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EVALUATION OF SHADE REPRODUCTION TOLERANCE TO MINOR VARIATION IN UNIVERSAL ENAMEL COMPOSITE LAYER THICKNESS

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ABSTRACT

Objective: To spectrophotometrically evaluate the effect of minor variation in outer enamel composite layer thickness on the final color of anterior resin composite restorations layered by a bilaminar technique.

Materials and methods: 54 resin composite discs of 10mm diameter were prepared in this study. The discs were equally divided into 9 groups (n = 6) according to the two levels of the study, Level-1: Final shade (A1, A2 and A3) and Level-2: A3 enamel shade thickness (0.25mm, 0.5mm, 0.75mm). Each group had a 3mm-thick core layer of dentin shade either A1, A2 or A3. VITA Easyshade® V was used to measure the L*, a* and b* values of reference A1, A2 and A3 VITA classical shade tabs and resin composite discs. CIEDE2000 color difference formula (ΔE00) was adopted. Data were analyzed using two-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects were done utilizing one-way ANOVA followed by Tukey's post hoc test.

Results: Closest shade matching to control occurred in groups: A3E(0.25- and 0.5mm)/A1D, A3E(0.75mm)/A2D, and A3E(0.5- and 0.75mm)/A3D. ΔE00 values for different final shades were: 8.78±0.72 for A1, 6.67±1.04 for A2, and 4.60±0.99 for A3 ($p<0.001$).

Conclusions: The manufacturer's recommendation of 0.5mm for the thickness of outer enamel composite layer applies well to reproduce shades A1 and A3 but needs to be increased to reproduce shade A2. The lighter the shade, the less the match when color recipes adopting grayish universal enamel shade are used.

KEYWORDS: Enamel composite; Layer thickness; Shade reproduction; Universal shade

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INTRODUCTION

Developing naturally colored resin composite restorations, that can intermingle with the natural tooth structure surrounding them, is one of the basic quests of esthetic dentistry. [1] Therefore, using restorative materials of different shades and translucencies is mandatory for an optimum shade match. Large class IV cavities pose a restorative challenge to dentists as they may feel confused which enamel and dentin shades to select from the wide array of available shades and which thickness of each shade is required. The high expenses of buying the full kit add an additional burden on dentists and their patients.

To simplify such complexity, StyleItaliano, a study group of researchers and clinicians who are specialized in the field of restorative dentistry, introduced color recipes for Filtek 350 XT (3M ESPE, USA) anterior composite system for easier shade match with the Vita classical shade guide (Vita Zahnfabrik, Bad Säckingen, Germany). The StyleItaliano color recipes use a universal A3 enamel shade and propose that combining A1D + A3E gives A1 shade, A2D + A3E gives A2 shade, while A3D + A3E gives A3 shade providing the outer A3 enamel composite layer is 0.5 mm in thickness. [2, 3] If the enamel composite layer thickness exceeded 0.5 mm, significant increase in grayness may occur and if it became less than 0.5 mm in thickness significant increase in chroma and opacity may occur. [4] A special instrument (LM Arte Misura) was introduced to re-model the dentin composite core before curing leaving an optimal space (around 0.5 mm) for the outer enamel composite layer.

However, minor changes of the thickness of the outer enamel composite layer are likely to occur either during layering or after final finishing and polishing. Therefore, a point worthy of research is to spectrophotometrically evaluate the effect of minor variation in outer enamel composite layer thickness on the final color of anterior resin composite restorations layered by a bilaminar technique. The null hypothesis is that variation in outer enamel composite layer thickness has no effect on the resultant final shade.

MATERIALS AND METHODS

Materials:

Four 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

Materials' names and manufacturer	Composition	Shade
Filtek 350 XT, 3M ESPE, USA	**- Matrix:** Bis-GMA, UDMA, TEGDMA, 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). Inorganic filler loading is about 78.5% by weight (63.3% by volume).	A3E A1D A2D A3D

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 [5]; 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. [6]

2. Grouping of Samples

A total of 54 resin composite discs of 10 mm diameter were prepared in this study. The discs were equally divided into 9 groups (n = 6) according to the two levels of the study, Level 1: Final shade (A1, A2 and A3) and Level 2: Enamel shade thickness (0.25 mm, 0.5 mm, 0.75 mm).

3. Sample Preparation

Dentin shade discs were prepared using a circular split copper mold with a central hole of 10 mm diameter and a thickness of 3 mm. 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 using double flat and ball burnisher instruments in one increment that is slightly overfilling the mold then covered with an acetate paper and pressed firmly with a 1-mm thick glass slide to extrude any excess material and to allow for compaction the material to prevent bubble formation. The increment was light cured for 40 seconds from each side using an LED light curing unit (Elipar, 3M ESPE, intensity of 1200 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.

A 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 was used for layering the enamel shades (Fig. 1). The piston can be depressed by turning a knob. 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.

The piston was depressed down by 3.25 mm, 3.5 mm, or 3.75 mm to create a 3-mm thick room for the 3-mm thick dentin shade disc and 0.25 mm, 0.5 mm, or 0.75 mm thick room for the for the overlying enamel shade layer.

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. 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.

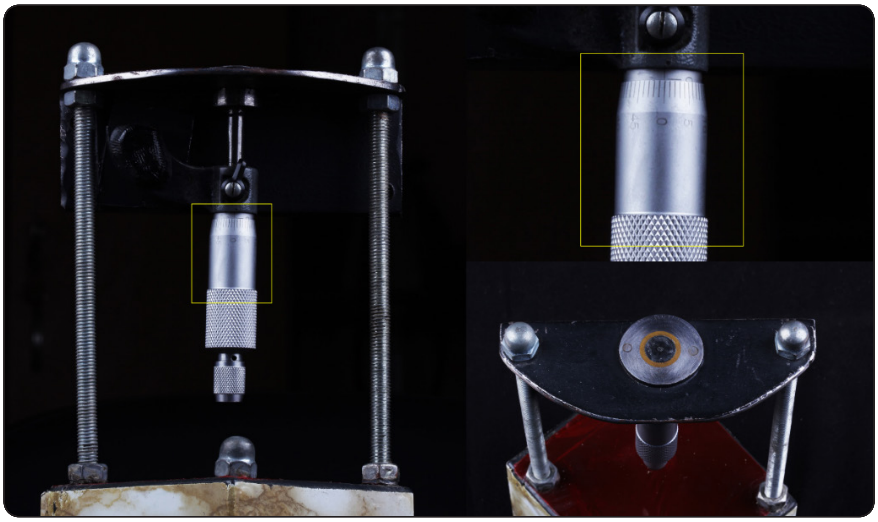

Fig. (1): A photograph showing the specially constructed device composed of a cylindrical mold with an internal diameter of 10 mm and length of 4 cm with a central piston of the same dimensions snugly fit into the internal chamber of the mold.

4. Color measurements:

VITA Easyshade® V (Vita Zahnfabrik, Bad Säckingen, Germany) was used to measure the L*, a* and b* values of the reference A1, A2 and A3 VITA classical shade tabs and the finalized resin composite discs placed over a black matt background. The VITA Easyshade® V was calibrated by placing its probe tip on the calibration port aperture before each color measurement. The probe tip was then held at 90 degrees on the center of the surface of each disc where the base shade determination mode was used for color measurements.

Three measurements were done for each resin composite disc at its center. The mean L*, a* and b* values of each three measurements were calculated and recorded.

Twelve measurements were done for each reference VITA classical shade tabs where each shade tab was measured at the center of the middle third using a custom-made positioning clear silicone mold then the mean L*, a* and b* values each reference VITA classical shade tabs were calculated and recorded.

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 between color measurements. 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]

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 two-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects were done utilizing one-way ANOVA followed by Tukey's post hoc test. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. 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. [10]W

RESULTS

Effect of different variables and their interaction

Effect of different variables and their interaction on color change (ΔE_{00}) were presented in table (2).

There was a significant interaction between final shade, shade combination and enamel thickness ($p<0.001$).

TABLE (2): Effect of different variables and their interactions on color change (ΔE_{00}):

Source	Sum of Squares	df	Mean Square	f-value	p-value
Final shade	314.57	2	157.28	694.15	**<0.001***
Enamel thickness	22.56	2	11.28	49.78	**<0.001***
Final shade* enamel thickness	45.93	4	11.48	50.68	**<0.001***

df =degree of freedom*; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Effect of final shade

Mean, Standard deviation (SD) values of color change (ΔE_{00}) for different final shades were presented in table (3).

There was a significant difference between different groups (p<0.001). The highest value was found in A1 (8.78±0.72), followed by A2 (6.67±1.04), while the lowest value was found in A3 (4.60±0.99). Post hoc pairwise comparisons were all statistically significant (p<0.001).

TABLE (3): Mean, Standard deviation (SD) values of color change (ΔE_{00}) for different final shades:

Color change (ΔE_{00}) (mean±SD)			p-value
A1	A2	A3	
8.78±0.7²A	6.67±1.0⁴B	4.60±0.9⁹C	**<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)

Effect of enamel thickness within other variables

Mean, Standard deviation (SD) values of color change (ΔE) (2000) (spectrophotometer) for different enamel thicknesses within other variables were presented in table (4).

1- A1:

There was a significant difference between different groups (p<0.001). The highest value was found in 0.75 mm (9.58±0.61), followed by 0.25 mm (8.43±0.21), while the lowest value was found in 0.50 mm (8.33±0.44). Post hoc pairwise comparisons showed 0.75 mm to have a significantly higher value than other groups (p<0.001).

2- A2:

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (7.89±0.31), followed by 0.50 mm (6.64±0.21), while the lowest value was found in 0.75 mm (5.47±0.34). Post hoc pairwise comparisons were all statistically significant (p<0.001).

3- A3:

There was a significant difference between different groups (p<0.001). The highest value was found in 0.25 mm (5.65±0.40), followed by 0.50 mm (4.35±0.60), while the lowest value was found in 0.75 mm (3.80±0.81). Post hoc pairwise comparisons showed 0.25 mm to have a significantly higher value than other groups (p<0.001).

TABLE (4): Mean, Standard deviation (SD) values of color change (ΔE_{00}) for different enamel thicknesses within other variables:

Final shade	Color change (ΔE_{00}) (mean±SD)			p-value
	0.25 mm	0.50 mm	0.75 mm	
A1	$8.43{\pm}0.21^{Ba}$	$8.33{\pm}0.44^{Ba}$	$9.58{\pm}0.61^{Aa}$	**<0.001***
A2	$7.89{\pm}0.31^{Ab}$	$6.64{\pm}0.21^{Bb}$	$5.47{\pm}0.34^{Cb}$	**<0.001***
A3	$5.65{\pm}0.40^{Ac}$	$4.35{\pm}0.60^{Bc}$	$3.80{\pm}0.81^{Bc}$	**<0.001***
p-value	**<0.001***	**<0.001***	**<0.001***	

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

DISCUSSION

Dental manufacturers provide a wide variety of anterior resin composite systems where each has an array of shades and opacities. Nevertheless, proper shade reproduction by those systems may be complicated by the difficulty in either selecting the proper shades and opacities or layering them relative to each other in optimum thicknesses to reproduce the desired final shade.

The bilaminar technique uses enamel and dentin composites for shade reproduction and is divided into two basic concepts. Concept-1 is based on the usage of dentin and enamel composites that have the same shade. [11] Examples of composite systems following Concept-1 are Clearfil Photo Bright (Kuraray), Herculite XRV Ultra (Kerr) and Venus

Diamond (Heraeus Kulzer). Concept-2 is based on usage of a highly translucent universal enamel composite shade along with different dentin composite shades. [11] Examples of composite systems following Concept-2 are Amaris (VOCO), CeramX Duo (DENTSPLY) and Point4 (Kerr) and the recently introduced StyleItaliano color recipes. [2, 11]

The outer A3 enamel composite layer used in StyleItaliano color recipes is recommended to be 0.5 mm in thickness for proper shade reproduction. [2-4] Obtaining an 0.5 mm thickness of the outer enamel composite layer is challenging as minor changes of the thickness of such layer are likely to occur either during layering or after final finishing and polishing. Therefore, a point worthy of research was to investigate the shade reproduction tolerance to minor variation in outer enamel composite layer thickness.

Kamishima et al., 2005 found that the minimum thickness at which each shade can avoid an unfavorable color change by masking the dark background color of the oral cavity was 2.76, 2.56 and 1.88 mm for the enamel-, body- and opaque-shades of Filtek Supreme respectively. [12] Therefore, the core layer for StyleItaliano color recipes was made of a 3-mm thick dentin shade increment on our study to ensure complete masking of the underlying black background simulating that of the oral cavity to avoid any unfavorable color change allowing for evaluation of the inherent color of the material.

VITA Easyshade® V (Vita Zahnfabrik, Bad Säckingen, Germany) was used to measure the CIELab color parameters by virtue of its increased accuracy compared to the previous version [13] which had an accuracy of 92.6% and a reliability of 96.4% [14] that was used in many studies as a reliable, accurate as well cost-effective way of instrumental color measurement. [15-22] Several recent studies used the VITA Easyshade® V for measurements of CIELab color parameters. [13, 23-25]

A custom-made positioning clear silicone mold was used during color measurements of the reference VITA classical shade tabs to ensure standardization of the measuring area and the measuring angle to overcome the difficulty of precise positioning of the probe tip of the VITA Easyshade® V over the convex surface of the reference VITA classical shade tabs.

The CIEDE2000 (ΔE_{00}), was applied to calculate ΔE_{00} between each mean L*a*b values of each finalized resin composite disc and the mean L*a*b values of its reference VITA classical shade tab. Several studies have reported that the CIEDE2000 (ΔE_{00}) color difference formula which has a 95% agreement provides a better fit than the CIELab (ΔE^*_{ab}) one which has 75% agreement) in the evaluation of perceptibility and acceptability thresholds, supporting its use in dentistry. [20, 26-30] An open-source color difference calculator add-in was installed to the Microsoft Excel to automatically calculate CIEDE2000 (ΔE_{00}) from the supplied mean L*a*b values of each finalized resin composite disc and the mean L*a*b values of its reference VITA classical shade tab. [7] In our study the parametric factors K_L, K_C, and K_H were set to be 1 due to having a standardized color measurement environment.

Spectrophotometric evaluation showed that A3 was generally the easiest final shade to be reproduced. This could be due to the usage of A3 enamel and A3 dentin composite shades in StyleItaliano color recipes and therefore following the Concept-1 bilaminar approach unlike the color recipes for A1 and A2 final shades. [11]

This came in agreement with Khashayar et al., 2014 who found that Concept-1 bilaminar approach exhibited lesser variations in ΔE with increasing thicknesses of the enamel composites and decreasing thicknesses of the dentin composites compared to Concept-2 bilaminar approach.

Concept-1 bilaminar approach which is based on the usage of dentin and enamel composites that have the same shade while Concept-2 bilaminar approach is based on the usage of a highly translucent universal enamel composite shade along with different dentin composite. [11]

On the other hand, A1 was generally the most difficult final shade to be reproduced. This could be due to the usage of the grayish A3 enamel composite shade.

Instrumental color measurement also showed that minor variation of outer enamel composite layer thickness had a significant effect on shade reproduction of reference VITA classical shade tabs. Therefore, the null hypothesis was rejected.

For A1 final shade, the best outer enamel composite layer thickness was found to be either 0.25 mm or 0.5 mm. This came in agreement with Manauta et al., 2014 who found that when the thickness of the outer A3 enamel composite layer thickness reached 0.75 mm, the value was lowered too much and suggested an optimum thickness of 0.5 mm for the outer enamel composite layer. [4]

Our results came in agreement also with Hajira et al., 2015 who found that with increased thickness of different enamel shades (white, neutral and gray), a significant decrease in value occurred where white enamel resulted in the greatest reduction in value, neutral enamel resulted in the least reduction in value, while grey enamel demonstrated an intermediate result. [31]

For A2 final shade, the best outer enamel composite layer thickness was found to be 0.75 mm while for A3 final shade, the best outer enamel composite layer thickness was found to be either 0.5 mm or 0.75 mm. This came in disagreement with Manauta et al., 2014. [4]

Acceptability threshold refers to the magnitude of color difference beyond which it is not visually acceptable. When the color difference between two objects can be accepted by 50% of observers while the other 50% will not accept it then we are talking about a 50:50% acceptability threshold. [30, 32]

Therefore, for an acceptable color match the color difference should be at or below the later one. [33] In dental literature, there has been a debate about the 50:50% acceptability threshold. Studies adopting the CIELab (ΔE^*_{ab}) color difference formula suggested 50:50% acceptability thresholds of 2 [34], 2.7 [28, 35], 3.3 [36, 37], 3.7 [38] and 5.5 [39] while studies adopting the CIEDE2000 (ΔE_{00}) color difference formula suggested 50:50% acceptability thresholds of 1.8 [28] and 1.9 [40]. This disagreement in results could be explained by difference in the type of color measuring device and the substrate to be measured.

We couldn't find any previous study that used the VITA Easyshade® V spectrophotometers or its predecessors to evaluate the 50:50% acceptability threshold. A recent study by Rioseco and Wagner, 2021 [41] was conducted to determine the ΔE between the same 3D Master shades obtained from natural teeth by Vita Easyshade® spectrophotometer and to compare the obtained values with the AT thresholds determined by Khaskayar et al., 2014 [32] and Paravina et al., 2015 [28]. They found that the ΔE values calculated from L*a*b color measurements by Vita Easyshade® are higher than the AT threshold determined by Khaskayar et al., 2014 [32] and Paravina et al., 2015 [28].

This came in agreement with the results of our study where all CIEDE2000 (ΔE00) values calculated from L*a*b color measurements by Vita Easyshade® were higher than the AT threshold determined by Paravina et al., 2015. [28] This could be attributed to the common methodology of calculating the color difference between two different materials with different optical properties.

More future research is required to develop a layering technique with improved shade reproduction ability and undetectable color change upon minor variation in outer enamel composite layer thickness.

CONCLUSIONS

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

1. The final color of anterior resin composite restorations layered by the bilaminar technique adopting universal enamel shade is highly affected by minor variation in outer enamel composite layer thickness.
2. The manufacturer's recommendation of 0.5mm for the thickness of outer enamel composite layer applies well to reproduce shades A1 and A3 but needs to be increased to reproduce shade A2.
3. The lighter the shade, the less the match when color recipes adopting grayish universal enamel shade are used.

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