Original Article

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Effect of tooth background color on the visual color adjustment potential of single-shade resin composites

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Objectives: This study aimed to assess the impact of different background tooth colors on the visual color adjustment potential (CAP-V) of two single-shade flowable resin composites, evaluating their suitability for anterior restorations.

Materials and Methods: Two single-shade flowable composite resins (Omnichroma : OMN and Essentia Highflo : ESH) were evaluated. Two different shades (A1 and A3.5) of Shofu Disk HC were milled into maxillary right central incisor models with a 1 mm MID bevel preparation to serve as background colors. Dual specimens (artificial central incisor models restored with the tested composites) and single specimens (Composite central incisor models) of all test materials were prepared (n = 5 per group). Visual scoring of color matching was performed by independent observers under controlled conditions. CAP-V values were calculated based on the visual scores. Statistical analysis was performed using Two-way analysis of variance (ANOVA) with a significance level set at $\alpha = 0.05$.

Results: CAP-V values and visual scores were significantly influenced by the composite resin type, tooth shade, and their interaction ($p < 0.001$). Positive CAP-V values were observed for all tested materials. Among them, OMN demonstrated a significantly higher CAP-V in the A1 shade compared to ESH, which corresponded with a lower visual color score. In the A3.5 shade, OMN and ESH exhibited similar CAP-V values; however, ESH showed a significantly lower visual color score.

Conclusions: OMN could serve as an alternative material for the injection molding technique in anterior teeth with lighter shades, while ESH may be more suitable for darker shades.

Keywords: color adjustment potential, color shifting, resin composites, single shade, visual score

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Introduction

Restoring anterior teeth by layering technique with multi-shade resin composites demands a high level of clinical skill and prolonged chair time to achieve optimal esthetic outcomes [1]. These challenges, particularly in pediatric patients and individuals with systemic conditions, have driven the development of more advanced restorative techniques, such as the injection mold technique. This method utilizes the injection of flowable composite resin into a matrix created from a wax-up model of the tooth. Nevertheless, its application has been limited by restricted shade options and blending capabilities [2].

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Recently, universal shade resin composites have been introduced, designed to seamlessly blend with a wide range of natural tooth colors [3]. Available in both paste and flowable consistencies, these materials offer greater versatility in clinical practice. The first single-shade composite evaluated was Omnichroma (OMN, Tokuyama Dental, Tokyo, Japan), which features an enhanced chameleon effect resulting from structural color technology [4]. This technology involves the interaction of supra-nano structures — specifically, 260 nm uniform spherical fillers that exhibit a notable peak around 560 nm, corresponding to the red to yellow region of the visible spectrum. This characteristic contributes to the material's resemblance to natural teeth. Additionally, the material's translucency increases after polymerization due to differences in refractive indices between the monomers [5]. The resulting increased translucency allows more light to be reflected from the background color into the composite resin restoration. Another universal shade composite available in a flowable form is Essentia Universal (ESH, GC, Tokyo, Japan). According to Chen et al., ESH demonstrated improved diffuse transmission and straight-line transmission properties compared to supra-nanofilled and cluster-nanofilled resin composites, thereby enhancing shade matching by incorporating reflections from both the cavity floor and cavity walls [6].

A study by Evans *et al.* (2020) revealed that OMN tended to exhibit poorer shade-matching ability compared to conventional multishade composite materials, particularly in darker tooth shades [7]. It was of interest to investigate the color adjustment potential (CAP-V) and visual score of different single-shade composites when restoring teeth with various tooth shades, as this may aid in achieving optimal esthetic outcomes in anterior tooth restorations. Therefore, the present study aims to explore the CAP-V and visual score of OMN and ESH in anterior tooth restoration. The null hypotheses of this study were i) There is no difference in the CAP-V among different tooth shades and materials tested. ii) There is no difference in the visual score among different tooth shades and materials tested.

Materials and Methods

Single shade resin composites

1. Omnichroma Flow (OMN; Tokuyama Dental, Tokyo, Japan) is a nanocomposite comprising 71% filler by weight and 57% by volume. It contained spherical silica-zirconia fillers measuring 0.2–0.4 µm, incorporated within a resin matrix of UDMA and TEGDMA.

2. Essentia Universal Hiflo (ESH; GC Dental, Tokyo, Japan) is a microhybrid composite containing 69 wt% filler, primarily composed of barium glass fillers (700 nm) and pre-polymerized silica. The resin matrix consisted of UDMA, Bis-MEPP, Bis-EMA, Bis-GMA, and TEGDMA, with particle sizes ranging from 0.02 to 1.3 µm.

Specimen preparation for CAP-V

Twenty maxillary right central incisors and adjacent teeth (canine to canine) were milled from Shofu Disk HC (Shofu Dental, Tokyo, Japan) in shades A1 and A3.5 to fit into a dentoform.

Two single-shade resin composites, OMN (Omnichroma Flow) and ESH (Essentia HiFlo), were tested. Specimens were divided into two groups: Single specimens (artificial central incisor tooth models) and Dual specimens (artificial central incisor tooth models restored with the tested composites), as demonstrated in Figure 1.

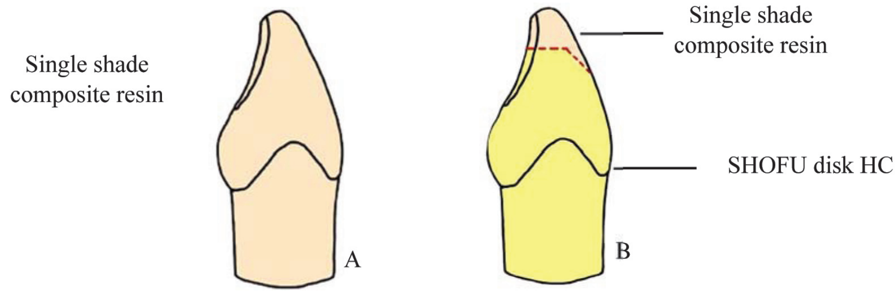

Figure 1 Example of a single specimen (A) and a dual specimen bevel 1 mm (B) group

For Single specimens, samples were replicated using the tested single-shade resin composites and a clear silicone mold (n = 5), then embedded in a dentoform for CAP-V evaluation. For Dual specimens, milled teeth were prepared with a 1 mm, 45-degree bevel, treated with a universal adhesive (Single Bond Universal, 3M Oral Care, MN, USA) cured using a light-curing unit (Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein) with a light intensity of 1,200 mW/cm^2. Restorations were fabricated using a clear silicone mold (Exaclear, GC Dental, Tokyo, Japan) and cured for 40 seconds.

All specimens were embedded in a dentoform and evaluated for CAP-V.

Visual color adjustment potential evaluation (CAP-V)

The color evaluations were conducted by two experienced dentists undergone a test for color blindness using Ishihara's color blindness test [8]. They were asked to assess the color match of each single-shade resin composite restoration against artificial tooth models with shades A1 and A3.5. All evaluations took place in a controlled environment, with the specimens (previously coded and presented in random sequence) placed on neutral gray paper under consistent D65 clinical illumination at a 90° angle to the specimen's surface. The evaluation time was set at 25 seconds, and to prevent eye strain, evaluators were instructed to gaze at neutral blue paper between assessments. Color differences were rated on a scale from 0 to 4: 0 for an excellent color match, 1 for a very good match, 2 for a borderline match, 3 for an obvious mismatch, and 4 for a significant mismatch [8].

CAP-V was calculated as follows:

$$CAP - V = 1 - (V_{DUAL} / V_{SINGLE})$$

Where V_{DUAL} is the visual rating between the non-restored artificial central incisors and dual specimens in which the artificial central incisor model was restored with a tested single-shade resin composite, and V_{SINGLE} is the visual rating between the non-restored artificial central incisors and single specimens replicated with the tested single-shade resin composite.

Color measurement by instrumental technique

Single-shade resin composite specimens, with a diameter of 10 mm and a thickness of 2 mm, were made using a custom stainless steel mold. The resin composite specified in Table 1 was applied to a depth of 2 mm and covered with a celluloid strip. A microscope slide was then pressed onto the strip to ensure uniform thickness before polymerization with a light curing unit. Afterward, the color was evaluated using a noncontact spectrophotometer

(SpectroShade Micro, MHT Optic Research, Niederhasli, Switzerland), calibrated with a white tile under controlled lighting. The evaluation followed the VITA CLASSIC guidelines.

Sample size calculation

The sample size will be calculated using nQuery Advisor MGT0-1 program, aiming for a power of 80% (β = 0.2) with a significance level (α) of 0.05. Calculation will be based on the mean and standard deviation reported in a previous study [9]. In this study, the minimum estimated sample size per experimental group was five, resulting in a total of 20 specimens to detect differences between groups.

Statistical analysis

The statistical analysis was conducted using STATA 17 software (StataCorp LLC, TX, USA). Data was presented as mean ± standard deviation (SD). The normality of the data distribution was evaluated using the Shapiro–Wilk tests. Comparisons among groups were determined by two-way analysis of variance (ANOVA). *p*-value was set at 0.05.

Results

The mean visual scoring and standard deviations for single and dual specimens and the corresponding CAP-V values are presented in Table 1. Positive CAP-V values were recorded for all of the test materials. The CAP-V values ranged from 0.10 to 0.70, with the highest values found for the OMN and ESH composite resin restored in A3.5 background tooth color. OMN exhibited the significantly highest CAP-V value against the A1 tooth shade. In contrast, in the A3.5 tooth shade, both OMN and ESH exhibited a CAP-V of 0.70 without a statistically significant difference.

Table 1 Visual color score and Visual color adjustment potential (CAP-V) by tooth shade, composite material and specimen type (mean ± standard deviation).

Tooth shade	Composite material	Visual color score		CAP-V
		Single specimen	Dual specimen (1 mm Bevel)	
A1	OMN	3.00 ± 0.00^{X}	1.60 ± 0.52^{A}	0.47 ± 0.17^{a}
	ESH	4.00 ± 0.00^{Y}	3.60 ± 0.52^{B}	0.10 ± 0.13^{b}
A3.5	OMN	4.00 ± 0.00^{Y}	1.20 ± 0.63^{C}	0.70 ± 0.16^{c}
	ESH	2.00 ± 0.00^{Z}	0.60 ± 0.52^{D}	0.70 ± 0.26^{c}

Abbreviations: ESH, Essentia high flow; OMN, Omnichroma

Same superscript uppercase letter indicates no significant difference among different tooth shade and material type for visual color score in dual specimen (p>0.05).

Same superscript lowercase letter indicates no significant difference among different tooth shade and material type for CAP-V (p>0.05).

Table 2 Two-way ANOVA for visual color adjustment potential (CAP-V) by tooth shade and composite material

Source of Variation	df	Mean Square	F	*p*-value
Corrected Model	3	0.803	23.275	<0.001
Intercept	1	9.669	280.349	<0.001
Tooth shade	1	1.736	50.336	<0.001
Composite material	1	0.336	9.745	<0.001
Tooth shade x Composite	1	0.336	9.745	<0.001
Residual error	36	0.034		
Total	40			

material
R Squared = .660 (Adjusted R Squared = .631)
Abbreviations: Tooth shade" = A1 vs. A3.5; "Composite material" = OMN vs. ESH).

Table 3 Two-way ANOVA for visual color score by tooth shade and composite material

Source of Variation	df	Mean Square	F	*p*-value
Corrected Model	3	16.9	56.333	<0.001
Intercept	1	122.5	408.333	<0.001
Tooth shade	1	28.9	96.333	<0.001
Composite material	1	4.9	16.333	<0.001
Tooth shade x Composite	1	16.9	56.333	<0.001
Residual error	36	0.3		
Total	40			

R Squared = .824 (Adjusted R Squared = .810)
Abbreviations: Tooth shade" = A1 vs. A3.5; "Composite material" = OMN vs. ESH).

The two-way ANOVA revealed statistically significant main effects of tooth shade (F = 50.34, *p*< 0.001) and composite material (F = 9.75, *p* = 0.004) on the CAP-V. Additionally, a significant interaction effect was observed between tooth shade and composite material (F = 9.75, *p* = 0.004), suggesting that the influence of composite material varies depending on the shade used. The model demonstrated a good fit, with an R Squared value of 0.660 and an Adjusted R Squared of 0.631, indicating that approximately 66% of the variation in CAP-V was explained by the main effects of tooth shade, composite material, and their interaction.

The two-way ANOVA showed that both tooth shade (F = 96.333, p <0.001) and composite material (F = 16.333, p<0.001) have a statistically significant impact on the visual score. Furthermore, a significant interaction effect was found between tooth shade and composite material (F = 56.333, p<0.001), indicating that the influence of composite material on the visual color score is influenced by the tooth shade. This significant interaction highlights that these factors are not independent and must be considered together to fully understand their effect on the visual outcome. The model accounted for a substantial proportion of variance in the visual color score, with an R Squared value of 0.824 (Adjusted R^2 = 0.810), indicating that 82.4% of the variation was explained by the combined effects of tooth shade, composite material, and their interaction.

Color measurement by instrumental technique

The color measurement according to VITA CLASSIC of OMN and ESH was B1 and A3, respectively.

Discussion

The results revealed significant differences in visual scores and CAP-V values across the different tooth shades. Consequently, the null hypotheses, which proposed no differences in color adjustment potential (CAP-V) and visual scores among the different tooth shades and materials tested, were rejected. Both the visual scores and CAP-V values varied depending on the material type and background color, leading to distinct esthetic outcomes among the composite resin restorations.

Tooth shades A1 and A3.5 were selected in this study to represent lighter and darker shades, respectively. It is interesting to evaluate the CAP-V and visual score with the darker tooth shade. However, a shade darker than A3.5 was not available for the Shofu disk. In this study, all tested composite resins demonstrated positive CAP-V values, suggesting that nearly all materials exhibited some degree of color shifting in response to different background colors.

For tooth shade A1, OMN exhibited significantly higher CAP-V compared to ESH, which corresponds to the lower visual color score. This could be due to its enhanced chameleon effect resulting from structural color technology [4]. This technology involved the interaction of supra-nano structures — specifically, 260 nm uniform spherical fillers that showed a notable peak around 560 nm, corresponding to the red to yellow region of the spectrum. This characteristic contributed to the material's resemblance to natural teeth. Furthermore, the material's translucency increased after polymerization, due to the variance in refractive indices between the monomers [5]. The high translucency of OMN may have contributed to its elevated CAP-V values. However, this property could have limited its ability to achieve optimal blending. Excessively translucent materials tended to transmit and reflect the underlying background color—particularly the dark shade of the oral cavity—thereby compromising esthetic outcomes in clinical conditions.

On the other hand, for tooth shade A3.5, OMN and ESH showed similar CAP-V at 0.70, which were significantly higher than those of A1. This indicates a better color-shifting effect with the darker tooth shade. Though similar CAP-V between OMN and ESH was demonstrated.

ESH showed significantly lower visual color score, which means excellent color match with the tooth shade A3.5. This could be explained by the color measurement result. As color measurement demonstrated color B1 and A3 for OMN and ESH, respectively. The color matching of ESH was closer to the background tooth shade (A3.5). Therefore, the visual color score of ESH was excellent with the shade A3.5. On the other hand. OMN has no pigment. The color of OMN is influenced by the background color. Since the color measurement was performed with the white tile. Therefore, the measured color of OMN was B1. Though the CAP-V of OMN was high, the visual score was significantly higher than ESH with tooth shade A3.5. This was supported by the previous article [10] demonstrated decreased color blending of OMN with the dark tooth shade.

The present study still had several limitations. Only two single-shade resin composites were assessed, and other factors, such as cavity preparation or material's property, may significantly influence CAP-V and visual scores. Additionally, the color stability of resin composites can be greatly affected by aging conditions in the oral environment, including temperature variations and the absorption of pigments from food and beverages, which may impact the esthetic outcomes and longevity of restorations. Further in vivo and in vitro studies are necessary to investigate these variables in greater details to provide more insight into the blending effect of resin composites.

Conclusion

Considering the limitations of this study, the following conclusions were reached:

1. Both the color adjustment potential (CAP-V) and visual color score were significantly influenced by the composite resin type and the background tooth color.

2. OMN showed favorable color-shifting capability and achieved high CAP-V across various background colors, while ESH demonstrated better visual score in the darker tooth shades.

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