ASDJ
AINSHAMS DENTAL JOURNAL

Print ISSN 1110-7642
Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
March 2024 • Vol. 33

Effect of enamel thickness and dentin shade of resin composite on the final color reproduction

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Aim: To evaluate the effect of different dentin shades and different enamel shade thicknesses on the final color reproduction in class IV anterior resin composite restorations restored using the 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: Dentin 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 (ceram.x® duo, Dentsply Sirona, Germany) followed by the designated enamel shade thickness. Clinical spectrophotometer (VITA Easyshade® V, Germany) 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 to calculate the color difference between the resin composite discs and their corresponding VITA classic shade tab. Data were analysed 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: Two-way ANOVA showed that the dentin shade and the enamel layer thickness as well as their interaction had a statistically significant effect on color difference (ΔE00) compared to the VITA classical reference tabs($p<0.001$). Best shade matching to the control was obtained when A3 dentin shade was used with both 0.25mm and 0.75mm enamel thickness (3.13±0.48 and3.04±0.39, respectively) while least shade matching was obtained when A1 dentin shade was combined with 0.5mm enamel shade (6.07±0.41).
Conclusions: When using the bilaminar technique in vertical anatomical layering of resin composite restorations, the thickness of the outer enamel composite together with the dentin shade used demonstrated a significant effect on the final shade. The lighter the dentin shade used the thicker the enamel thickness needed for better shade reproduction and matching.

Keywords: Enamel composite; Layering; Shade reproduction; Universal enamel shade; Layer thickness

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Introduction

Naturally colored resin composite restorations that can mimic the natural tooth structure surrounding them are constantly sought in esthetic dentistry.[1] The hard tooth structure contains multi-shades and multi-translucencies as a result of the unique shade map of the enamel and dentin of each individual tooth. To be able to match the optical properties of such a natural structure, it becomes essential to use restorative materials of different shades and translucencies.

The three basic translucencies of anterior resin composites are enamel, body and dentin shades. Enamel shades are translucent and used to provide depth of color, opalescence and both their shade and layer thickness can significantly modify the color on the peripheral surface of a restoration.[2,3] Dentin shades are chromatic and block the darkness of the oral cavity with their opacity, the extent of which also depends on the thickness of its layer in addition to the manufacturer variations.[1,4] Large class IV cavities pose a restorative challenge to dentists as regard to obtaining an acceptable color match with multi-shaded restorations. Dentists are usually confused when it comes to the wide array of enamel and dentin shade selection as well as the layer thicknesses. Additionally, buying a full kit of all shades financially burdens both dentists and patients.

To simplify the complexity associated with bilaminar layering approach, some manufacturers introduced an anterior layering concept in which a universal usually gray enamel shade is used over different dentin shades. However, the universal enamel shade should be used in a thickness of 0.5 mm, beyond which a significant increase in greyness may entail and below which a significant increase in chroma and opacity may occur.[5]

To overcome this challenge, LM-Dental™ developed a special conical instrument called LM Arte Misura in co-operation with StyleItaliano. This instrument is designed to re-model the dentin composite core before curing, leaving an optimal space (around 0.5 mm) for the outer enamel composite layer.[6,7]

However, maintaining a 0.5 mm thickness of the outer enamel composite layer after final finishing and polishing of the restoration is challenging, and clinicians may accidentally decrease the thickness of the outer enamel composite layer.

The aim of this study was to evaluate the effect of different dentin shades and different enamel shade thicknesses on the final color reproduction in class IV anterior resin composite restorations restored using the bilaminar technique. The null hypothesis is that different outer enamel layer thicknesses and dentin shade do not affect the final shade of the restoration.

Materials and Methods

Specimen preparation

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). All the specimens were prepared by a single operator using one nano-hybrid resin composite restorative materials systems of different shades (Ceram.x duo, Dentsply, USA). Table 1 shows the materials used, their compositions and manufacturer.

Using a circular split copper mold with a central hole of 10mm diameter and a thickness of 3mm, a 3mm thick dentin shade discs were prepared. The central hole of the mold was placed on top of an acetate strip that was supported by a glass slide on the bottom. Dentin shade resin composite material was packed into the mold in one increment that was slightly overfilled. Another acetate strip was placed on top of the mold followed by firm finger pressure using a glass slide to extrude any excess resin composite material. The resin composite increment was then cured for 40 seconds from the top and bottom sides using an LED blue light (Elipar™ S10, 3M ESPE, St. Paul, MN, USA) operated at 1200 mW/cm^2 then the glass slide was removed, and additional curing was performed for seconds from each side.

Table 1: Materials used, their compositions and manufacturer.

Material	Composition	Shade	Manufacturer	Lot No.
ceram.x® duo	Methacrylate modified polysiloxane, dimethacrylate resin, fluorescence pigment UV stabilizer, camphorquinone, ethyl-4(dimethylamino)benzoate, barium-aluminium-borosilicate glass, methacrylate functionalized silicon dioxide nano filler(2–3 nm), iron oxide pigments and titanium oxide pigments and aluminium-sulfo-silicate pigments, 76 Vol% fillers	E2	Dentsply Sirona, Konstanz, Germany	1811001029
		E3		1811000419
		D1		1806000736
		D2		1810000057
		D3		1809000057

After light curing, the cured disc was removed from the mold and gently trimmed to remove any excess material. 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 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. The piston was 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 by 3.25 mm, 3.5 mm, or 3.75 mm to produce an enamel layer thickness of 0.75mm, 0.5mm and 0.25mm respectively. The enamel shade (A3E) was packed over the dentin shade disc slightly overfilling the mold, then covered with an acetate strip and pressed firmly with a glass slide to extrude any excess material. The increment was light cured for 20 seconds using an LED light curing unit (Elipar™ S10, 3M ESPE, St. Paul, MN, USA) then the glass slide was removed, and the disc was additionally cured for 20 seconds.

The cured disc was removed from the mold and the sides of the discs was gently trimmed to remove any excess flashes. The required thickness of the final enamel/dentin shade disc was verified using a digital caliper. The finalized resin composite discs were stored dry in light-proof plastic containers at room temperature for 24 hours before color measurement.

Color measurements:

Clinical spectrophotometric device (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.

For the resin composite discs, three measurements were recorded from the centre of the disc and their average were calculated as the mean L*, a* and b* value for each specimen. For the reference VITA classical shade tabs; twelve measurements were taken for each shade tab at the centre of the middle third guided by a custom-made clear silicone positioning mold. The mean L*, a* and b* value for each shade tab was calculated and recorded. The CIELab color coordinates were recorded in a Microsoft Excel sheet (Office 365). An open-source color difference calculator add-in was installed to the Microsoft Excel to calculate CIEDE2000 (ΔE00) available from http://rgbcmyk.com.ar/en/xla-2/.

Statistical analysis

Numerical data was represented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity and were analyzed using two-way ANOVA followed by Tukey's post hoc test. Comparisons of simple main effects were done utilizing the error term of the two-way model with p-values adjustment using Bonferroni correction. The significance level was set at p<0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.1 for Windows.

Results

Two-way ANOVA presented in table (2) showed that the dentin shade and the enamel shade thickness as well as their interaction had a statistically significant effect on color difference (ΔE00) (p<0.001).

Table (2): Two-way ANOVA for the effect of **different dentin shades and enamel thicknesses** *and their interactions on color change (ΔE00)*

Parameter	Sum of squares	df	Mean square	f-value	p-value
Final shade	89.62	2	44.81	**252.63**	**<0.001***
Enamel thickness	26.44	2	13.22	**74.53**	**<0.001***
*Shade * Thickness*	30.39	4	7.60	**42.84**	**<0.001***

df: Degree of freedom, (*) significant (p ≤ 0.05)

A comparison of simple main effects is presented in table (3). Results showed that within all thicknesses there was a significant difference between samples of different dentin shades (p<0.001). For 0.25mm thick samples, post hoc pairwise comparisons showed A1 and A2 samples to have significantly higher values than A3 samples (p<0.001). For 0.50mm thick samples, they showed A1 samples to have significantly higher value than other samples (p<0.001). While for 0.75mm samples they showed A1 to have the highest value followed by A2 then A3 with all pairwise comparisons being statistically significant (p<0.001).

Results also showed that within all shades there was a significant difference between different enamel thicknesses (p<0.001). For A1 samples, post hoc pairwise comparisons showed 0.25- and 0.50-mm samples to have significantly higher values than 0.75mm samples (p<0.001). For A2 samples, the highest value was found in samples with 0.25mm thick enamel, followed 0.50 mm then 0.75mm and all pairwise comparisons were statistically significant (p<0.001). For A3 samples, pairwise comparisons showed 0.50mm samples to have significantly higher value than other samples (p<0.001).

Table (3): Mean, Standard deviation (SD) values of color change (ΔE00) for different dentin shades and enamel thicknesses

Enamel thickness \ Final shade	Color change (ΔE) (Mean±SD)			f-value	p-value
	A1	*A2*	*A3*		
0.25 mm	6.03 ± 0.53^{Aa}	5.87 ± 0.28^{Aa}	3.13 ± 0.48^{Bb}	179.99	<0.001*
0.50 mm	6.07 ± 0.41^{Aa}	4.57 ± 0.39^{Bb}	4.72 ± 0.47^{Ba}	46.53	<0.001*
0.75 mm	5.48 ± 0.38^{Ab}	3.54 ± 0.42^{Bc}	3.04 ± 0.39^{Cb}	111.78	<0.001*
f-value	7.47	92.74	59.99		
p-value	<0.001*	<0.001*	<0.001*		

Different capital superscript letters indicate a statistically significant difference within the same horizontal row
Different small superscript letters indicate a statistically significant difference within the same vertical column.
(*) significant at (p ≤ 0.05)

Discussion

The present study aimed to spectrophotometrically evaluate the effect of dentin shade and enamel layer thickness on the final color of anterior resin composite restorations layered by bilaminar esthetic layering techniques. When restoring anterior teeth, the bilaminar approach has been frequently reported to be the ideal and relatively simple technique.[8] Several studies found that varying the thickness of enamel and dentin composites have a strong influence on the overall color and translucency of the final restoration.[2, 3, 9]

The core layer for the bilaminar technique was made of a 3-mm thick dentin shade increment to ensure complete masking of the underlying black background simulating that of the oral cavity to avoid any unfavourable color change allowing for evaluation of the inherent color of the material in light of studies conducted by Kamishima et al., 2005[9] who found that the minimum thickness at which each shade can avoid an unfavourable 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 and Kim et al., 2009[1] who found the A3D of Filtek Z350 required a minimum thickness of 1 mm and preferably 1.5 mm to mask a black background.

On the other hand, Kamishima et al., 2005[9] found that the minimum thickness at which each shade can avoid an unfavourable color change by masking the dark background color of the oral cavity was 3.19, 3.04 and 2.69 mm for the enamel-, body- and opaque-shades of Gradia Direct respectively. Therefore, the brands and shades of the resin composite have a clear effect on their masking ability in relation to their layer thickness.[1, 9, 10]

A specially constructed device was used to overcome the difficulty in manufacturing precise 3.25-, 3.5- and 3.75-mm thick split copper molds aiming to avoid any potential unfavorable color change by minute changes in the final enamel layer thickness as reported by previous studies.[2,11]

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[12], which had an accuracy of 92.6% and a reliability of 96.4%[13] that was used in many studies as a reliable, accurate, and cost-effective way of instrumental color measurement.[14-21] Several recent studies used the VITA Easyshade® V for measurements of CIELab color parameters.[12, 22-24]

The CIEDE2000 (ΔE_{00}), was applied to calculate ΔE_{00} between the 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.[25-28]

Spectrophotometric color measurement by VITA Easyshade® V generally found the recommended thickness of outer enamel composite layer thickness to be 0.75. This came in disagreement with Manauta et al., 2014 who suggested an optimum thickness of 0.5 mm for the outer enamel composite layer.[25] This might be due to the less chromatic dentin of that system and the less translucent enamel, so enamel thickness lower than 0.75 mm would not result in the right depth of color. This might also be attributed to the device used for measuring. Spectrophotometer was mainly manufactured and calibrated for shade matching of ceramic restorations, and it is possible that light interaction between the spectrophotometer and the enamel composite used are not the same as with ceramics. This finding is worthy of further investigations especially that the composite used had a modified filler technology that altered its shape and size and hence its interaction with light.

Based on the findings on this study the null hypothesis was rejected, as both the dentin shade and enamel layer thickness had no effect on final shade reproduced compared to the reference shade. Within the limitations of this study, we can conclude that when using the bilaminar technique in vertical anatomical layering of resin composite restorations, the thickness of the outer enamel composite together with the dentin shade used demonstrated a significant effect on the final shade. The lighter the dentin shade used the thicker the enamel thickness needed for better shade reproduction and matching. We recommend further studies to match the objective color measurements of our study with the subjective color perception for both dentist and patients.

Conclusions

Within the limitations of this study the following conclusion could be deduced:

When using the bilaminar technique in vertical anatomical layering of resin composite restorations, the thickness of the outer enamel composite together with the dentin shade used demonstrated a significant effect on the final shade. The lighter the dentin shade used the thicker the enamel thickness needed for better shade reproduction and matching.

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