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EVALUATION OF TECHNIQUE SENSITIVITY OF BILAMINAR AND TRILAMINAR LAYERING SYSTEMS USING DIGITALLY CALIBRATED CROSS-POLARIZED PHOTOGRAPHY

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ABSTRACT

Objectives: To compare the effect of variation of the outer enamel layer thickness on the final shade for a bilaminar versus a trilaminar technique and to compare the effect of variation of the core layers thicknesses on the final shade for a trilaminar technique.

Materials and Methods: 144 resin composite discs of 10mm diameter were prepared and equally divided into 24 groups (n=6) according to the three levels of the study, Level 1: Color recipe (A1, A2 and A3). Level 2: Outer enamel layer thickness (0.25 mm and 0.75 mm). Level 3: Shade combination (Bilaminar, Trilaminar-1, Trilaminar-2, Trilaminar-3). Another 72 discs of same shade combination groups with outer enamel layer thickness of 0.5mm were prepared to serve as controls (12 groups, n=6). eLAB_prime software was used to digitally calibrate the cross-polarized photographs of the discs and measure the L*, a* and b* values. CIEDE2000 color difference formula (ΔE00) was adopted. Data were analyzed using three-way ANOVA and one-way ANOVA followed by Tukey's post hoc test.

Results: The bilaminar technique (1.09±0.65) had significantly higher color change value than the trilaminar technique (0.84±0.49) (p=0.010). The trilaminar-2 technique had the least color change value (0.70±0.36) (<0.001).

Conclusions: The trilaminar technique is less sensitive to minor variation in outer enamel composite layer thickness compared to the bilaminar technique. Using equal thicknesses of body and dentin composites in the trilaminar technique produces the least change in color upon minor variation in outer enamel composite layer thickness.

KEYWORDS: Anterior composite; Layer thickness; Bilaminar technique; Trilaminar technique; Cross-polarized photography

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INTRODUCTION

The increased awareness and demand for conservative direct esthetic solutions to fractured and malformed anterior teeth, highlighted the importance of developing layering protocols for anterior composite systems that offer the best possible shade reproduction. For this purpose, commercial resin-based composites have been developed in different shades and different opacities.

Selecting the proper shade of enamel and dentin composites from the wide array of shades produced by each manufacturer may cause confusion to dentists. The high expenses of buying the full kit of enamel, body and dentin shades for the sixteen VITA shades adds an additional financial burden. To reduce the number of resin composite shades, some manufacturers adopted a bilaminar layering concept which utilizes a universal enamel shade (usually grayish) over different dentin shades to obtain the required shade.[1, 2]

However, the universal enamel shade should be used in a thickness of 0.5 mm to avoid noticeable increase in grayness or noticeable increase in opacity with increased or decreased thickness of the outer enamel composite layer respectively.[2] An instrument called LM Arte Misura can be used to re-shape the dentin composite core prior to curing to leave the required 0.5 mm space for the outer enamel composite layer.[2]

In a study that spectrophotometrically evaluated the previous bilaminar layering strategy, it was found that shade reproduction was affected by ± 0.25 mm variation in the universal enamel composite layer thickness which is likely to occur either during layering or after final finishing and polishing.[3]

In this essence, the authors of this study introduced an idea for an experimental layering technique that is based on the trilaminar concept where one universal enamel shade (A2E) is used to obtain depth of color. One universal dentin shade (A3D) is used to block the darkness of the oral cavity. Three body shades, either A1B, A3B, or A4B are placed in between. The translucent enamel layer and opaque dentin layer are separated by an intermediary translucent layer (body shade) to provide the desired chroma and to act as transitional layer to potentially make the technique less sensitive to minor variation in outer enamel composite layer thickness.

The present study aimed to compare the effect of variation of the outer enamel layer thickness on the final shade for a bilaminar versus a trilaminar technique and to compare the effect of variation of the core layers thicknesses on the final shade for a trilaminar technique. The null hypothesis is that different thicknesses of outer enamel composite layer in bilaminar and trilaminar techniques and different thicknesses of core layers in trilaminar technique have no effect on the resultant final shade.

MATERIAL AND METHODS

Materials:

Eight shades of one anterior resin composite restorative material; Filtek 350 XT (3M ESPE, USA) were used in this study. Materials, composition, and manufacturer were presented in table (1).

TABLE (1) Materials, composition, and manufacturer:

Material	Composition	Shade	Manufacturer
Filtek 350 XT	**- Matrix:** Bis-GMA, TEGDMA, UDMA, Bis-EMA(6), PEGDMA **- Fillers:** Non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles). The dentin, enamel and body shades have an average cluster particle size of 0.6 to 10 microns. The inorganic filler loading is about 78.5% by weight (63.3% by volume) for dentin, enamel and body shades.	A2E A3E A1B A3B A4B A1D A2D A3D	3M ESPE, USA

Methods:

1. Sample size calculation

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups. By adopting an alpha (α) level of (0.05), a beta (β) of (0.2) (i.e. power=80%), and an effect size (f) of (0.371) calculated based on the results of a previous study[4]; the minimum number of samples required in each group (n) was found to be (6) samples. Sample size calculation was performed using G*Power version 3.1.9.7.[5]

2. Grouping of Samples

144 resin composite discs of 10 mm diameter were prepared and equally divided into 24 groups (n = 6) according to the three levels of the study, Level 1: Color recipe (A1, A2 and A3). Level 2: Outer enamel layer thickness (0.25 mm and 0.75 mm). Level 3: Shade combination (Bilaminar, Trilaminar-1, Trilaminar-2, Trilaminar-3). Another 72 discs of same shade combination groups with outer enamel layer thickness of 0.5mm were prepared to serve as controls (12 groups, n=6).

Color recipes groups for bilaminar and trilaminar techniques are illustrated in Figure (1). Shade combination groups are illustrated in Figure (2).

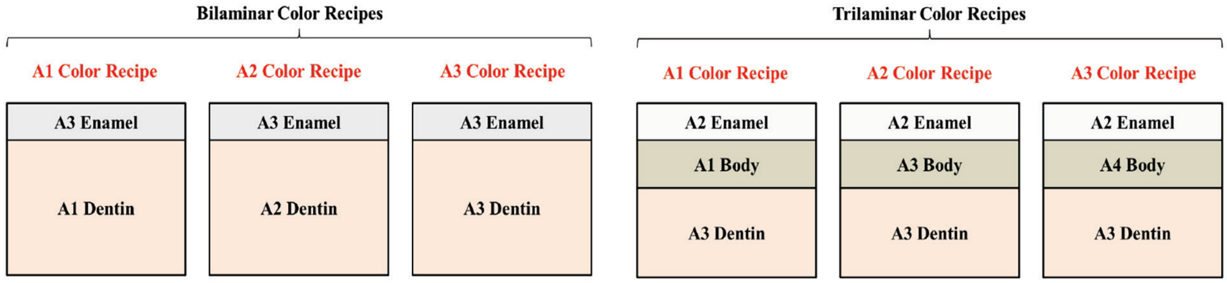


Fig. (1) Color recipes groups for bilaminar (following the manufacturer's instructions) [6] and trilaminar (proposed by the authors of the study) techniques.

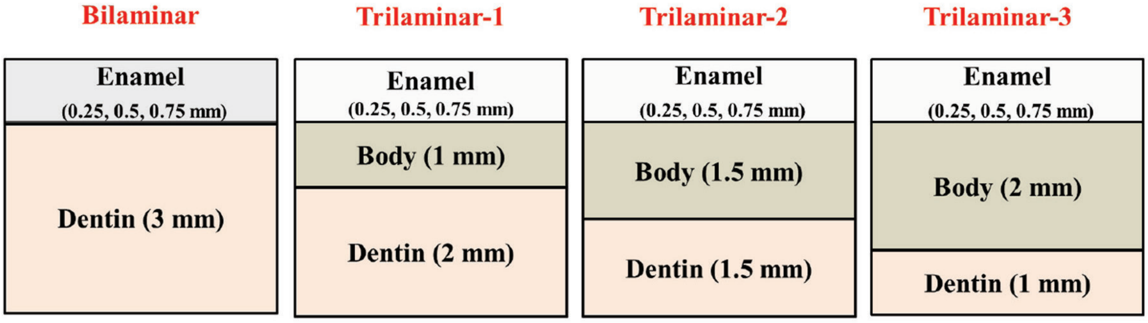


Fig. (2) Shade combination groups.

3. Sample Preparation

Circular split copper molds were used to construct the body/dentin shade discs. The molds have a central hole of 10 mm in diameter and a thickness of either 1.5 mm (M-1.5 mold), 2 mm (M-2 mold), or 3 mm (M-3 mold). A custom-made device was used to create the space required to layer the outer enamel composite layers. The device is composed of a cylindrical mold with a height of 4 cm and an internal diameter of 10 mm. The mold has a central piston of the same dimensions that fits snugly into it. The device has a built-in knob that is used to depress the piston where each half turn of the knob depresses the central piston by 0.25 mm (Fig. 3).

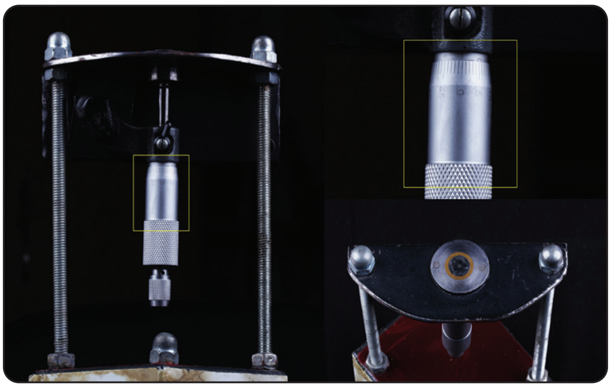


Fig. (3) A photograph showing the specially constructed device composed of a cylindrical mold with an internal diameter of 10 mm and length of 4 cm with a central piston of the same dimensions snugly fit into the internal chamber of the mold.

For Bilaminar technique, dentin shade discs were prepared using the M-3 mold. The mold was placed on an acetate paper on top of a glass slide then the A1D, A2D and A3D dentin shades were packed separately in the mold in one increment that was slightly overfilling the mold then covered with an acetate paper and pressed firmly with a glass slide to extrude any excess material and to allow for compaction the material to minimize the risk of bubble formation. The increment was light cured for 40 seconds from each side using an LED light curing unit (Elipar, 3M ESPE, intensity of 1300 mW/cm^2). The light cure tip was held perpendicular to the surface. The light intensity was verified by a dental radiometer (APOZA curing light meter CM300- 2000). The required thickness of each dentin shade disc was verified using a digital caliper. Each of the 3-mm thick dentin shade discs was then inserted into the specially constructed device where the enamel shade (A3E) was packed over the dentin shade disc slightly overfilling the mold, then covered with an acetate paper and pressed firmly with a glass slide to extrude any excess material. The increment was light cured for 20 seconds using the LED light curing unit (Elipar, 3M ESPE, intensity of 1300 mW/cm2). The required thickness of each enamel/dentin shade disc was verified using a digital caliper. The finalized resin composite discs were stored dry in light proof plastic containers for 24 hours before color measurement.

For Trilaminar1- technique, dentin shade discs were prepared using the M-2 mold. The cured dentin shade discs were then into inserted the M-3 mold. The mold was placed on an acetate paper on top of a glass slide then the body shades (A1B, A3B, A4B) were packed separately in the mold in one increment that was slightly overfilling the mold, then covered with an acetate paper and pressed firmly with a glass slide to extrude any excess material. The increment was light cured for 20 seconds using the LED light curing unit. The required thickness of each body/dentin shade disc was verified using a digital caliper. Each of the 3-mm thick body/dentin shade discs was then inserted into the specially constructed device to layer either 0.25 mm, 0.5 mm, or 0.75 mm enamel shade layer (A2E) as previously elaborated. The same concept was applied to Trilaminar-2 and Trilaminar-3 techniques with respect to the proposed thicknesses of each shade.

4. Color measurements:

A full frame digital single-lens reflex camera (Canon EOS 6D Mark II) with mounted Canon EF 100 mm f/2.8 L IS USM Macro Lens and an external ring flash (Meike MK-14EXT Macro Ring Lite) attached to a cross-polarizing filter (polar_eyes, Emulation, Frankfurt, Germany) were used for the cross-polarized photography. The camera settings were adjusted according to manufacturer's instructions of the cross-polarizing filter using the manual mode. The aperture was set to be f/22. The shutter speed was set to be 1/125 of a second. The ISO was set to be 100 while the flash intensity was set to be 1:1. Image quality was set to be in RAW format.

Each resin composite disc to be photographed was placed over a black matt background with the gray reference card (white_balance, Emulation, $L^*79 + a^*0 + b^*0$) placed directly below them.

The camera was attached to a tripod (055PRO3 kit, Manfrotto, Italy) adjusted using its built-in water balance indicators to allow the optical axis of the camera to be perpendicular to the horizontal plane. The distance between the camera lens and the horizontal plane was adjusted and fixed to 19 cm so that the two lower crop marks of the gray reference were fully captured following the manufacturer's recommendation (Fig. 4). A specialized software (eLAB_prime software; Emulation, Freiburg, Germany) was used to digitally calibrate and analyze the cross-polarized RAW files and measure the L*, a* and b* values of the resin composite discs (Fig. 5).

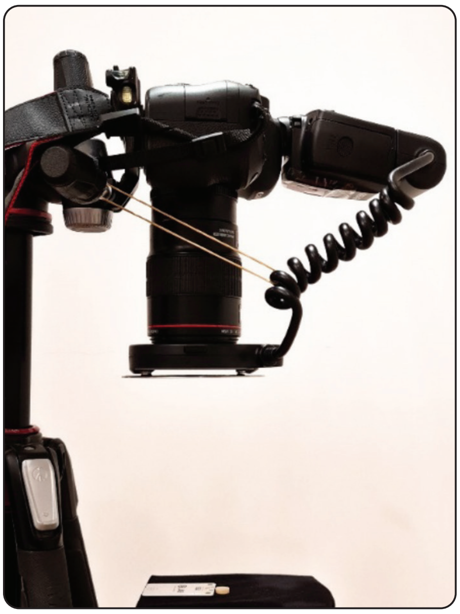
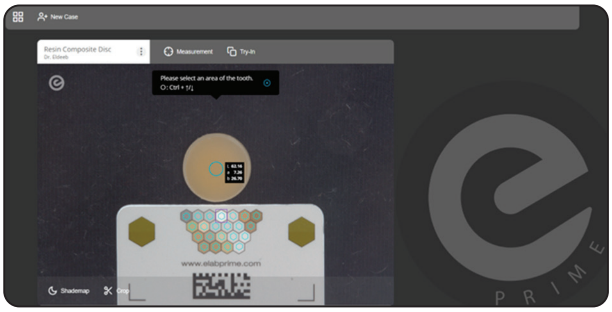


Fig. (4) A photograph showing the cross-polarized photography assembly attached to a tripod (055PRO3 kit, Manfrotto, Italy) adjusted to allow the optical axis of the camera to be perpendicular to the horizontal plane and fixed to 19 cm so that the two lower crop marks of the gray reference were fully captured.



Resin Composite Disc
Dr. Eldeeb

Please select an area of the tooth.
O: Ctrl + ↑/↓

Fig. (5) A photograph showing L*a*b* measurements of a resin composite disc using the eLAB_prime software; Emulation, Freiburg, Germany.

The CIELab color coordinates were registered in a Microsoft Excel sheet (Office 365). An open-source color difference calculator add-in was installed to the Microsoft Excel to calculate CIEDE2000 (ΔE_{00}). [7]

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

where $\Delta L'$, $\Delta C'$, and $\Delta H'$ denote lightness, chroma, and hue differences respectively. K_L, K_C, and K_H denote the parametric factors to be adjusted according to different viewing parameters.[8,9] S_L, S_C, and S_H denote the weighting functions for the adjustment of color difference considering the location variation of L*, a*, and b* color coordinates. R_T denotes the function for the hue and chroma differences interaction in the blue region. [8]

Chroma (C^*_{ab}) was calculated from the following equation $C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$ using Microsoft Excel.[10]

Statistical analysis:

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution and using Shapiro-Wilk test. Data were normally distributed and were analyzed using three-way ANOVA followed by Tukey's post hoc test. One-way ANOVA followed by Tukey's post hoc test was performed to test the effect of enamel composite layer thickness on lightness and chroma within the other variables. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.[11]

RESULTS

1- Effect of variation of outer enamel layer thickness by ± 0.25 mm on color change (ΔE00) for bilaminar versus trilaminar technique:

Mean and standard deviation (SD) values of color change (ΔE_{00}) upon variation of outer enamel layer thickness by ± 0.25 mm in bilaminar versus trilaminar technique were presented in table (2).

Bilaminar technique (1.09±0.65) had significantly higher value than trilaminar technique (0.84±0.49) (p=0.010).

Table (2) Mean and standard deviation (SD) values of color change (ΔE_{00}) upon variation of outer enamel layer thickness by ± 0.25 mm in bilaminar versus trilaminar technique:

Color change (ΔE_{00}) (mean±SD)		p-value
Bilaminar	**Trilaminar**	
1.09 ± 0.65^{A}	0.84 ± 0.49^{B}	**0.010***

; significant (p ≤ 0.05) ns; non-significant (p>0.05)

2- Effect of variation of outer enamel layer thickness by ± 0.25 mm on color change (ΔE_{00}) for bilaminar versus different trilaminar techniques:

Mean and standard deviation (SD) values of color change (ΔE_{00}) upon variation of outer enamel layer thickness by ± 0.25 mm in bilaminar versus different trilaminar techniques were presented in table (3).

TABLE (3) Mean and standard deviation (SD) values of color change (ΔE00) upon variation of outer enamel layer thickness by ± 0.25 mm in bilaminar versus different trilaminar techniques:

Color change (ΔE00) (mean±SD)				p-value
Bilaminar	**Trilaminar-1**	**Trilaminar-2**	**Trilaminar-3**	
1.09 ± 0.65^{A}	0.86 ± 0.44^{BC}	0.70 ± 0.36^{C}	0.97 ± 0.60^{AB}	**<0.001***

Means with different superscript letters within the same horizontal row are significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

There was a significant difference between different groups (p<0.001). The highest value was found in bilaminar technique (1.09±0.65), followed by trilaminar-3 (0.97±0.60), then trilaminar-1

(0.86±0.44), while the lowest value was found in trilaminar-2 (0.70±0.36). Post hoc pairwise comparisons showed bilaminar technique to have significantly higher value than other groups except for trilaminar-3 (p<0.001). In addition, they showed trilaminar-3 to have significantly higher value than trilaminar-2 (p<0.001).

3- Effect of variation of outer enamel layer thickness within other variables on lightness:

Mean, Standard deviation (SD) values of lightness for different enamel thicknesses within other variables were presented in table (4)

1- A1 color recipe:

- ***Bilaminar:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (79.66±0.11), followed by 0.50 mm (77.91±0.14), while the lowest value was found in 0.75 mm (77.11±1.22). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-1:***

There was a significant difference between different groups (p=0.01). The highest value was found in 0.25 mm (72.84±0.06), followed by 0.50 mm (72.68±0.13), while the lowest value was found in 0.75 mm (72.32±0.22). Post hoc pairwise comparisons showed 0.25 mm to have a significantly higher value than 0.75 mm (p=0.01).

- ***Trilaminar-2:***

There was a significant difference between different groups (p=0.002). The highest value was found in 0.25 mm (72.71±0.09), followed by 0.50 mm (72.34±0.09), while the lowest value was found in 0.75 mm (72.01±0.33). Post hoc pairwise comparisons showed 0.25 mm to have a significantly higher value than 0.75 mm (p=0.002).

- ***Trilaminar-3:***

There was no significant difference between different groups (p=0.06). The highest value was found in 0.25 mm (72.28±0.26), followed by 0.50 mm (71.94±0.08), while the lowest value was found in 0.75 mm (71.86±0.23).

2- A2 color recipe:

- ***Bilaminar:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (76.95± 0.12), followed by 0.50 mm (75.84± 0.09), while the lowest value was found in 0.75 mm (74.15± 0.16). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-1:***

There was a significant difference between different groups (p=0.04). The highest value was found in 0.25 mm (70.85± 0.09), followed by 0.50 mm (70.45± 0.07), while the lowest value was found in 0.75 mm (70.26± 0.05). Post hoc pairwise comparisons were all statistically significant (p=0.04).

- ***Trilaminar-2:***

There was a significant difference between different groups (p=0.02). The highest value was found in 0.75 mm (70.22± 0.13), followed by 0.25 mm (70.16± 0.16), while the lowest value was found in 0.50 mm (70.07± 0.09). Post hoc pairwise comparisons showed 0.75 mm to have a significantly higher value than 0.50 mm (p=0.02).

- ***Trilaminar-3:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (69.87± 0.14), followed by 0.75 mm (69.72± 0.14), while the lowest value was found in 0.50 mm (69.56± 0.07). Post hoc pairwise comparisons were all statistically significant (p<0.001).

3- A3 color recipe:

- ***Bilaminar:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (73.64± 0.12), followed by 0.50 mm (72.92± 0.16), while the lowest value was found in 0.75 mm (72.39± 0.28). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-1:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (67.49± 0.46), followed by 0.50 mm (67.08± 0.43), while the lowest value was found in 0.25 mm (66.89± 0.12). Post hoc pairwise comparisons showed 0.75 mm to have a significantly higher value than other groups (p<0.001).

- ***Trilaminar-2:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (65.54± 0.25), followed by 0.25 mm (65.03± 0.08), while the lowest value was found in 0.50 mm (64.98± 0.12). Post hoc pairwise comparisons showed 0.75 mm to have a significantly higher value than other groups (p<0.001).

- ***Trilaminar-3:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (65.53± 0.45), followed by 0.50 mm (64.5± 0.18), while the lowest value was found in 0.25 mm (63.48± 0.30). Post hoc pairwise comparisons were all statistically significant (p<0.001).

TABLE (4) Mean, Standard deviation (SD) values of lightness for different enamel thicknesses within other variables:

Color recipe	**Shade combination**	**Lightness (mean±SD)**			**p-value**
		0.25 mm	**0.50 mm**	**0.75 mm**	
A1	**Bilaminar**	79.66±0.11^{A}	77.91±0.14^{B}	77.11±1.22^{C}	**<0.001***
	Trilaminar-1	72.84±0.06^{A}	72.68±0.13^{AB}	72.32±0.22^{B}	**0.01***
	Trilaminar-2	72.71±0.09^{A}	72.34±0.09^{AB}	72.01±0.33^{B}	**0.002***
	Trilaminar-3	72.28±0.26^{A}	71.94±0.08^{A}	71.86±0.23^{A}	**0.06ns**
A2	**Bilaminar**	76.95± 0.12^{A}	75.84± 0.09^{B}	74.15± 0.16^{C}	**<0.001***
	Trilaminar-1	70.85± 0.09^{A}	70.45± 0.07^{B}	70.26± 0.05^{C}	**0.04***
	Trilaminar-2	70.16± 0.16^{AB}	70.07± 0.09^{B}	70.22± 0.13^{A}	**0.02***
	Trilaminar-3	69.87± 0.14^{A}	69.56± 0.07^{C}	69.72± 0.14^{B}	**0.001***
A3	**Bilaminar**	73.64± 0.12^{A}	72.92± 0.16^{B}	72.39± 0.28^{C}	**<0.001***
	Trilaminar-1	66.89± 0.12^{B}	67.08± 0.43^{B}	67.49± 0.46^{A}	**<0.001***
	Trilaminar-2	65.03± 0.08^{B}	64.98± 0.12^{B}	65.54± 0.25^{A}	**<0.001***
	Trilaminar-3	63.48± 0.30^{C}	64.5± 0.18^{B}	65.53± 0.45^{A}	**<0.001***

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

4- Effect of variation of outer enamel layer thickness within other variables on chroma:

Mean, Standard deviation (SD) values of chroma for different enamel thicknesses within other variables were presented in table (5)

1- A1 color recipe:

- ***Bilaminar:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (25.57±0.80), followed by 0.50 mm (24.57±0.24), while the lowest value was found in 0.25 mm (21.72±0.10). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-1:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (20.67±0.40), followed by 0.50 mm (20.06±0.27), while the lowest value was found in 0.25 mm (19.21±0.09). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-2:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (18.99±0.17), followed by 0.50 mm (18.69±0.16), while the lowest value was found in 0.25 mm (17.28±0.19). Post hoc pairwise comparisons showed 0.25 mm to have a significantly lower value than other groups (p<0.001).

- ***Trilaminar-3:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (18.06±0.32), followed by 0.50 mm (17.71±0.14), while the lowest value was found in 0.25 mm (16.39±0.12). Post hoc pairwise comparisons were all statistically significant (p<0.001).

2- A2 color recipe:

- ***Bilaminar:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (26.7±0.24), followed by 0.50 mm (25.86±0.14), while the lowest value was found in 0.25 mm (25.33±0.18). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-1:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (26.45±0.13), followed by 0.50 mm (24.50±0.17), while the lowest value was found in 0.75 mm (24.26±0.15). Post hoc pairwise comparisons showed 0.25 mm to have a significantly higher value than other groups (p<0.001).

- ***Trilaminar-2:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (24.92±0.32), followed by 0.50 mm (24.15±0.15), while the lowest value was found in 0.75 mm (23.11±0.56). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-3:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (24.74±0.09), followed by 0.50 mm (23.06±0.18), while the lowest value was found in 0.75 mm (22.28±0.12). Post hoc pairwise comparisons were all statistically significant (p<0.001).

3- A3 color recipe:

- ***Bilaminar:***

There was no significant difference between different groups (p=0.3). The highest value was found in 0.5 mm (27.01±0.09), followed by 0.25mm

(26.98±0.15), while the lowest value was found in 0.75 mm (26.84±0.11).

- ***Trilaminar-1:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (29.55±0.36), followed by 0.50 mm (26.64±0.34), while the lowest value was found in 0.75 mm (24.17±0.45). Post hoc pairwise comparisons were all statistically significant (p<0.001).

- ***Trilaminar-2:***

There was a significant difference between different groups (p=0.004). The highest value was found in 0.25 mm (27.51±0.10), followed by 0.50 mm (24.74±0.18), while the lowest value was found in 0.75 mm (23.5±0.19). Post hoc pairwise comparisons were all statistically significant (p=0.004).

- ***Trilaminar-3:***

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (26.69±0.63), followed by 0.50 mm (23.22±1.05), while the lowest value was found in 0.75 mm (21.12±0.25). Post hoc pairwise comparisons were all statistically significant (p<0.001).

TABLE (5) Mean, Standard deviation (SD) values of chroma for different enamel thicknesses within other variables:

Color recipe	**Shade combination**	**Chroma (mean±SD)**			**p-value**
		0.25 mm	**0.50 mm**	**0.75 mm**	
A1	**Bilaminar**	21.72±0.10 ^{C}	24.57±0.24 ^{B}	25.57±0.80 ^{A}	**<0.001***
	Trilaminar-1	19.21±0.09 ^{C}	20.06±0.27 ^{B}	20.67±0.40 ^{A}	**<0.001***
	Trilaminar-2	17.28±0.19 ^{B}	18.69±0.16 ^{A}	18.99±0.17 ^{A}	**<0.001***
	Trilaminar-3	16.39±0.12 ^{C}	17.71±0.14 ^{B}	18.06±0.32 ^{A}	**<0.001***
A2	**Bilaminar**	25.33±0.18 ^{C}	25.86±0.14 ^{B}	26.7±0.24 ^{A}	**<0.001***
	Trilaminar-1	26.45±0.13 ^{A}	24.50±0.17 ^{B}	24.26±0.15 ^{B}	**<0.001***
	Trilaminar-2	24.92±0.32 ^{A}	24.15±0.15 ^{B}	23.11±0.56 ^{C}	**<0.001***
	Trilaminar-3	24.74±0.09 ^{A}	23.06±0.18 ^{B}	22.28±0.12 ^{C}	**<0.001***
A3	**Bilaminar**	26.98±0.15 ^{A}	27.01±0.09 ^{A}	26.84±0.11 ^{A}	**0.3ns**
	Trilaminar-1	29.55±0.36 ^{A}	26.64±0.34 ^{B}	24.17±0.45 ^{C}	**<0.001***
	Trilaminar-2	27.51±0.10 ^{A}	24.74±0.18 ^{B}	23.5±0.19 ^{C}	**0.004***
	Trilaminar-3	26.69±0.63 ^{A}	23.22±1.05 ^{B}	21.12±0.25 ^{C}	**<0.001***

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

DISCUSSION

The present study aimed to compare the effect of variation of the outer enamel layer thickness on the final shade for the bilaminar technique versus the experimental trilaminar technique and to compare the effect of variation of the core layers thicknesses on the final shade for the experimental trilaminar technique using cross-polarized photography and eLAB_prime software (Emulation, Freiburg, Germany).

Color measurements showed that the bilaminar technique is more sensitive to minor variation of outer enamel composite layer thickness (0.25 mm, 0.5 mm, and 0.75 mm) compared to the trilaminar technique. This came in agreement with previous studies that found that varying the thickness of the outer enamel composite layer had a strong influence on the final shade of the bilaminar technique especially when a highly translucent universal enamel composite shade is used along with different dentin composite shades.[1, 3, 4, 12, 13]

The increased sensitivity of the bilaminar technique to minor variation of outer enamel composite layer thickness could be attributed to the usage of the translucent and chromatic A3 enamel composite shade (A3E) as a universal enamel composite shade in the bilaminar technique. The present study found that increasing the thickness of A3E generally caused an increase in both grayness and chroma. Our results came in agreement with Duarte et al., 2011.[14] This could be attributed to the higher chroma and translucency of A3E used in the bilaminar technique compared to those of A2E used in the trilaminar technique. The only exception of the bilaminar technique was the A3 color recipe in which increasing the thickness of A3E didn't affect chroma. This could be attributed to using the same shade of enamel and dentin composites. Our results came in agreement with Khashayar et al., 2014.[1]

On the other hand, the effect of variation of A2E thickness on grayness and chroma was dependent on the underlying body shade. If the body shade is less chromatic than the overlying enamel shade, then increasing the A2E thickness was found to result in increased grayness and chroma. If the body shade is more chromatic than the overlying enamel shade, then increasing the A2E thickness was generally found to result in decreased grayness and chroma. This could be attributed to the lower chroma and translucency of A2E used in the trilaminar technique compared to those of A3E used in the bilaminar technique.

Moreover, placement of an intermediary layer of body shade between the translucent enamel composite layer and the opaque dentin composite layer in the trilaminar technique may have served to mitigate the increase in opacity with decreased thickness of the outer enamel composite layer.

The dentin composite layer in the trilaminar is essential to aid in blocking the darkness of the oral cavity along with the overlying body composite layer.[13, 15] The A3 dentin composite shade (A3D) was selected to be the universal dentin composite as A3 was found to be the most common classical tooth shade.[16, 17]

The trilaminar-2 technique was found to be the least sensitive trilaminar technique to minor variation of outer enamel composite layer thickness. The trilaminar-2 technique is based on the usage of equal thicknesses of body and dentin composites that possibly resulted in a more optimized overall chroma and opacity that made the technique to be less sensitive to minor variation in outer enamel composite layer thickness. Therefore, the null hypothesis was rejected.

The low standard deviation in the present study could be attributed to standardization of layer thickness and color measurement technique. A specially constructed device was used to precisely obtain the critical 0.25-, 0.5- and 0.75-mm thickness of the outer enamel composite layer to ensure accurate color measurements. The device allows to obtain differences of 10 microns by virtue of its snugly fit central piston that can be depressed by turning a knob where each full turn of the knob depresses the central piston by 0.5 mm. Each full turn is divided into 50 equal divisions. Therefore, each of the 50 divisions can depress the central piston by 10 microns.

Traditional 2- and 3- mm thick split copper molds were used for fabricating the dentin or body/dentin shade discs to allow for ease of retrievability of each cured disc for verification of its thickness by a digital caliper before proceeding to the next step in the layering procedure to ensure standardization of core layers thicknesses.

Standardization of color measurements was achieved through cross-polarized photography which is beneficial to eliminate surface reflections for accurate color measurements and subsequent shade analysis.[18-20]. Standardization of distance and angulation was achieved by attaching the camera body to a tripod. Our methodology helps to overcome the positioning difficulty of handheld spectrophotometers like Vita Easyshade (Vita Zahnfabrik, Bad Säckingen, Germany) used in many studies for instrumental color measurement[21-28] as changing the angulation of Vita Easyshade probe tip was found to affect the obtained color measurements.[29]

Standardization of color calibration process was achieved through the usage of eLAB_prime software (Emulation, Freiburg, Germany) and a gray reference card. The eLAB_prime software (Emulation, Freiburg, Germany) was used in our study as it allows for both digital color calibration and subsequent color measurements. The software analyses the photographed gray reference card which has known CIE L*a*b* values through artificial intelligence for digital color calibration.[28,30-32]

The CIEDE2000 (ΔE_{00}) color difference formula was adopted in our study as it was found to have a 95% agreement leading to more accuracy in evaluation of color differences compared to the CIELab (ΔE^*_{ab}) which has 75% agreement in the evaluation of perceptibility and acceptability thresholds.[26,33-37] Moreover, a recent study found that subjective shade evaluation through standardized cross-polarized photographic shade analysis was found to be better than visual shade matching in a controlled clinical environment only when the CIEDE2000 color difference formula was used.[38]

The proposed experimental trilaminar technique is also very economic as it utilizes only five shades where three of them are body shades which are commonly used to restore posterior cavities and minor Class IV fractures unlike the bilaminar technique which utilize several dentin shades that may become expired before the dentist is able to use them. The technique is also relatively not confusing to the dentist as the enamel and dentin shades are fixed and the dentist needs to only select the body shade according to the color recipe to be obtained.

Further future research is required to evaluate the shade reproduction of A1, A2 and A3 Vita shades with the trilaminar color recipes relative to the bilaminar ones to optimize the employed enamel, body, and dentin composites shades in the trilaminar technique.

Under the limitations of this study the following conclusions could be deduced:

1. The trilaminar technique is less sensitive to minor variation in outer enamel composite layer thickness compared to the bilaminar technique.
2. Using equal thicknesses of body and dentin composites in the trilaminar technique produces the least change in color upon minor variation in outer enamel composite layer thickness.

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