envolvidos pelo compósito A3, formando espécimes duplos. Medições de cor de espécimes simples foram feitas contra um fundo cinza usando um espectrofotômetro. Todos os espécimes foram posicionados a um ângulo de 45º em uma cabine de visualização sob iluminante D65, e as imagens foram capturadas com uma câmera DSLR contra fundos cinza ou A3. As cores da imagem foram medidas usando um software de processamento de imagem e convertidas em coordenadas CIELAB. Diferenças de cor ($\Delta E00$) entre os compósitos de cor única e o compósito A3 foram calculados. O CAP foi determinado comparando dados de espécimes simples e duplos. Não foram observadas diferenças clinicamente significativas entre as medidas de cor obtidas das imagens e do espectrofotômetro. CAP foi maior para DO em comparação com VU e aumentou à medida que a distância da interface composta diminuiu e quando os espécimes foram posicionados contra um fundo A3. Portanto, o potencial de ajuste de cor aumentou com a diminuição da distância da interface composta e contra um fundo cromático.

Palavras-chave: potencial de ajuste de cor; mistura de cores; resina composta; composito de tonalidade única.

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RESEARCH ARTICLE

WILEY

The role of interface distance and underlying substrate on the color adjustment potential of single-shade composites

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Abstract

Objective: This study assessed how the distance from the composite interface and the underlying chromatic substrate affect the color adjustment potential (CAP) of two single-shade composites.

Materials and Methods: Cylinder-shaped specimens were created using Vittra APS Unique (VU), Charisma Diamond One (DO), and a shaded (A3) composite. Some single-shade specimens were surrounded by the A3 composite, forming dual specimens. Color measurements of simple specimens were taken against a gray background using a spectrophotometer. All specimens were positioned at a 45° angle in a viewing booth under illuminant D65, and images were captured with a DSLR camera against gray or A3 backgrounds. Image colors were measured using image processing software and converted to CIELAB coordinates. Color differences (ΔE_{00}) between the single-shade composites and the A3 composite were calculated. CAP was determined by comparing data from simple and dual specimens.

Results: No clinically significant differences were observed between color measurements obtained from images and the spectrophotometer. CAP was higher for DO compared to VU and increased as the distance from the composite interface decreased and when specimens were positioned against an A3 background.

Conclusion: The color adjustment potential increased with decreased distance from the composite interface and against a chromatic background.

Clinical Significance: Achieving satisfactory color match in restorations using single-shade composites is crucial, and selecting an appropriate underlying substrate is essential. The color adjustment gradually decreases from the restoration margins towards its center.

KEYWORDS
color adjustment potential, color blending, resin composite, single-shade composite

1 | INTRODUCTION

Selecting the appropriate resin composite shades is crucial when performing direct esthetic restorations, especially in areas of high esthetic demand, such as anterior teeth. Even when the color is accurately measured, achieving imperceptible restorations[1] also depends on correctly blending the thickness of opaquer and more translucent composites to obtain optical properties that match those of the surrounding teeth.[2,3]

However, most composite brands use the VITA classical shade guide, which only includes 16 color tabs, covering only about a third of the colors observed in human teeth.[4] Therefore, an improved color match between the composite and the tooth structure relies on the restorative material's ability to adjust to the adjacent substrate's color.[5,6]

In recent years, scientists have developed composites with improved color adjustment potentials (CAP) to enhance the predictability of color-matching restorations.[7–12] This eliminates the need for shade selection by utilizing single-shade composites that can adjust their color to match the tooth structure. This is possible due to their translucency, which allows the "mirroring" of the underlying substrate color to affect the restoration's final color.[11] However, the CAP may be reduced in clinical situations where the restoration is placed in the absence of a palatal wall, such as class IV cavities or diastema closure. The restoration may present a grayish aspect due to the blackness of the oral cavity affecting its final color.[13] Additionally, placing single-shade composites on color-altered dental substrates can compromise the restoration color match, and the manufacturers of some composites recommend using an opaquer and chromatic composite layer in this scenario.

Studies have shown that the underlying substrate can affect the restoration color, and it is expected that the color adjustment improves toward the restoration margins.[14,15] However, previous studies have used spectrophotometers that do not allow for the measurement of color in different areas of the specimen.[9–12,16] In contrast, digital methods based on imaging systems and software, such as DSLR cameras combined with a white balance gray card, allow for the measurement of the color of diverse and small areas of a specimen.[17–19]

Therefore, the present study aimed to evaluate the effect of the distance from the composite interface and an underlying chromatic substrate on the CAP of two single-shade composites. The hypothesis is that the CAP would increase closer to the composite interface and over a chromatic background.

2 | MATERIALS AND METHODS

2.1 | Experimental design

This study aimed to evaluate the CAP of two single-shade composites, Charisma Diamond One and Vittra APS Unique, under different conditions. The independent variables were the distance from the composite interface (1, 3, or 5 mm) and the background color (gray or shade A3), and the dependent variables were the color difference (ΔE_{00}) and CAP. The color difference was calculated based on the difference between the single-shade composite in the center of dual specimens and the surrounding composite at shade A3, while the CAP was calculated based on the ratio of the ΔE_{00} measured on simple and dual specimens.

2.2 | Sample size calculation

The sample size was determined in advance for the repeated measures ANOVA (within factors) with two groups (composites) and six measurements (three distances vs. two backgrounds). We specified the Cohen's effect size as 0.5, the type error as 5%, the power test as 80%, and the correlation among repeated measures as 0.5. Based on these parameters, a minimum sample size of 5 was established.

2.3 | Confection of specimens

The specimens were disc-shaped and built up by placing the single-shade and a more chromatic composite, Forma, into a metallic matrix with a 10-mm diameter and 2.0-mm depth ($n = 5$). The composites were light-cured for 40s with a light-curing unit (Radii-Cal, SDI, Victoria, Australia) positioned 2 mm from the matrix to ensure uniform curing. Dual specimens were obtained using a matrix with a 16-mm internal diameter and a metal cylinder with 10-mm in its center. The Forma composite was inserted into the matrix and light-cured with four 40s-photoactivations, and then the central metal cylinder was moved down, leaving a 10-mm diameter space, which was filled with one of the single-shade composites. All specimens were polished with aluminum oxide discs (Sof-lex, 3 M ESPE, St. Paul, USA).

2.4 | Color measurement of specimen images

The color of the simple specimens was measured with a spectrophotometer (SP60, X-Rite, Grand Rapids, MI, USA) in reflectance mode over a gray ($L^* = 73.1$, $a^* = 0.5$, $b^* = 0.2$) background. The readings were carried out with a 2° observer angle and illuminant D65,[20] and the device has an aperture diameter of 8 mm. The specimens' color was also measured over white ($L^* = 92.6$; $a^* = 1.0$, and $b^* = -0.5$) and black ($L^* = 24.7$, $a^* = 0.1$, $b^* = 0.1$) backgrounds, and the opacity was automatically calculated by the spectrophotometer. This instrumental color evaluation was used to evaluate the reliability of the values measured using the images.

2.5 | Color measurement of specimen images

The specimens were placed inside a viewing booth, over a neutral gray sample-holder inclined at 45° for a D65 illuminant (CRI ≥90; four 30 w lamps). Images were taken with a DSLR camera (Canon EOS Rebel T5, Canon, Taiwan) with a macro lens (Canon EF 100 mm f/2.8 L Macro IS USM, Canon, Taiwan) positioned perpendicular to the specimen's surface, and were saved in .raw format. The experimental set-up is illustrated in Figure 1. The camera was set at manual mode with an aperture of F20, shutter speed of 1/125 s, ISO 3200, and without flashlight. The specimens were imaged over both a neutral gray background and a single specimen of Forma composite, with no coupling agent placed between the specimen and backgrounds.[21,22]

The images were imported into Adobe Photoshop Lightroom Classic software (Adobe Systems, San José, CA, USA) and the white balance was adjusted based on the neutral gray background of the images. The images were then opened in CorelDraw Graphics Suite

X8 software (Corel Corporation, Ottawa, ON, Canada), and measurement areas were delimited. For simple specimens, a circle with an 8-mm diameter was drawn at the center (Figure 2A). For dual specimens, four circles with a 1-mm diameter each were drawn, with one on the surrounding composite and the others on the single-shade composite evaluated at 1, 3, and 5 mm from the interface between the materials (Figure 2B,C). The images with the measurement areas delimited were saved at 600 dpi and RGB color system in .jpg format. The color of the delimited areas was measured using the open-source image processing software ImageJ (NIH, Bethesda, MD, USA). The RGB values were converted into CIELAB coordinates using an MS Excel spreadsheet based on EasyRGB software (Logicol S.l.r., Trieste, Italy). RGB data was first converted to the CIE 1931 XYZ color space before obtaining CIELAB values. The conversion was carried out using $X = 95{,}047$, $Y = 100{,}000$, and $Z = 108{,}883$ as reference values, considering a 1931 2° supplementary standard observer and the CIE D65 standard illuminant.[23,24]

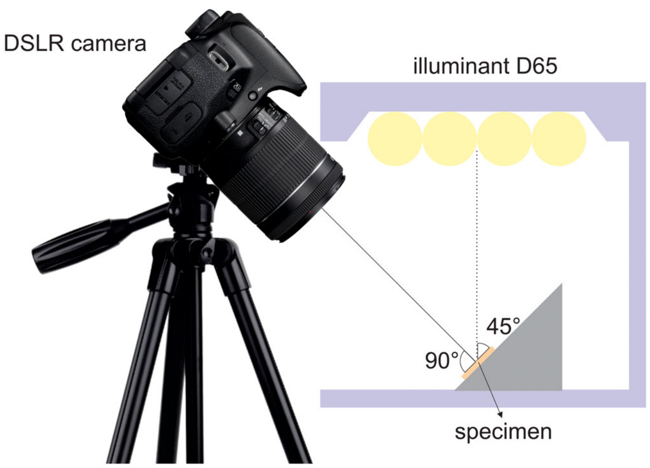

FIGURE 1 Schematic representation of the images acquisition set-up.

2.6 | Calculations of color differences and adjustment potential

The color differences between the simple specimens (ΔE_{00_simple}) of the single-shade composites and Forma composite were calculated using the equation below:[25,26]

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \frac{\Delta C'}{K_C S_C}\frac{\Delta H'}{K_H S_H}}. \quad (1)$$

Here, $\Delta L'$, $\Delta C'$, and $\Delta H'$ denote the changes in luminosity, chroma, and hue, respectively. SL, SC, and SH are the weighted functions for each component. KL, KC, and KH are the weighted factors for Lightness, Chroma, and Hue, respectively, where KL = KC = KH = 1. RT is the interactive term between chroma and hue differences.

For the dual specimens (ΔE_{00_dual}), color differences were calculated between the inner single-shade composites (measured at 1, 3, and 5 mm from the interface) and the outer composite, using the same equation (Equation 1). The CAP was determined using the following equation:[8]

$$\mathrm{CAP} = 1 - (\Delta E_{00_2} / \Delta E_{00_1}). \quad (2)$$

2.7 | Data analyses

The normal distribution of data was verified using the Shapiro–Wilk test, and the homogeneity of variance was assessed using Levene's

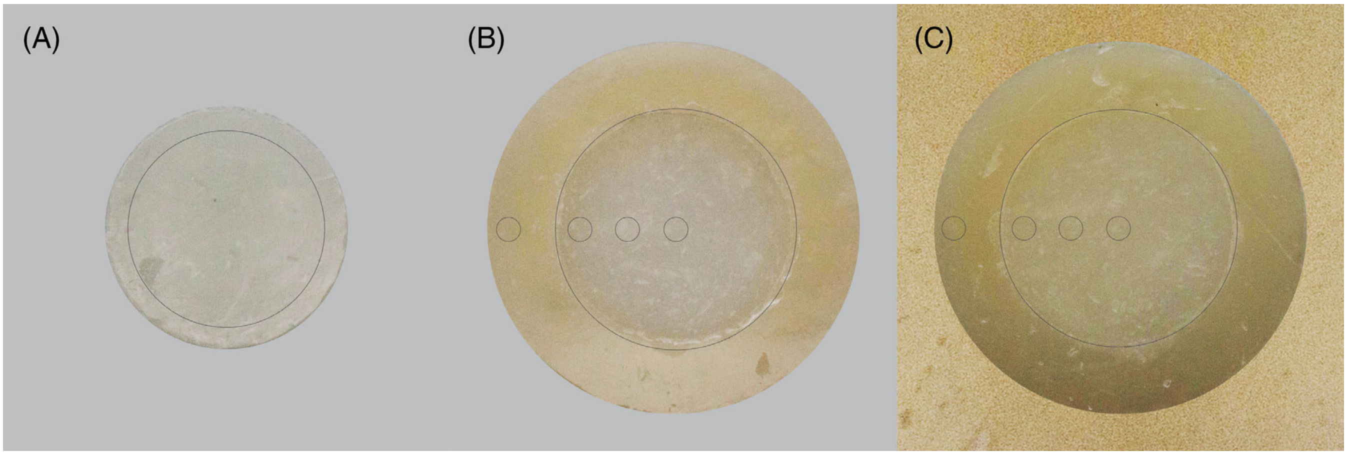

FIGURE 2 Image illustrative showing the delimited areas for color measurement using the image processing software. Simple (A) and dual (B,C) specimens were built using the Charisma Diamond One composite. For dual specimens, color readings were done over gray (B) and A3 (C) backgrounds. A single 8 mm diameter reading area was used for simple specimens. For dual specimens, four 1 mm of diameter reading areas were used: one on the surrounding composite and the other three on the inner composite distant 1, 3, or 5 mm from the interface.

test. The values of ΔE_{00_simple} were analyzed using Repeated Measures (RM) ANOVA, with the independent variables "composite" and "measurement method" (images or spectrophotometer) defined as the repetition factor. The difference in ΔE_{00_simple} between the methods was calculated and submitted to a T-test. Opacity differences between the single-shade composites were also assessed using this test.

The data from ΔE_{00_dual} and CAP were individually analyzed using RM ANOVA. The independent variables included "composite," "background," and "distance from the interface," and the last two variables were defined as repetition measures factors. Pairwise comparisons were made using Tukey's test. All analyses were performed with a 95% confidence level, and the open statistical platform Jamovi 1.6.15 (www.jamovi.org) was used for these analyses.

3 | RESULTS

Table 1 shows the values for ΔE_{00_simple} and opacity. RM ANOVA revealed that both "composite" and "measurement method" had a significant effect on the ΔE_{00_simple} values ($p < 0.001$). However, there was no significant interaction between the two factors ($p = 0.465$). Vittra APS Unique had the highest color differences, and the spectrophotometer yielded slightly higher values than images. Regarding the difference in the ΔE_{00_simple} values between the methods, there was no significant difference between the single-shade composites ($p = 0.467$). Vittra APS Unique had a higher opacity than Charisma Diamond One ($p = 0.004$).

The results for ΔE_{00_dual} are shown in Figure 3. RM ANOVA revealed that all independent variables had a significant effect on the results ($p < 0.001$). However, there was no significant interaction between any two variables or involving all factors. The highest ΔE_{00_dual} values were observed for specimens measured over a gray background, and Vittra APS Unique differed more from the surrounding composite than Charisma Diamond One. The lowest ΔE_{00_dual} values were observed at 1 mm from the interface ($p < 0.001$), without statistical difference between 3 and 5 mm ($p = 0.342$). All ΔE_{00_dual} values were higher than the 50:50% perceptibility threshold (0.8) defined in a previous study.[24] Except for Charisma Diamond One at 1 mm from the margin and over an A3 background (1.70 ± 0.79), all other experimental conditions also showed ΔE_{00_dual} values above the 50%:50% acceptability threshold (1.8).[1]

Figure 4 presents the results for CAP, and RM ANOVA showed that all independent variables had a significant effect on the CAP values ($p = 0.009$ for "composite" and $p < 0.001$ for the others). However, there was no significant interaction between any two

TABLE 1 Means ± standard deviations for ΔE_{00_simple} and opacity according to the single-shade composite or method of color assessment ($n = 5$).

Outcome		ΔE_{00_simple}				
Method of color assessment		Images	Spectrophotometer	Pooled average	Difference	Opacity (in %)
Composite	Charisma Diamond One	8.86 ± 0.94	9.73 ± 0.36	9.29 ± 0.83^B	−0.87 ± 0.87^A	53.96 ± 1.97^B
	Vittra APS Unique	12.11 ± 1.36	12.74 ± 0.26	12.43 ± 1.02^A	−0.63 ± 1.41^A	58.26 ± 1.38^A
	Pooled average	10.49 ± 2.01^b	11.24 ± 1.55^a		−0.75 ± 1.17	

Note: Distinct letters (uppercase comparing composites, lowercase comparing methods of color assessment) indicate statistical difference ($p < 0.05$). Opacity measured for Forma composite was 66.17 ± 1.73%.

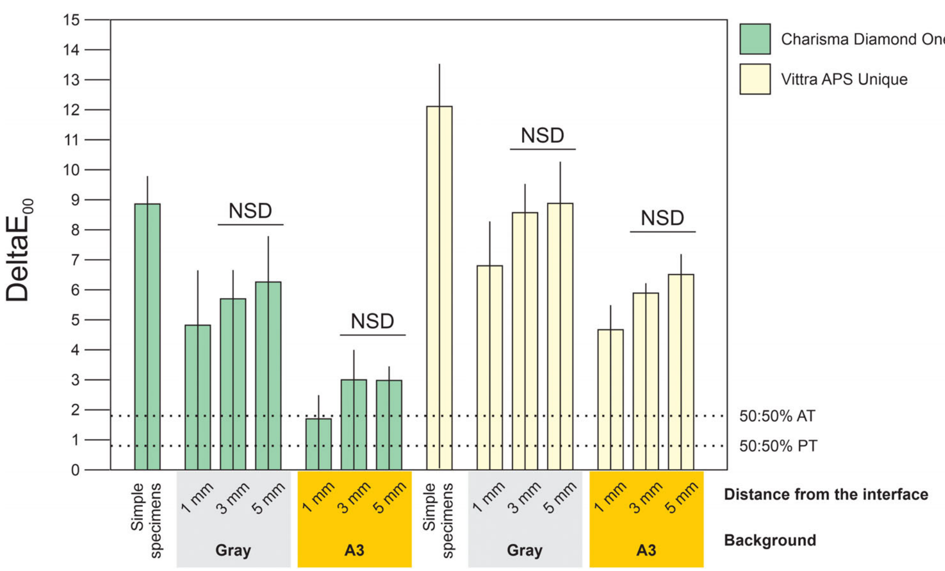

FIGURE 3 Means ± standard deviations of ΔE_{00_dual} measured according to composite, background, and distance from the interface. Dashed lines indicate the values corresponding to 50%:50% perceptibility (PT) and acceptability (AT) calculated in a prior study.[8] NSD, non-significant difference ($p \geq 0.05$).

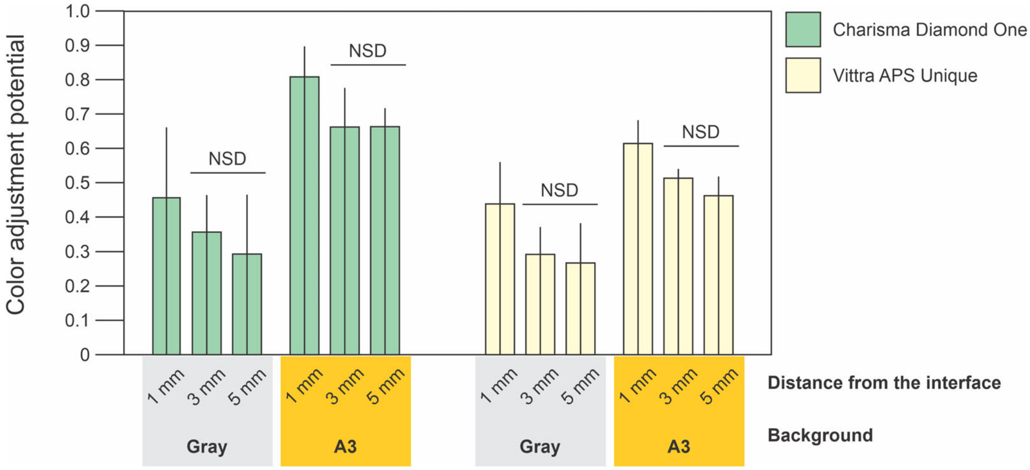

FIGURE 4 Means ± standard deviations of color adjustment potential measured according to composite, background, and distance from the interface. NSD, non-significant difference ($p \geq 0.05$).

variables or involving all factors. Using an A3 background improved the color adjustment, and Charisma Diamond One had higher values than Vittra APS Unique. The CAP values tended to increase toward the interface, but there was no statistical difference between the measurements taken at 3 and 5 mm from the interface ($p = 0.429$).

4 | DISCUSSION

The findings of the present study demonstrate that the color appearance of two single-shade composites increased as they approached the interface with a more chromatic and opaquer composite, especially when the latter material was placed beneath the evaluated materials. This supports the study's hypothesis. To assess the color of the specimens, images were taken using a DSLR camera at various locations. It is crucial to ensure accurate color representation in the photographs to obtain reliable results, like those using devices specifically designed for color assessment (e.g., colorimeters). Although the use of images is not a validated method for color measurements, previous studies have shown that standardizing image acquisition and correcting white balance using a neutral gray card can yield reliable results comparable to those obtained with spectrophotometers.[17–19] Another important consideration is the conversion of RGB values to CIELAB color coordinates, which depends on factors like the illuminant and observer angle.[20,24]

The choice of an appropriate illuminant was a key parameter in our study, as we aimed to evaluate the color match of single-shade composites to the surrounding substrate. A color difference between two adjacent objects that is imperceptible under certain illumination conditions can become noticeable when the lighting changes.[6] This phenomenon, known as metamerism, underscores the importance of using image acquisition to assess the color adjustment of single-shade composites. In our methodology, the specimens were placed inside a viewing booth with a CIE standard illuminant D65, which represents daylight illumination. To address any issues related to observer angle, we followed a similar experimental setup employed in previous studies that evaluated color using visual and instrumental methods (e.g., noncontact spectroradiometer).[1] The camera lens was positioned perpendicular to the specimen's surface at a distance of approximately 30 cm, while the illuminant was set at a 45° angle. One challenge with this setup was the relatively low illuminance of the specimens, which we compensated for by increasing the camera's ISO to 3200. Despite controlling parameters related to the illuminant and observer angle, we also adjusted the white balance of the images to achieve results that closely resemble the actual specimens.

We conducted a comparison between the color differences measured using data from a spectrophotometer and images of simple specimens to evaluate the accuracy of the proposed method in determining color adjustments for the single-shade composites. The ΔE_{00} values calculated from the images were consistently lower than those obtained from the spectrophotometer. The differences between the two methods ranged from 0.63 to 0.87, resulting in reductions of 4.9% to 8.9% compared to the spectrophotometer values. It is worth noting that the average differences were lower than the standard deviation calculated for the image data, and were close to the 50%:50% perceptibility threshold (0.8) established in a previous study.[1] In the same study, the 50:50% acceptability threshold for ΔE_{00} was determined to be 1.8, which is approximately twice as high as the average absolute reduction in ΔE_{00} observed when using the images. Additionally, both methods indicated that the mean ΔE_{00} was higher for Vittra APS Unique than for Charisma Diamond One, with similar differences observed between the composites (3.01 for spectrophotometer vs. 3.25 for images). Thus, the results obtained from the analysis of the simple specimens demonstrated the reliability of using DSLR images to measure ΔE_{00} values.

The color difference between the single-shade composites and the composite at shade A3 (dual specimens) was effectively reduced when they were surrounded by the latter, as anticipated. The decrease in ΔE_{00} values indicates that the inner composite adjusted its color to match that of the outer composite. This color blending can be attributed to the high translucency of the single-shade composites, which allows the color of the surrounding substrate to influence the overall color of the composite.[10,12] By using images captured with a DSLR camera, we were able to evaluate the extent of color adjustment based on the distance from the interface between the composites. As expected, the greatest color adjustment occurred near the interface, with the CAP values diminishing toward the center of the inner composite. This reduction in the mirroring effect of the surrounding color can be attributed to the passage of reflected light through the translucent inner composite. However, it is important to note that a gradual decrease in color blending between the composite and the surrounding substrate does not necessarily result in a color mismatch at the center of the restoration. Achieving an imperceptible restoration relies on precise color adjustment near the interface, and an acceptable color difference (ΔE_{00} lower than 1.8) was observed only with the Charisma Diamond One composite when the A3 shade was used as the background.

Using the composite shaded A3 as a background significantly increased the CAP values for both single-shade composites, regardless of the distance from the surrounding composite interface. On average, changing the background from gray to A3 resulted in a 60% increase in CAP values for the Vittra APS Unique composite and a twofold increase for Charisma Diamond One. This difference between the evaluated composites can be attributed to the higher translucency observed in the latter. The results clearly demonstrate that the color blending of single-shade composites is strongly influenced by their translucency, emphasizing the importance of using a suitable substrate to achieve optimal aesthetics with these materials. However, relying solely on the CAP of single-shade composites may not be sufficient to achieve a restoration that matches the adjacent tooth substrate when there is a significant color discrepancy between the actual composite color and the substrate. In our study, all ΔE_{00} values calculated for Vittra APS Unique exceeded the 50:50% acceptability threshold,[1] which can be attributed to the substantial color difference between this composite and the shade A3. Nevertheless, it is clinically expected that the adjacent tooth structure would be less chromatic than the underlying substrate due to the presence of enamel, which covers the more chromatic dentin. Even if the final restoration color does not perfectly match the underlying dentin, the attenuation of dentin color throughout the composite bulk can still contribute to achieving an acceptable color match with the adjacent enamel. It is worth noting that this study has limitations, and further research utilizing bilayer surrounding composites to simulate enamel-dentin superposition could provide additional insights and clarity on this matter.

5 | CONCLUSIONS

The color adjustment potential of the evaluated single-shade composites significantly improved when the background was changed from gray to a composite at shade A3. The observed color blending for the single-shade composites tended to increase closer to the interface. Among the composites tested, Charisma Diamond One, which is more translucent, demonstrated higher color adjustment values compared to Vittra APS Unique.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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