Evaluate the influence of enamel-shade composite thickness on the overall color of aesthetic dental restorations

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Abstract

Background: Composite materials are widely used in aesthetic dental restorations due to their advantages, including minimal invasive preparation, high mechanical strength, adhesive durability, biocompatibility, time and cost-effectiveness. In composite layering techniques, material thickness significantly impacts the aesthetic outcome. **Objectives:** This study investigates the effect of enamel-shade composite thickness on the final color values of restorations using a two-layer technique to replace enamel and dentine. **Materials and Method:** Forty-five A2 enamel-shade composite discs were created from three composite groups: DenFil (Vericom Corp.), Harmonize (Kerr), and Beautifil II (Shofu Inc.) with five thicknesses: 0.3, 0.5, 1.0, 1.5, and 2.0 mm. Parameters measured included translucency, chroma, value, and color difference. Samples were photographed against black-white backgrounds and a 3.0 mm thick OA3 dentine-shade composite background. Color parameters (L, a, b) were collected using image analysis software to assess translucency, chroma, value, and color difference. **Results:** Translucency and chroma were inversely proportional to thickness for the three composite groups. With value, in the DenFil group, increased thickness decreased value, while no statistically significant correlation was found in the other two groups. When comparing the restoration color with the same enamel-shade composite thickness, no significant differences were found between Harmonize and Beautifil II, but DenFil significantly differed. **Conclusion:** In the two-layer technique for replacing enamel and dentine, enamel-shade composite thickness affects restoration color characteristics, varying among composite materials.

Keywords: *composite thickness; translucency; chroma; value; aesthetic dental restorations.*

1. INTRODUCTION

One challenge in aesthetic dentistry is achieving maximum shade matching between the restorative material and natural tooth tissue. According to Munsell's color theory, three basic color properties are hue, chroma, and value [1]. The CIE Lab color space, built on this theory and the human eye's color perception, is widely used in dentistry. In this color space, each shade is encoded with three coordinates: L, which is related to value; a, which refers to red to green; and b, which refers to yellow to blue [2, 3]. Among these primary color properties, the human eye is most sensitive to the value [3]. In addition to hue, chroma, and value, translucency, which is the degree of light transmission, is another critical aesthetic characteristic of natural teeth [4]. Natural tooth color is primarily determined by enamel and dentine, which have different optical properties. The color of natural teeth changes anatomically from the cervical third to the incisal third due to variations in enamel and dentine thickness [5]. Therefore, selecting an appropriate thickness of composites, which is intimately related to mimicking the translucency and value of enamel, as well as the hue and chroma of dentine, is crucial for achieving aesthetic success with layering techniques.

Various direct layering methods are proposed for the anterior region, including mono-laminar, bi-laminar, and multi-laminar techniques. When comparing these methods, the two-layer composite technique, which replaces enamel and dentine, stands out for its simplicity, time efficiency, and aesthetic effectiveness [6]. Selecting the correct shade for the restorative material is vital to mimicking the natural tooth. Currently, shade selection methods can be categorised into two groups: visual techniques using shade guides (VITA or non-VITA) and instrumental techniques (colorimeters/ spectrophotometers or digital photography combined with image processing software) [1, 2]. According to some studies, digital photography combined with image processing software is gradually becoming reliable for composite color matching in clinical practice [7]. This allows clinicians to evaluate the restoration region

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and adjacent areas, record anatomical details on the tooth surface, enhance laboratory communication and follow up on the treatment outcomes [2, 7].

Recent studies have evaluated the impact of composite thickness on restoration color, both clinical and in-vitro, utilizing various evaluation methods and parameters [4, 8]. These studies consistently highlight that thickness is a critical factor significantly influencing the aesthetic properties of the restoration. Despite the available findings, there is a substantial demand for additional research in Vietnam concerning the influence of composite thickness on cosmetic restorations. The lack of local data is crucial to underscore the importance of conducting targeted investigations in this field. Therefore, we conducted a study to investigate the effect of enamel-shade composite thickness on restoration color using a two-layer technique that replaces enamel and dentine. Our research focused on main color criteria such as translucency, chroma, value, and color difference. The null hypothesis posits that changes in the thickness of the enamel-shade composite do not affect the restoration's color. Based on this study, we hope to offer valuable insights and practical guidelines to help clinicians in Vietnam achieve optimal aesthetic outcomes in dental restorations.

2. MATERIALS AND METHOD

Forty-five A2 enamel-shade composite discs were created from three composite materials: DenFil (Vericom Corp.), Harmonize (Kerr), and Beautifil II (Shofu Inc.) (Table 1). All sample discs had the same diameter and were made in five thicknesses: 0.3, 0.5, 1.0, 1.5, and 2.0 mm, with three discs per thickness. Three materials belong to two composite types: microhybrid (DenFil) and nanohybrid (Kerr and Beautifil II). The samples must meet the following criteria: correct thickness (±0.02 mm), no air bubbles, and no fractures.

Table 1. Materials Used in the Study

	Group	Type	Manufacturer	Composition	
				Matrix	Filler
1	DenFil	microhybrid	Vericom Corp., South Korea	Bis-GMA, TEGDMA	80 wt% Barium aluminosilicate, Fumed silica (0.04 - 1 µm)
2	Harmonize	nanohybrid	Kerr, USA	Bis-GMA, Bis-EMA, TEGDMA	81 wt% Spherical zirconia-silica nano, Barium-aluminum-borosilicate glass (5 - 400 nm)
3	Beautifil II	nanohybrid/ giomer	Shofu Inc., Japan	Bis-GMA, TEGDMA	83.3 wt% S-PRG filler, multifunctional glass (0.01 - 4 µm and 10 - 20 nm)

Specimen preparation

The sample discs were created with a diameter of 12 mm and five thicknesses (0.3, 0.5, 1.0, 1.5, 2.0 mm) using a sample production kit from Smile Line (Porcelain Sampler, Smile Line) and light-cured for 60 seconds (X-Cure – Woodpecker, China, with a power output of 1000 - 1200 mW/cm²), as described by Ferraris et al. (2014) [4]. For each composite group and thickness, 3 sample discs were created. Thus, the sample size for the study is 45 (n=15). To simulate the two-layer technique and evaluate the effect of enamel-shade composite thickness on restoration color, the study used a fixed dentine-shade composite background: a 3.0 mm thick A3 dentine-shade disc (Beautifil II). The composite discs that met the sample criteria were stored in a desiccator for seven days before imaging.

Assessing the effect of enamel-shade composite thickness on the color of restoration with a two-layer technique

The sample imaging, image calibration and measuring color parameters from images were determined, as detailed by S. Hein et al. (2017) [7]. For sample imaging, the CieLab color parameters (L,a,b) were assessed through images taken with a digital camera using a cross-polarization filter and a white balance card (eLAB Prime, Germany) in fixed conditions. For image calibration, the L value of the white balance card area on the images was adjusted to the manufacturer's standard: standard L=79 using Adobe Lightroom Classic CC 2019 software (Adobe Inc., USA). For measuring color parameters from images, the samples' CIE Lab parameters (L, a, b) were recorded using Adobe Lightroom Classic

CC 2019 software (Adobe Inc., USA) at multiple positions. These parameters were denoted based on the background

L_b, a_b, b_b	L, a, b values measured on a black background
L_w, a_w, b_w	L, a, b values measured on a white background
L_d, a_d, b_d	L, a, b values measured on a dentine background

From the L, a, and b values, the parameters of translucency, chroma, value, and color difference were calculated using the following formulas:

- Chroma (C): $C = (a_d{}^2 + b_d{}^2)^{1/2}$
- Value (L_d): L_d
- Translucency Parameter (TP):
  $TP = [(L_b - L_w)^2 + (a_b - a_w)^2 + (b_b - b_w)^2]^{1/2}$

TP values range from 0 to 100: TP = 0 indicates complete opacity, and TP = 100 indicates complete transparency.

- Color Difference (ΔE_{ab}):
  $\Delta E_{ab} = [\Delta L_d{}^2 + \Delta a_d{}^2 + \Delta b_d{}^2]^{\frac{1}{2}}$

Where $\Delta L_d, \Delta a_d, \Delta b_d$ are the differences in L_d, a_d, b_d values between two samples of the same thickness but different composite groups. The ΔEab values are denoted as ΔEab(12), ΔEab(23), Δand Eab(31), corresponding to the color differences when comparing groups 1 with 2, 2 with 3, and 3 with 1, respectively. An ΔEab <3.3 means the color difference is acceptable [10].

Statistical Analysis

The collected color data were calculated and analyzed using Rstudio and R4.3.0 software (Posit, PBC). Pearson correlation analysis at a 95% confidence level was used to evaluate the effect of thickness on the samples' color parameters (translucency, chroma, value). Two-way ANOVA with Tukey's post hoc test at a 95% confidence level was used to determine if there were significant differences in the color parameters of the samples.

3. RESULTS

3.1. Effect of enamel-shade composite thickness on color parameters of restorations using the two-layer technique

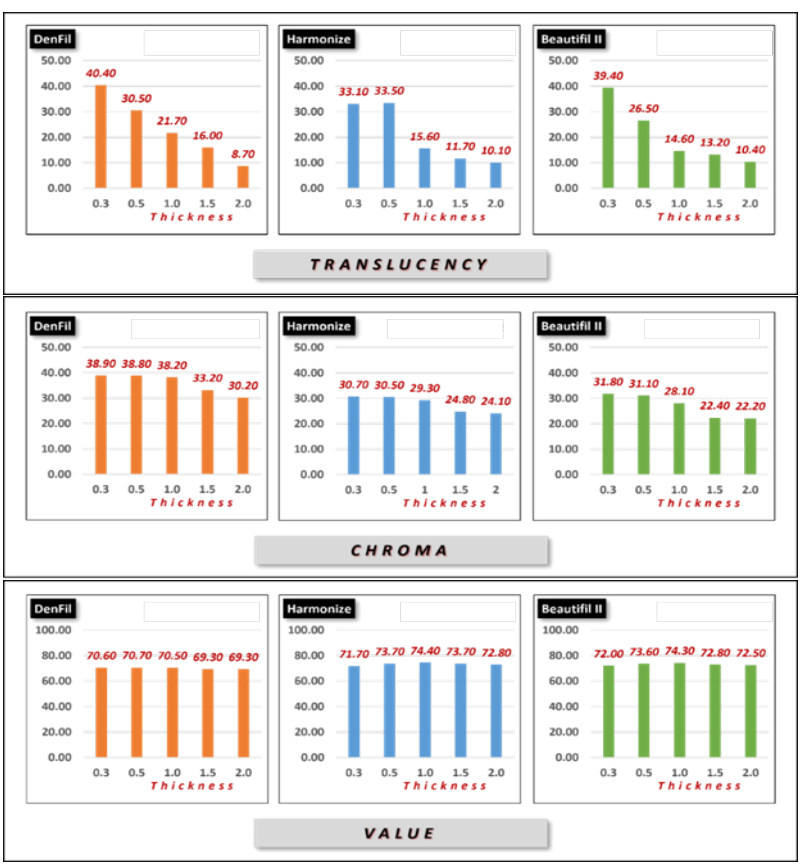

Figure 1. Changes in Translucency, Chroma, and Value with Thickness

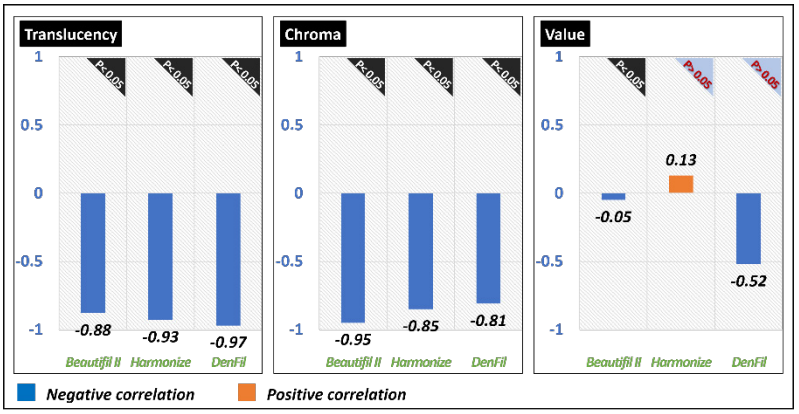

Figure 2. Results of Pearson Correlation Analysis Showing Correlation Coefficient (r) and p-value for the Relationship Between Thickness and Translucency, Chroma, and Value

Translucency and Chroma: For all three composite groups, translucency and chroma are inversely correlated with thickness (r<0) and statistically significant (p<0.05). This means the restoration's translucency and chroma decrease as the enamel-shade composite layer's thickness increases.

Value: For the DenFil group, value is inversely correlated with thickness statistically (r<0, p<0.05). For the other two groups, there is no statistically significant relationship (p>0.05).

3.2. Comparison of color parameters of restorations using the two-layer technique with the same thickness for enamel-shade composite

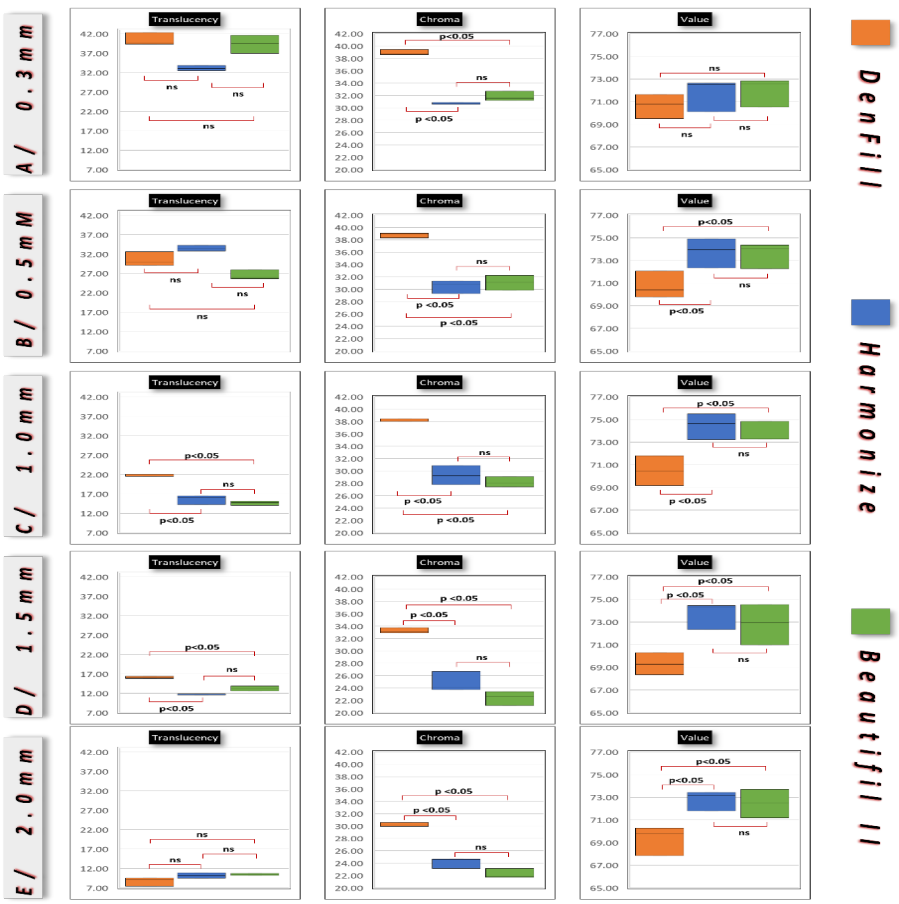

Figure 3. Two-Way ANOVA with Tukey's Post Hoc Test Evaluating Differences in Translucency, Chroma, and Value

When comparing the color parameters (translucency, chroma, value) of restorations using the two-layer technique replacing enamel and dentine with the same thickness for the surveyed composite groups, there is no statistically significant difference between the Harmonize and Beautifil II groups ($p>0.05$ at all thicknesses). However, there is a statistically significant difference between DenFil and the other two groups ($p<0.05$ at all thicknesses).

3.3. Color differences of restorations using the two-layer technique with the same thickness for enamel-shade composite

Table 2. Evaluation of Color Differences Using ΔEab Values

Thickness (mm)	$\Delta E_{ab(12)}$	$\Delta E_{ab(23)}$	$\Delta E_{ab(31)}$
0.3	5.54	2.6	8.1
0.5	9.65	1.93	11.2
1.0	10.4	1.44	11.5
1.5	9.19	1.17	8.6
2.0	8.48	1.64	7.25

When comparing the DenFil group to the other groups, there is a significant difference in the restoration color with the same enamel-shade composite thickness ($\Delta E_{ab}>3.3$ at all thicknesses), with a minor difference at a thickness of 0.3 mm. However, between Harmonize and Beautifil II groups, this color difference is within the acceptable range ($\Delta E_{ab}<3.3$ at all thicknesses).

4. DISCUSSION

The translucency of natural enamel decreases with increasing thickness, corresponding to the anatomical color changes of teeth. From the incisal third to the cervical third, enamel becomes thinner, revealing the underlying dentine and making teeth appear more opaque and darker [3]. Therefore, a crucial material replacement for natural enamel should simulate this optical effect. The inverse correlation between translucency and composite thickness in our study, which is illustrated in Figure 1 and Figure 2, aligns with the findings of Kamishima et al. (2005), Ayako Arimoto et al. (2010), Schmeling et al. (2012), Ferraris et al. (2014), Layal Jbara et al. (2019), and Sumi Kang et al. (2023) [4, 11-15]. This result can be explained by the interaction of light with composite compositions. Two main composite components are the resin matrix and fillers, which differ in refractive index, making composite material an inhomogeneous medium and, therefore, translucent [16]. This difference causes light scattering upon contact with the filler particles [13, 17]. As the composite thickness increases, the volume of fillers increases, leading to more scattering and making the material more opaque. Several studies have shown that the translucency of composite is negatively proportional to the filler content (with constant filler size) [18-20].

As for chroma, Figure 1 and Figure 2 show a statistically negative correlation between the restoration's chroma and enamel-shade composite thickness. The composites in the research of Ferraris et al. (2014) and Layal Jbara et al. (2019) are also reported to have this property [4, 11]. This outcome is the consequence of the relationship between composite thickness and translucency. As the covering layer thickens, its translucency decreases, reducing the exposure of the underlying layer and thus lowering the chroma of the restoration. Figure 3 shows that, at the same thickness, the chroma of the DenFil group is higher than that of the others, while there is no significant difference between Harmonize and Beautifil II. This can be explained by the difference in the materials' translucency.

Human eyes are most sensitive to value, which is determined by enamel. Therefore, an ideal enamel-shade composite needs to reach this characteristic. The study shows that the value of DenFil composite restorations decreases when the thickness increases. This is consistent with the properties of microhybrid composites observed in the study by Schmeling et al. (2010), Friebel et al. (2012), Ferraris et al. (2014), and Ismail et al. (2020) [4, 21, 22, 23]. According to Figure 1, with a thickness between 0.3 and 1.0mm, Harmonize and Beautifil II groups appear lighter when the enamel-shade composite is thicker; however, the opposite occurs from 1.0 to 2.0 mm. This trend is similar to the findings of Layal Jbara et al. (2019) and Kim et al. (2018) for these two nanohybrid composites [11, 24]. However, when examining UE2 (Micerium), a nanofilled composite, Ferraris et al. (2014) found that the value of restorations increases with the thickness of the enamel-shade composite [4]. Thus, the effect of the composite thickness on the value of restorations among the microhybrid, nano-hybrid, and nanofilled groups is different. This difference can be attributed to the refractive index and homogeneity of the filler particles in these materials. Increasing the thickness of natural enamel makes the teeth lighter. Because of not reaching the natural enamel's refractive index (approximately 1.63), most commercial enamel-shade composites do not possess this optical effect [3, 16]. The refractive index of the composite increases when the

filler and resin matrix have similar refractive indices. The primary composition of DenFil is barium glass filler, with a refractive index of approximately 1.98, significantly different from the average refractive index of the resin matrix (1.49-1.56) [15]. On the other hand, DenFil is a microhybrid composite with significant heterogeneity in filler particle size. These factors result in DenFil composite having a lower refractive index than natural enamel, so this material cannot meet the natural enamel optical property. The homogeneity of filler size increases from nanohybrid to nanofilled composites, affecting the interaction between thickness and value. According to the manufacturer, UE2 (Micerium) has a refractive index of 1.62, exhibiting properties similar to natural enamel. Figure 3 shows the similarity in value between Harmonize and Beautifil II when layered at the same thickness, while DenFil is distinct. This has been discussed previously, as these two products belong to the nanohybrid group with more homogeneous fillers than the microhybrid group. Based on the properties of Harmonize and Beautifil II investigated in this study, the advisable thickness when using the two products to replace enamel, whose thickness ranges from 0.3 to 1.5 mm, is 1.0mm. Exceeding this threshold will make the restoration darker. A material matching natural enamel's refractive index should be chosen in cases requiring a thicker layer. Selecting the correct shade, understanding the material properties, and controlling the material's thickness are keys to successful direct restorations.

Some studies have established thresholds for perceptibility (PT) and acceptability (AT) to evaluate the difference in color [25]. A 50%:50% PT means that 50% of observers can perceive a color difference between two objects, while the other 50% cannot. Similarly, a 50%:50% AT implies that 50% of observers find the color difference acceptable [25]. Some studies use the 50%:50% AT as a clinical reference, with PT as a benchmark. The thresholds for AT and PT are various [25]. In this study, we used a 50%:50% AT threshold of ΔE_{ab}=3.3 to evaluate color differences [10].

In our study, the color difference between Harmonize and Beautifil II, which is shown in Table 2, is acceptable at all thicknesses, and below 1.0 mm, this difference is imperceptible (ΔE_{ab}<1.8) [26]. The color similarity in the two nanohybrid composites is predictable based on their similarity in the color parameters at the same thickness. DenFil composite shows a color difference from the other two composites, which can be predicted from the differences in color parameters at various thicknesses (Figure 3). This difference is most significant at a thickness of 1.0 mm. Based on these findings, two nanohybrid composites exhibit similar aesthetic properties, while DenFil differs. The aesthetic properties of DenFil are inferior to the other two products due to its larger size and lower homogeneity of filler, resulting in lower surface gloss and higher susceptibility to extrinsic staining. Additionally, DenFil does not contain functional fillers. Between Harmonize and Beautifil II, we can consider other factors in choosing the appropriate material besides aesthetics in specific clinical cases. Therefore, Beautifil II, containing an SPG-S filler with fluoride-releasing and recharging ability, would be advantageous for patients having a high risk of dental caries or deep cavities without a pulp cap required.

5. CONCLUSIONS

The composition and thickness of the examined composites affect the aesthetic and color properties of restorations using the two-layer technique replacing enamel and dentine. Increasing the thickness of the enamel-shade composite reduces translucency and chroma while changes in value depend on the composite's structure. Therefore, understanding the properties and controlling the thickness of composite materials is crucial for achieving high aesthetic outcomes with the two-layer technique.

The number of composite brands and shades in the study is limited. Therefore. Future studies should expand the scope, providing more information and a basis for selecting the optimal composite for restorations. The study was conducted on flat sample discs, whereas natural teeth have anatomical contours, which can influence the color of restorations. Therefore, future studies should use tab samples with a dentine core and enamel shell to better simulate the shape of natural teeth.

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