**Original Research**
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# Background and surrounding colors affect the color blending of a single-shade composite

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**Abstract:** This study evaluated the background and effect of surrounding colors on the color blending of a single-shade composite used in a thin layer. Disc-shaped specimens (1.0 mm thickness) were built with the Vittra APS Unique composite surrounded (dual specimens) or not surrounded (simple specimens) by a control composite (shade A1, A2, or A3). Simple specimens were also built with only control composites. The specimen color was measured against white and black backgrounds with a spectrophotometer (CIELAB system). The whiteness index for dentistry ($WI_D$) was calculated for simple specimens. Differences ($\Delta E_{00}$) in color and translucency parameters ($\Delta TP_{00}$) between the simple/dual specimens and the controls were calculated. The translucency adjustment potential (TAP) and color adjustment potential (CAP) were estimated based on the ratios between data from simple and dual specimens. The Vittra APS Unique composite showed higher $WI_D$ values than the controls. No differences between $\Delta TP_{00\_SIMPLE}$ and $\Delta TP_{00\_DUAL}$ were observed for any of the shades. The composite shade did not affect TAP values. The lowest values of $\Delta E_{00\_SIMPLE}$ and $\Delta E_{00\_DUAL}$ were observed for shade A1 regardless of the background color. For the white background, $\Delta E_{00\_SIMPLE}$ values did not differ from those of $\Delta E_{00\_DUAL}$ for all shades. Only A1 showed $\Delta E_{00\_DUAL}$ values lower than $\Delta E_{00\_SIMPLE}$ when the black background was used. The highest modulus of CAP (negative values for the white background) was observed when shade A1 surrounded the Vittra APS Unique composite. The color blending ability of the single-shade resin composite used in a thin layer was affected by both the surrounding shade and background color.

**Keywords:** Color; Composite Resins; Dental Materials; Dental Restoration, Permanent; Esthetics, Dental.

**Declaration of Interests:** The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

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## Introduction

The stratification of direct composite restorations involving esthetic demands is a challenge for clinicians, and the color match between the restoration and remaining dental structure is sometimes unpredictable.[1,2] Selecting the composite shade relies on adequate illumination of teeth, the distance between the observer and the substrate, and several factors related to clinicians such as their experience, visual accuracy, fatigue, and mood.[3-5] Additionally, the relationship between translucency and thickness of the composite strongly affects the ultimate color of the restoration.[6,7] Using more translucent composites or reducing the thickness of the composite layer increases the visualization of the underlying substrate and its effect on the restoration color.[8]

Single shade composites have been developed to simplify restorative procedures by eliminating the step of color selection and reducing the requirement for several composites with different translucencies.[9-11] These single-shade composites permit enhanced color adjustment potential (CAP) compared with regular composite systems based on multiple shades. The color blending ability of these innovative materials is based on both color shifting and enhanced translucency.[12] For instance, the addition of well-distributed round filler particles with an average diameter of approximately 260 nm generates red-to-yellow colors (the so-called "structural color").[13] These colors can be slightly modified according to the light angle of the material. The structural color is well known in some animal colors (e.g., peacocks), but this optical phenomenon is not fully elucidated in dentistry.[14]

Ideally, a single shade composite must have a high CAP, which indicates that its shade shifts toward surrounding colors. However, the color-shifting ability of these composites is limited, and the color match with the surrounding substrate might be higher to some determined shades. Color blending is also directly proportional to the composite translucency parameter, and the underlying substrate color can strongly intervene in the final color of the restoration.[15-17] Thin composite layers are commonly used to restore esthetic areas such as incisal edges of class IV cavities. In these scenarios, by restoring fractured teeth without the palatal wall, the background blackness can compromise the color match ability of the composite. Furthermore, for CAP, composites can change their translucency when inserted into cavities, which is referred to as the so-called translucency adjustment potential (TAP).[18] Therefore, this study assessed the effect of background and surrounding colors on the CAP and TAP values of a single shade composite.

## Methodology

The single-shade Vittra APS Unique composite (FGM, Joinville, SC, Brazil) was evaluated in this study. Specimens were built with single (simple) and two (dual) composites. The Forma composite (Ultradent, Indaiatuba, Brazil) was used in the outer area of dual specimens and as the control (simple specimen) to calculate the CAP. The shades A1D, A2D, and A3D of this last composite were used to obtain three different surrounding colors.

Disc-shaped simple specimens were confectioned by inserting composites into a silicon matrix (10 mm diameter, 1.0 mm depth) and covered with a polyester strip on both sides. The composites were light-cured for 40 s using the light-curing unit Radii-Cal (SDI, Victoria, Australia) with an irradiance of 1,200 Mw/cm$^2$. The tip of the light-curing unit was placed far from the composite to allow the light to reach its entire surface. Three simple specimens were confectioned for each shade of the Forma composite. Twelve simple specimens were confectioned for the composite Vittra APS Unique, while nine were used to obtain dual specimens. For dual specimens, the single specimens were fixed in the center of another silicon matrix (24 mm diameter, 1.0 mm depth). The empty area surrounding the cylinder of Vittra APS Unique was filled with the Forma composite with three specimens per shade. The composite was covered with a polyester strip and light-cured with four 40 s photoactivations. The position of the light-curing unit tip was changed between each photoactivation to cover the entire surface of the specimen. Specimens were stored in dry conditions for at least one week before color readings.

Color readings were conducted (triplicate) using a spherical spectrophotometer (SP60, X-Rite, Grand Rapids, USA) with specimens placed against white and black backgrounds (ColorChecker grayscale, X-Rite, Grand Rapids, USA). No coupling agent was placed between the specimen and backgrounds. A spectrophotometer with a reading aperture of 8 mm in diameter was used in reflectance mode. The observer angle was defined as 2°, and a D65 illuminant was used during color measurements. The CIELAB system from the Commission Internationale de L'Eclairage (CIE) was used, and the color coordinates L* (lightness), a* (red–green axis), and b* (yellow–blue axis) were recorded. For dual specimens, the color was measured only at the specimen center corresponding to the composite Vittra APS Unique.

The whiteness Index for dentistry ($WI_D$) of composites was calculated using the color coordinates of simple specimens measured against the black background since the equation was developed using this background color.[19] The following equation was used:

Equation 1: $WI_D = 0.551 \times L^* + 2.324 \times a^* + 1.1 \times b^*$

The difference in color coordinates of simple specimens measured against the black and white backgrounds was used to calculate the translucency parameters ($TP_{00}$) of the specimens. The CIEDE2000 color difference was calculated using the following equation:[20,21]

Equation 2:

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

where ΔL', ΔC', and ΔH' are the changes in luminosity, chroma, and hue, respectively. $S_L$, $S_C$, and $S_H$ are the weighted functions for each component. $K_L$, $K_C$, and $K_H$ are the weighted factors for Lightness, Chroma, and Hue, respectively ($K_L = K_C = K_H = 1$). $R_T$ is the interactive term between chroma and hue differences.

Translucency differences ($\Delta TP_{00}$) among controls (A1, A2, and A3) and the simple ($\Delta TP_{00\_SIMPLE}$) and dual ($\Delta TP_{00\_DUAL}$) specimens of the tested composite were calculated. The TP of the tested composite was calculated for each control shade using the following equation:[18]

Equation 3: $TAP = 1 - (\Delta TP_{00\_SIMPLE} / \Delta TP_{00\_DUAL})$

Using only simple specimens, $\Delta E_{00\_SIMPLE}$ was calculated using the color difference between Forma (shades A1D, A2D, and A3D) and Vittra APS Unique based on Equation 4.

Equation 4:

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

The values of $\Delta E_{00\_DUAL}$ were calculated by comparing the color measured in simple specimens of composite Forma with those assessed in the center of dual specimens (Equation 4). Figure 1 schematically illustrates the calculation of $\Delta TP_{00}$ and $\Delta E_{00}$.

For each experimental condition (background color vs. composite shade), the CAP was calculated using the following equation:[18]

Equation 5: $CAP = 1 - (\Delta E_{00\_DUAL} / \Delta E_{00\_SIMPLE})$

The data were analyzed for the normal distribution (Shapiro–Wilk test) and homogeneity of variance (Levene's test). $WI_D$ data were analyzed by one-way ANOVA and compared to the composite shades. A two-way repeated-measures ANOVA was used to analyze the ΔTP00 and ΔE00 data (one analysis per background color). The independent variables were 'composite shade' vs. 'specimens design' (simple or dual), which was a repetition factor. A two-way repeated-measures ANOVA was also used to analyze TAP and CAP data. For these last analyses, the independent variables were 'composite shade' and 'background color' (repetition factor). Pairwise comparisons were performed using Tukey's test, and a significance level of 95% was set for all analyses.

## Results

$WI_D$ results are presented in Table 1. The one-way ANOVA ($p < 0.001$) showed a significant difference among composites regarding $WI_D$. The Vittra APS Unique composite showed the whitest color, and the lowest $WI_D$ values were observed for Forma A3D. A two-way repeated-measures ANOVA showed that neither 'composite shade' ($p = 0.218$) nor 'specimen design' ($p = 0.801$) affected the values of $\Delta TP_{00}$ (for the interaction, $p = 0.256$) (Table 2). The 'composite

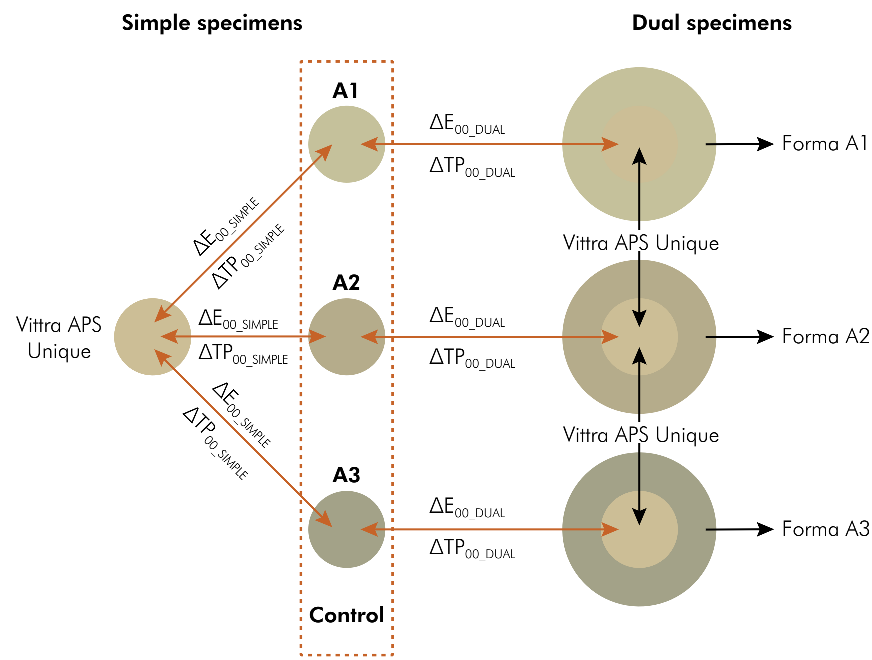


**Figure 1.** A schematic showing the specimen arrangement used to calculate color differences.

**Table 1.** Means (and standard deviations) of whiteness indices evaluated in simple specimens.

| Composite | $WI_D$ |
|---|---|
| Forma A1D | 33.0 (0.3) $^{B}$ |
| Forma A2D | 29.2 (0.6) $^{C}$ |
| Forma A3D | 22.1 (0.4) $^{D}$ |
| Vittra APS Unique | 40.8 (1.7) $^{A}$ |

For each outcome, distinct letters indicate a significant difference in Tukey`s test ($p < 0.05$). WID: whiteness index for dentistry

**Table 2.** Means (and standard deviations) for ΔTP00 values for simple or dual specimens of the composite Vittra APS Unique compared to control specimens.

| Composite shade | $\Delta TP_{00\_SIMPLE}$ | $\Delta TP_{00\_DUAL}$ |
|---|---|---|
| A1 | 8.8 (1.9) | 8.1 (1.4) |
| A2 | 7.0 (2.0) | 7.4 (1.3) |
| A3 | 7.9 (1.9) | 8.1 (0.8) |

No significant difference was observed for any experimental condition.

shade' significantly affected the TAP values (Figure 2). The highest TAP values were observed for shade A1 and the lowest for shade A2.

Table 3 presents the results for $\Delta E_{00}$ measured against white and black backgrounds. A two-way repeated-measures ANOVA showed that $\Delta E_{00}$ values were affected only by the factor 'composite shade' ($p < 0.001$). The factor 'specimen design' ($p = 0.059$; interaction, $p = 0.425$) did not affect $\Delta E_{00}$. For both $\Delta E_{00\_SIMPLE}$ and $\Delta E_{00\_DUAL}$, the highest color difference was observed for shade A3, while shade A1 had the closest color to Vittra APS Unique. For the black background, both the 'composite shade' ($p < 0.001$) and 'specimen design' ($p < 0.001$) affected the $\Delta E_{00}$ values, and the interaction between the factors was also significant ($p = 0.047$). For both $\Delta E_{00\_SIMPLE}$ and $\Delta E_{00\_DUAL}$, the lowest values were observed for A1. Shade A3 resulted in the highest $\Delta E_{00}$ values, but there was no difference from shade A2 for $\Delta E_{00\_SIMPLE}$. Differences between the specimen designs were only observed for shade A1 ($\Delta E_{00\_SIMPLE} > \Delta E_{00\_DUAL}$).

A two-way repeated-measures ANOVA showed that both 'background color' ($p < 0.001$) and 'composite shade' ($p = 0.007$) affected CAP values, and the interaction between the factors was not significant ($p = 0.061$) (Figure 3). The lowest and the highest CAP values were observed for the surrounding shade A1 for white and black backgrounds, respectively, and no difference was observed between shade A2 and shade A3. Regardless of the composite shade, higher CAP

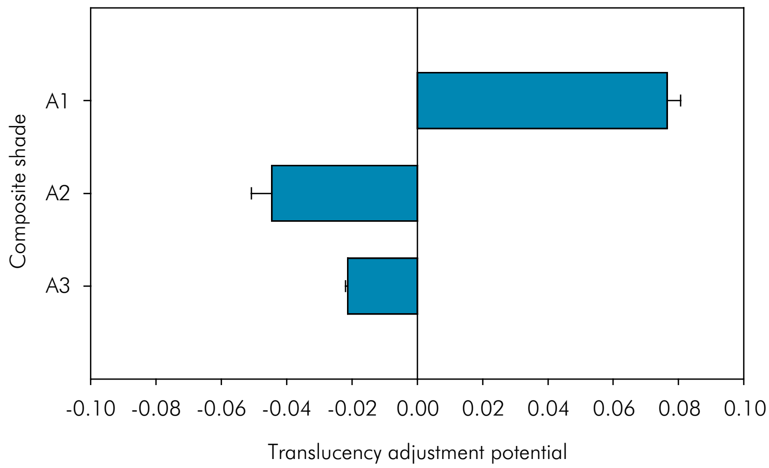


**Figure 2.** Means and standard deviations of the translucency adjustment potential (TAP) according to the composite shade. Distinct letters indicate significant differences according to Tukey`s test ($p < 0.05$).

**Table 3.** Means (and standard deviations) for ΔE00 values for simple or dual specimens of the Vittra APS Unique composite compared with control specimens.

| Variable | Background color | | | |
|---|---|---|---|---|
| | White | | Black | |
| Color difference | $\Delta E_{00\_SIMPLE}$ | $\Delta E_{00\_DUAL}$ | $\Delta E_{00\_SIMPLE}$ | $\Delta E_{00\_DUAL}$ |
| Composite shade* | | | | |
| A1 | 7.3 (1.2) $^{Ca}$ | 8.3 (0.3) $^{Ca}$ | 8.7 (1.3) $^{Ba}$ | 7.0 (0.9) $^{Cb}$ |
| A2 | 9.2 (0.9) $^{Ba}$ | 9.5 (0.4) $^{Ba}$ | 10.1 (1.2) $^{Aa}$ | 9.3 (0.7) $^{Ba}$ |
| A3 | 11.9 (1.0) $^{Aa}$ | 12.4 (0.1) $^{Aa}$ | 11.8 (0.9) $^{Aa}$ | 11.0 (1.2) $^{Aa}$ |

For each background color, distinct letters (uppercase comparing composite shades and lowercase comparing backgrounds) indicate significant differences using Tukey`s test ($p < 0.05$). *Composite shade of control simple specimens and the surrounding composite for dual specimens.

values were observed for the black background compared to the white background.

## Discussion

Esthetic direct restorations that mimic the remaining tooth structure are a challenge for most clinicians. Using composites that change their color based on those of the adjacent substrate would make the restorative procedure more predictable. When simple specimens were evaluated, the single-shade composite was whiter than the others used as controls in this study. Among the controls, the wither composite (shade A1D) presented a mean $WI_D$ of 33.0, while the average value for the Vittra APS Unique was 40.8. The difference in $WI_D$ (7.8 units) between these two materials is 3-fold higher than the 50:50% acceptability threshold (2.6 units) calculated in a prior study.[22] This same study found a difference of 5.9 $WI_D$ units as clinically unacceptable. Shade A1 is the second lightest tab (darker only than B1) in the Vita Classical shade guide. Obtaining esthetic restoration using a light single-shade composite (whiter than A1) significantly relies on its color-shifting ability.

Even though thin composite layers are used to restore anterior teeth, specimens thicker than 2 mm are commonly used in studies evaluating the CAP of resin composites.[23,24] However, certain areas of the incisal border of an upper incisor, are thinner, and the effect of the dark background (oral cavity) is more pronounced as the translucency of the composite increases. The manufacturer of Vittra APS Unique states that its color blending ability is mainly due

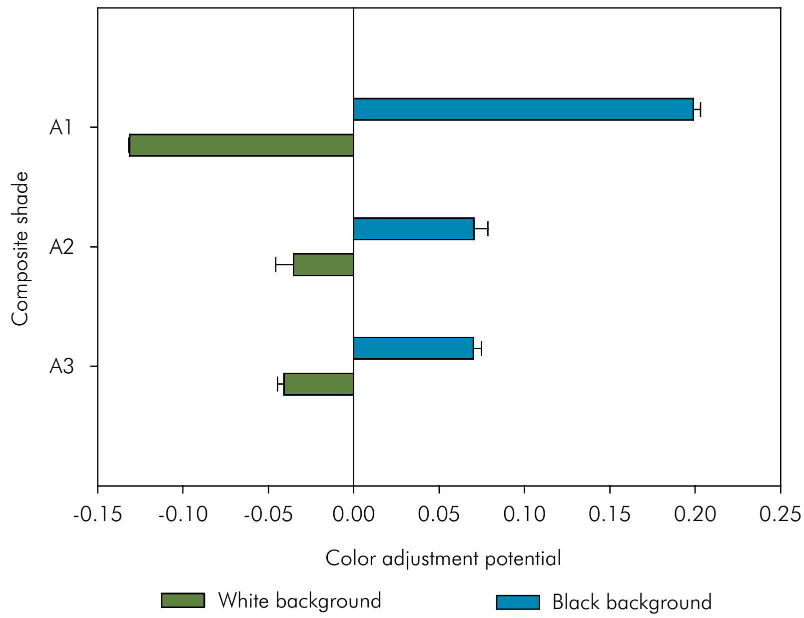


**Figure 3.** Means and standard deviations of the color adjustment potential (CAP) according to the composite shade and background color.

to its translucency increasing after polymerization. Indeed, the $TP_{00}$ measured for Vittra APS Unique in this study was at least 7.0 units higher than the controls, which were developed to have a similar translucency to tooth dentin. Therefore, all $TP_{00}$ differences were more than 2-fold higher than the 50:50% acceptability threshold (2.62) estimated in a prior study,[25] which indicates a significant effect of the background color on the final color of the composite. Regardless of the composite shade, surrounding the tested composite with the controls did not significantly modify the $\Delta TP_{00}$ values. Moreover, a tendency of $\Delta TP_{00}$ reduction (translucency shifting) was observed only for A1. Consequently, a positive TAP was observed only for this last shade, and a TAP modulus lower than 0.1 was observed for all other shades. However, it is important to emphasize that Cohen's d effect size up to 0.2 is considered small.[26] Then, despite the significant differences, it is essential to emphasize that no clinically relevant color difference is expected among the composite shades due to their TAP.

Ideally, the composite color should match that of the adjacent substrate. In the present study, $\Delta E_{00\_SIMPLE}$ quantifies the discrepancy in the composite color without any effect of the surrounding substrate. As expected, the lowest $\Delta E_{00\_SIMPLE}$ values were observed for shade A1 measured against white (7.3) and black (8.7) backgrounds. Considering that the composites have some color shifting ability, the color difference is expected to be lower for dual specimens ($\Delta E_{00\_DUAL}$) than for the simples ($\Delta E_{00\_SIMPLE}$). However, no significant difference was observed for the surrounding shades between $\Delta E_{00\_DUAL}$ and $\Delta E_{00\_SIMPLE}$ when a white background was used. Otherwise, a tendency of higher $\Delta E_{00\_DUAL}$ values (no significant difference) than $\Delta E_{00\_SIMPLE}$ was observed for all shades. This increase in $\Delta E_{00}$ caused by the surrounding color resulted in negative CAP values, which indicates that the composite color did not shift with the surrounding shade. The opposite tendency was observed for the black background, and $\Delta E_{00\_DUAL}$ was lower than $\Delta E_{00\_SIMPLE}$ (a significant difference for A1). Consequently, higher CAP values were observed against the black background compared to when a white background was used.

The highest modulus of differences between $\Delta E_{00\_DUAL}$ and $\Delta E_{00\_SIMPLE}$ were observed for shade A1 (1.0 and 1.7 for white and black backgrounds, respectively). These values are between the

50:50% perceptibility (0.81) and acceptability (1.77) thresholds.[27] This indicates that color shifting can be perceptible for most observers but it is not clinically irrelevant. However, the modulus of differences below the 50:50% perceptibility threshold was observed for the other shades (from 0.3 to 0.8).[27] As a result, the highest CAP values (negative against the white background) were found surrounding the Vittra APS Unique with composite A1. However, irrespective of the surrounding shade and even for shade A1 (-0.13 and 0.20), the CAP values were considered small based on observed Cohen's d effect size.[26]

Considering the high translucency of Vittra APS Unique, its manufacturer recommends an additional underlying layer of a more opaque composite to cover very dark substrates. This recommendation suggests that the color blending of this material is mainly due to visualization of the underlying substrate that should have a similar color compared to the surrounding substrate. However, this study's findings showed that placing a thin layer of this single-shade composite over a white background (like some resin opacifiers) reduced the CAP value compared to those observed for the black background. Moreover, $\Delta E_{00\_DUAL}$ values higher than eight were observed against the white background for all surrounding shades. These results indicate that simply covering the dark substrate with an opaque resin does not assure an esthetic restoration. In addition, an opaque resin with a similar color compared to the adjacent substrate can be needed. In this scenario, the advantages of using a single-shade composite are lost. Finally, it is essential to emphasize that only a single material was evaluated in this study and results cannot be extrapolated to other single-shade composites.

## Conclusions

This study's findings demonstrate that the color of both the surroundings and background affects the color adjustment potential of a single-shade composite used in a thin layer. However, these factors did not interfere with the translucency adjustment potential.

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