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Effect of Composite Thickness and Dimensions of Class IV Restorations on Color Match of Omnichroma Single-Shade Composite Resin

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A B S T R A C T

Objectives: This study aimed to investigate the effect of composite thickness and dimensions of Class IV restorations on color match of Omnichroma single-shade composite resin.

Materials and Methods: In this in vitro study, 48 composite discs were fabricated from A2 shade of Estelite Sigma Quick composite resin. The specimens were randomly assigned to three groups based on restoration width (2mm, 3mm, and 4mm), while preparation depth was standardized at 1.5mm. Each group was further subdivided according to Omnichroma blocker thickness (0.5mm or 0.8mm). Restorations were completed using Omnichroma layered over the blocker material. Color difference (ΔE_{00}) was determined using the CIEDE2000 formula with a non-contact spectrophotometer. Statistical analysis was conducted using two-way ANOVA with a significance level set at 0.05.

Results: A significant reduction in ΔE_{00} values was observed with increasing restoration width ($P<0.0001$). Blocker thickness did not have a statistically significant effect on ΔE_{00} ($P=0.92$). No significant interaction was found between restoration width and blocker thickness in terms of lightness change (ΔL_{00}).

Conclusion: The color match of Omnichroma was found to be clinically unacceptable in simulated anterior restorations; however, its performance improved as restoration width increased. Variations in blocker thickness did not significantly influence the color match.

Keywords: Color; Composite Resins; Dental Restoration; Anterior Teeth

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INTRODUCTION

Composite resins are extensively used in restorative dentistry due to their favorable esthetic properties, conservative application, cost-effectiveness, and satisfactory mechanical performance [1]. The natural dentition exhibits a broad spectrum of color variations, leading manufacturers to develop multi-shade composite resins commonly based on the Vita Classic shade guide [2]. Additionally, composite resins are available with different degrees of opacity, commonly known as opaque, dentin, body, enamel, or translucent, intended to mimic the optical characteristics of different tooth areas [3]. The layering technique has been used for many years in order to create life-like composite restorations. This technique incorporates composites with different opacities to simulate each layer of natural tooth. Despite their effectiveness, these

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techniques are often technique-sensitive and require longer clinical time [4].

Composite resins with simplified clinical procedures are favored by clinicians because of shorter chair-side time and less operator-dependence [5]. This has led to the introduction of single-shade composites [5]. According to the manufacturers, the primary benefit of these composites lies in improved color adjustment ability, defined as the ability of the composite to blend with the surrounding dental structure, thus enhancing esthetics [6-8]. Omnichroma (Tokuyama Dental, Tokyo, Japan) is a recently developed single-shade composite, claimed to match a full range of tooth colors using structural coloration rather than pigments [5,9].

Given the clinical interest in simplifying shade selection in composite restorations and the development of recent composites to facilitate this, together with limited number of investigations regarding the optical behavior of Omnichroma as a newly introduced composite resin, the aim of the present study was to assess the color match of Omnichroma in Class IV restorations using composite discs. The null hypothesis tested was that the shade match of Omnichroma would not differ based on cavity dimension or thickness of composite resin.

MATERIALS AND METHODS

This in vitro study was conducted following obtaining ethical approval from the Institutional Research Ethics Committee of Tehran Medical Sciences, Islamic Azad University (Approval No. IR.IAU.DENTAL.REC.1401.031).

Simulated cavity preparation:

Details of the composite materials evaluated in this study are presented in Table 1.

Sample size calculation was performed using PASS 11 software. Considering an alpha level of 0.05, effect sizes of 0.97 for restoration width and 0.77 for composite thickness were determined. A sample size of 8 specimens per subgroup provided a statistical power exceeding 0.99.

A customized ring-shaped silicone mold with an internal diameter of 8mm and a depth of 1.5mm was fabricated using transparent addition silicone impression material (Kristal, Müller-Omicron GmbH & Co. KG, Germany). Forty-eight composite discs were fabricated by filling the mold with A2 shade of Estelite Sigma Quick (Tokuyama Dental, Tokyo, Japan) as shown in Figure 1A. Composite discs were fabricated in the following order: the thickness of the discs was 1.5mm. The specimens were randomly divided into

Table 1. Evaluated composite resin materials and their composition

Material	Composition	Manufacturer	Shade
Omnichroma	Filler: 79wt% uniform sized supra-nano spherical filler (SiO_2-ZrO_2 260nm), round-shaped composite filler (containing 260nm spherical SiO_2-ZrO_2) Base resin: UDMA, TEGDMA	Tokuyama Dental, Tokyo, Japan	Universal
Estelite Sigma Quick	Filler: 82wt% uniform sized supra-nano spherical filler [SiO_2-ZrO_2, SiO_2-TiO_2 100–300nm (average 200nm)], round-shaped composite filler (100–300nm (average 200nm), spherical SiO_2-ZrO_2) Base resin: Bis-GMA, TEGDMA	Tokuyama Dental, Tokyo, Japan	A2
Omnichroma blocker	Filler: 82% of silica zirconia filler and composite filler, spherical filler (mean particle size 0.2µm, particle size range: 0.1 to 0.3µm). Bis-GMA and Triethylene glycol dimethacrylate	Tokuyama Dental, Tokyo, Japan	-

TEGDMA: triethylene glycol dimethacrylate; UDMA: urethane dimethacrylate; Bis-GMA: bisphenol-A-glycidyl methacrylate.

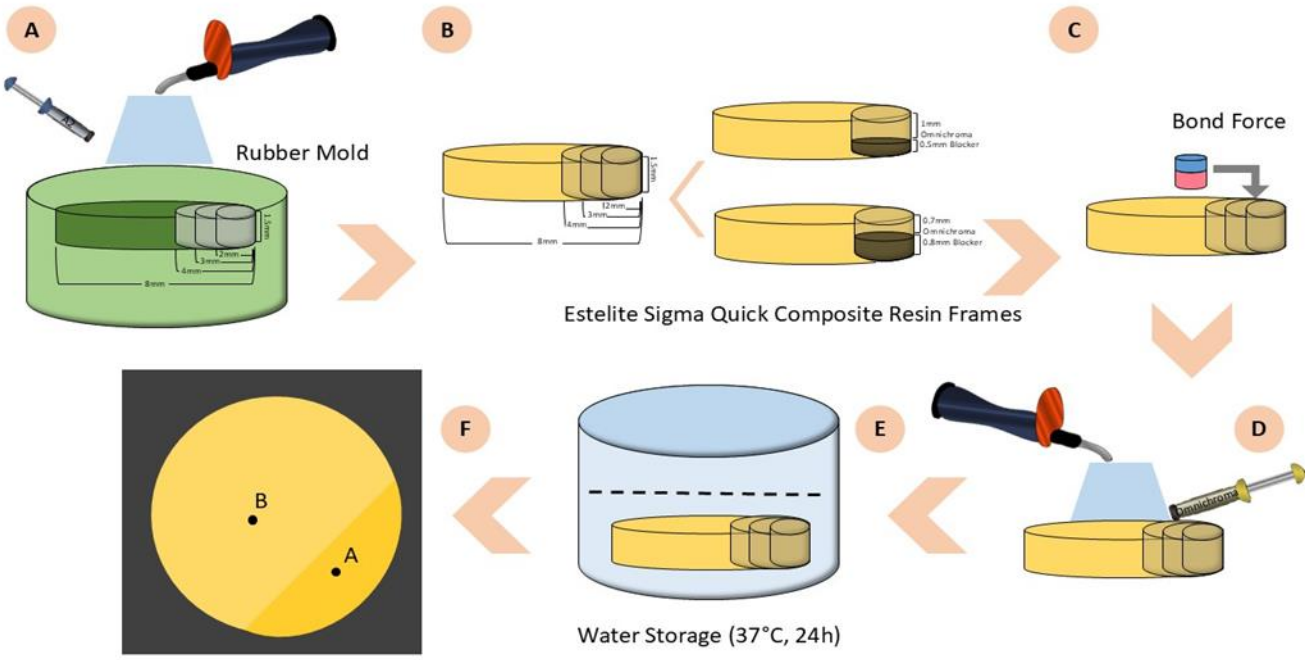


Fig. 1. Schematic view of specimen preparation process.

three groups (n=16) based on restoration width (2, 3 and 4mm). Each group was further subdivided into two subgroups (n=8) according to the thickness of Omnichroma blocker (Tokuyama Dental, Tokyo, Japan) (0.5and 0.8mm) as shown in Figure 1B. Preparations were performed using a coarse grit 007 diamond bur (DZ, Germany) mounted on a high-speed handpiece (Goldent, China), with the bur replaced after every five preparations. To ensure the standardization of the preparations, a transparent index (Kristal, Muller-Omicron GmbH & Co.KG, Germany) was fabricated from the first approved preparation. In all composite discs, Palfique Bond (Tokuyama Dental, Tokyo, Japan) was first applied per the manufacturer's instructions and light-cured using Bluephase G2 light curing unit (Ivoclar Vivadent, Amherst, NY, USA) for 20 seconds as shown in Figure 1C with a light intensity of 1300mW/cm2 which was checked after every three uses by means of a radiometer (Bluephase Meter II; Ivoclar Vivadent, Amherst, NY, USA).

Next, the blocker composite was placed in the cavity and the desired index was placed on blocker and cured for 20 seconds with the Bluephase G2 light curing unit. Next, Omnichroma was applied in one single increment to complete the restoration. In other words, if the thickness of the blocker was 0.5mm, 1mm of Omnichroma, and if the thickness of the blocker was 0.8mm, 0.7mm of Omnichroma was applied. A stamp technique was used to reproduce the original disc contour. In this method, a transparent occlusal stamp was fabricated earlier from an intact Estelite Sigma Quick composite disc, using the afore-mentioned transparent addition silicone material. After the application of Omnichroma composite, the stamp was pressed on it and after removing composite flashes, it was polymerized using the light curing unit as described above. Finally, to eliminate the oxygen-inhibited layer, a 5mm layer of glycerin was applied prior to an additional 20 second curing cycle. After rinsing off glycerin for 20 seconds, the final restoration was polished with Optrapol (Ivoclar Vivadent, Zurich, Germany) for 20 seconds with light hand pressure in a circular motion. The specimens were then stored in distilled water at 37°C for 24 hours (Figure 1)

Shade matching evaluation:

Color measurements of each restored disc and the surrounding Estelite Sigma Quick frame were performed using a noncontact spectrophotometer (CS-2000; Konica Minolta, Tokyo, Japan) equipped with 2 fiber optic cables (Model 70050; Newport Strat-ford Inc., Franklin, MA, USA) and a xenon lamp (300W; Newport Stratford Inc., Franklin, MA, USA). Measurements were performed against a black background to simulate the oral cavity's dark environment.

Reflection values of a 1mm circular area in the middle of each sample were converted into CIE L*a*b* color parameters (D65 illuminant, standard 2o observer). The L* value represents the psychometric lightness axis from black to white (achromatic coordinate) [22]. The spectrophotometer was calibrated using a white calibration plate (cs-A5) under controlled illumination.

The CIEDE 2000 color difference (ΔE_{00}) was calculated using an Excel spreadsheet implementation of the CIEDE 2000 color difference formula developed by Sharma et al. [10]. The parametric factors were set to 1 in the related formula. The three ΔE_{00} values measured for each composite restoration and the frame were averaged to consider as the data points.

Statistical analysis:

Two-way ANOVA was employed to analyze the effects of restoration dimensions and blocker thickness, followed by the Tukey's HSD test and t-test. The level of significance was set at α=0.05. The statistical analysis was performed with SPSS version 26.0 (SPSS Inc., IL, USA).

RESULTS

Two-way ANOVA revealed statistically significant interaction effect of restoration width and blocker thickness on ΔE_{00} value (P=0.001). Table 2 summarizes the mean and standard deviation of ΔE_{00} values for each group.

According to the Tukey's HSD test, restoration width had a significant effect on ΔE_{00} across all groups (P<0.0001). Specifically, groups with a blocker thickness of 0.5mm exhibited the largest ΔE_{00} values, particularly for a restoration width of 2mm (ΔE_{00}=7.89). As restoration width increased to 3mm and 4mm, ΔE_{00} values significantly decreased for both blocker thicknesses.

Table 2. Mean and standard deviation of ΔE_{00} for the simulated Class IV cavities

Cavity width (mm)	Blocker thickness (mm)	ΔE_{00}
2	0.5	7.89 (0.53)
	0.8	7.94 (0.55)
3	0.5	6.42 (0.58)
	0.8	5.10 (0.45)
4	0.5	4.22 (0.23)
	0.8	3.83 (0.59)

ΔE_{00}: Color difference.

Independent t-test was conducted to assess the influence of blocker thickness on ΔE_{00}. For restorations with a width of 2mm, the mean ΔE_{00} value was 7.94 for blocker thickness of 0.5mm and 7.89 for blocker thickness of 0.8mm. No statistically significant difference was observed between the groups (P=0.92). Similarly, with a restoration width of 3mm, the ΔE_{00} value was 6.42 for blocker thickness of 0.5mm, and 5.10 for blocker thickness of 0.8mm. Again, there was no significant difference between the groups (P=0.59). However, for restorations with 4mm width, a statistically significant difference was noted between blocker thicknesses of 0.5mm (ΔE_{00}=4.22) and 0.8mm (ΔE_{00}=3.83).

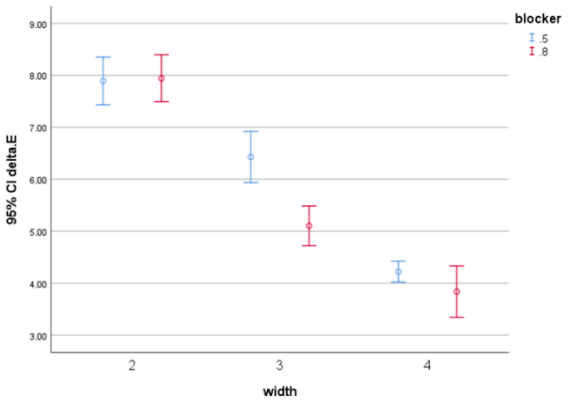


Fig. 2. ΔE_{00} with 95% confidence interval values for instrumental analysis of blocker thickness and cavity dimension for simulated Class IV cavities.

(P=0.05). Figure 2 graphically illustrates the impact of blocker thickness and restoration dimensions on ΔE_{00}Two-way ANOVA also showed that the interaction effect of restoration width and blocker thickness on ΔL_{00} was not significant
(P=0.41). However, the Tukey's HSD test demonstrated the statistically significant effect of restoration width on ΔL_{00} (P<0.0001). Table 3 summarizes the mean and standard deviation of ΔL_{00} for each group. When comparing groups with a blocker thickness of 0.5mm, a restoration width of 2mm resulted in the largest mean color difference ΔL_{00} (-6.90), followed by 3mm (-5.02) and 4mm (-3.63). All of these differences were statistically significant (P<0.0001). Similarly, for groups with a blocker thickness of 0.8mm, a restoration width of 2mm yielded the largest mean color difference ΔL_{00} (-6.63), followed by 3mm (-4.36) and 4mm (-2.97). Again, these differences were statistically significant (P<0.0001).

Table 3. Mean and standard deviation of ΔL_{00} values for simulated Class IV cavities

Cavity width (mm)	Blocker thickness (mm)	ΔL_{00}
2	0.5	-6.90 (0.32)
	0.8	-6.63 (0.55)
3	0.5	-5.02 (0.53)
	0.8	-4.36 (0.46)
4	0.5	-3.63 (0.25)
	0.8	-2.97 (0.62)

ΔL_{00}: lightness change.

Independent t-test was conducted to assess the impact of blocker thickness on ΔL_{00} across different restoration widths. For a restoration width of 2mm, there was no statistically significant difference in ΔL_{00} between blocker thicknesses of 0.5mm (-6.90) and 0.8mm (-6.63) (P=0.11). Similarly, no significant differences were observed between blocker thicknesses for restoration widths of 3mm (P=0.88) and 4mm (P=0.007). However, when comparing restoration width of 4mm with blocker thicknesses of 0.5mm (-5.02) versus 0.8mm (-2.97), a statistically significant difference was found (P=0.007). Figure 3 provides a visual representation of these findings.

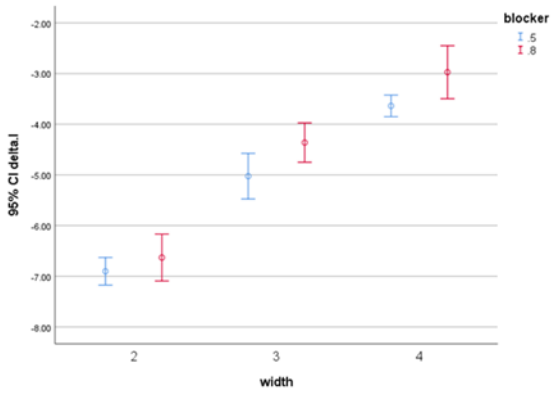


Fig. 3. ΔL_{00} with 95% confidence interval values for instrumental analysis of blocker thickness and cavity dimension for simulated Class IV cavities.

DISCUSSION

The present study evaluated the effect of restoration width and blocker thickness on the color matching ability of Omnichroma single-shade composite resin in simulated Class IV restorations. The results demonstrated that restoration width significantly influenced color matching, with larger restoration widths resulting in lower ΔE_{00} values and improved shade matching. In contrast, blocker thickness has no significant effect on color matching in most groups. Despite this improvement, the color match of Omnichroma remained clinically unacceptable in all tested conditions. Therefore, the null hypothesis was partially rejected. While restoration width significantly affected the shade-matching ability of Omnichroma, blocker thickness did not significantly influence the results under most experimental conditions.
The blending effect in dentistry refers to how dental materials interact with teeth, creating a less noticeable color difference when viewed together [11]. This occurs when two colors are placed next to each other, causing the perceived color to shift towards the surrounding area [12]. Dentists benefit from this effect as it helps minimize color mismatch and the shortage of suitable shades in restorative materials [5]. The appearance of composite resins in dentistry is influenced by how much light passes through the material [13]. The amount and size of filler particles in composite resins can affect their optical properties and light transmission [14]. These

composites contain filler particles of various sizes and shapes [15], which can influence how certain wavelengths of light are reflected or absorbed [16]. Interestingly, some materials display different colors due to their structural composition rather than pigmentation [17].

Omnichroma, a unique dental composite resin, utilizes smart chromatic technology to achieve a natural tooth-like appearance without the need for pigments. Unlike traditional composites, Omnichroma employs structural color to reflect a specific wavelength within the Vita Classic A1-D4 shade range, effectively matching various tooth colors with one single shade [18].

Composed of uniformly sized supra-nanospherical fillers of zirconium dioxide and silicon dioxide, along with round-shaped composite fillers, Omnichroma boasts a high refractive index monomer. This property enhances the material's transparency after polymerization, simplifying shade selection and reproduction.

The blending effect resulting from color shifting is closely linked to the translucency parameter [11]. By incorporating smart chromatic materials, this technology offers a significant advancement in dental materials, reducing the number of shades required for achieving optimal esthetic outcomes.

Abreu et al. [19] investigated the color match of various composites in Class III cavities and found that Omnichroma exhibited the highest ΔE compared to other materials, regardless of tooth shade. Our study corroborates these findings, demonstrating that Omnichroma's blending effect with the surrounding composite frame was unsatisfactory in all simulated Class IV cavities.

Achieving accurate color match is essential for esthetically pleasant composite restorations [20]. Our results highlight significant discrepancies in color match between Omnichroma and the surrounding composite, irrespective of cavity width or blocker thickness. The CIEDE 2000 color parameter, a widely used metric, establishes a perceptible threshold of 0.8 and an acceptable threshold of 1.8 [21]. Omnichroma composite consistently exceeded the acceptable threshold, with significantly higher ΔE_{00} values in all simulated Class IV cavities.

A previous study reported lower ΔE_{00} values (3.1±0.8) for Omnichroma composite resin, but their methodology differed from ours, as they employed the CIE L*a*b* color parameter and evaluated composite for occlusal restorations in posterior teeth [5]. Recent research has indicated that the CIEDE 2000 formula more accurately represents the human eye's perception of color difference compared to the CIE L*a*b* parameter [22].

Manufacturers confront a significant hurdle in developing universal composites which is choosing the ideal translucency that closely resembles the optical properties of dentin and enamel [23]. The amount of filler in composites directly affects their translucency and light scattering [23, 24]. Previous studies revealed that composites with a higher filler content exhibit greater translucency, leading to improved blending with natural teeth. Moreover, research indicates that increased translucency correlates with enhanced blending effect [24].

While Omnichroma composite demonstrates potential for blending with various shades, its translucency parameter requires enhancement to more effectively mimic the adjacent tooth substrate in anterior restorations. The Omnichroma's high translucency parameter hinders its ability to compensate for the oral cavity's dark background, even when used with a blocker composite. To address this limitation, the manufacturer could explore developing a specialized blocker composite designed for Class III and IV restorations [19]. However, our study revealed that even with the addition of an 0.8mm blocker, Omnichroma still exhibited unsatisfactory color match. All ΔL_{00} values fell within the negative range, indicating that Omnichroma's high translucency prevented it from adequately masking the oral cavity's dark shadow.

The color attributes of chroma and hue influence the Vita shade of composite resins, while material lightness directly correlates with its translucency [25]. However, research indicates that the human eye is more sensitive to black and white variations (value or gray scale) than other colors, making lightness a

more critical color determinant [25]. Another study confirmed this, revealing higher acceptability values for ΔL_{00} using CIEDE 2000 compared to chroma and hue [26].

Iyer et al. [27] suggested that Omnichroma composite may have limitations in shade-matching compared to multi-shade composites, potentially restricting its use in highly esthetic dental procedures. Conversely, Omnichroma exhibited a wider range of ΔE values (4.08 to 10.34), aligning with our results.

Human teeth typically exhibit a limited color spectrum, predominantly ranging from red to yellow tones [28]. Approximately half of the population possess teeth with an orange hue [29]. The CIE L*a*b* results in the present study indicate that the supra-nano filled composite resin effectively complements A1, A2, and A3 natural tooth shades. This alignment is the primary reason why A2 shade was selected in our study.

The findings of this study significantly contribute to the existing body of knowledge regarding the use of this innovative universal composite material in anterior tooth restorations. By providing valuable insights into color matching and clinical performance, this research aids in advancing dental restorative procedures.

The perception of shade matching in the oral cavity is influenced by a variety of factors, such as tooth shape, size of restoration, and the surrounding soft tissues. Natural teeth are complex structures with multiple layers, varying colors, and a curved shape, which can affect how light reflects and scatters off them. These factors may also impact the performance and evaluation of composite materials in real-world conditions. Further research is needed to fully understand the predictability of these materials by conducting in vivo studies on natural teeth and examining a wider range of shades [27].

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that the color match of Omnichroma in simulated Class IV restorations was not acceptable and its value was always lower than expected. The shade matching ability of Omnichroma improved in wider restorations in anterior teeth. Different thicknesses of blocker composite did not make a difference with respect to color matching ability except in 4mm wide restorations.

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CONFLICT OF INTEREST STATEMENT

The authors declare that no conflict of interests exists in relation to this study.

GENERATIVE AI IN SCIENTIFIC WRITING

No artificial intelligence (AI) tools were used in the preparation of manuscript.

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