

# Effect of Ceramic Thickness and Luting Agent Shade on the Color Masking Ability of Laminate Veneers

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**Abstract** The main objective of the study was to recognize the effect of ceramic thickness and luting agent on the extent to which the restoration masks color variations that may be present in the underlying dental structure. Two pressable ceramics were used: Lithium disilicate reinforced (IPS e.max- Ivoclar Vivadent) and Leucite reinforced (Cergo- Dentsply). Fifteen ceramic discs were manufactured from each ceramic and divided into three groups, according to the thickness (0.5, 1, 1.5 mm). To simulate the color of a dark underlying dental structure, background discs, color C3, with 20 mm diameter, were made using resin composite. The ceramic discs with varying thicknesses were seated on the dark background of the resin composite with either resinous opaque cement or resinous cement. The color parameters were determined by the CIE Lab system of colors using a spectrophotometer and color differences ( $\Delta E$ ) were calculated. The results were then statistically analyzed, using ANOVA test and Tukey HSD test. The  $\Delta E$  values of both ceramic systems were affected by both the luting agent and the ceramic thickness ( $P < 0.05$ ). The use of an opaque luting agent resulted in an increase of the  $\Delta E^*$  values for all ceramics tested, regardless of the thickness. For the 1.5-mm thick veneers, higher values in the color parameters were obtained for both ceramic materials. The color masking ability of

ceramics used for laminate veneers is significantly affected by the thickness of the ceramic and the shade of the luting agent used.

**Keywords** Laminate veneers · Color · Pressable ceramics · Luting agent · Thickness

## Introduction

The patients' demand for treatment of unaesthetic anterior teeth is steadily growing. Accordingly, several treatment options have been proposed to restore the aesthetic appearance of the dentition. The great progress in bonding capability to both enamel and dentine made with the introduction of multi-step total-etch adhesive systems, along with the development of high performance and more universally applicable small particle hybrid resin composites has led to more conservative restorative adhesive techniques to deal with unaesthetic tooth appearance [1].

Resin composite veneers can be used to mask tooth discolorations and/or to correct unaesthetic tooth forms and/or positions [1]. However, such restorations still suffer from a limited longevity, because resin composites remain susceptible to discoloration, wear and marginal fractures, reducing thereby the aesthetic result in the long term [2]. In search for more durable aesthetics, porcelain veneers have been introduced during the last decade [1]. They are bio-compatible, allow adequate reflection and transmission of light, and they exhibit good mechanical strength [3].

Porcelain laminate veneers (PLV), which are more conservative than crown restorations, allow for superior translucency and consist of 0.5- to 1.0-mm-thick ceramic bonded to prepared or unprepared teeth with resin cement [4]. The need for an optimal anterior tooth restoration with ceramic

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**Table 1** The mean and Standard deviation Of  $\Delta E$  values of different thicknesses Of IPS-emax with translucent (TR) and opaque (O) cement shades

Type of cement		Thickness (mm)			<i>P</i> value
		0.5	1	1.5	
Translucent cement	Mean	5.992 <sup>a</sup>	9.438 <sup>b</sup>	9.586 <sup>b</sup>	0.02*
	SD	1.105224	0.599767	0.787991	
Opaque cement	Mean	10.638 <sup>b,c</sup>	11.068 <sup>c</sup>	11.356 <sup>c</sup>	
	SD	1.117417	0.367927	0.486241	

\* indicates significant difference between groups ( $P < 0.05$ )

Same superscript alphabets indicate statistically homogenous sub-groups ( $P > 0.05$ )

lamine veneers has also intensified in recent decades because of patients' expectations for achieving aesthetic results that include an individualized shade matching between the ceramic and adjacent natural dentition [5].

A significant challenge in esthetics is to match the optical properties of natural teeth with restorations. Factors such as the degree of opalescence, translucency, fluorescence, surface texture and shape properties, ceramic brand and batches, number of ceramic firings, and the condensation technique may affect the final shade of the ceramic [6].

In addition, the final shade may be affected by the combination of ceramic shade and thickness, together with the luting agent and the color of the underlying dental structure [7]. The translucency of PLV restorations adds another level of complexity to the color-matching process because ceramics allow more light to enter and scatter, which means that the underlying substrates have a significant influence on the final color [4].

When evaluating the final aesthetic quality of ceramic veneers, recognizing the extent to which the restoration masks color variations that may be present in the underlying dental structure is mandatory in composing a harmonious effect with the adjacent natural teeth and reproducing optical properties similar to those present in the dental structure [6]. As a consequence, the overall color produced should not be separately evaluated [8].

Only few studies have evaluated the interaction of factors that comprise the ceramic restoration, especially considering that the restoration will function as one body (underlying dental structure, luting agent, and ceramic thickness) resulting in the final aesthetic aspect. Taking this into account, a comprehensive determination of thickness, luting agent, and background color altogether will optimize color selection [9]. This study was thus conducted to determine the effect of three thicknesses (0.5, 1.0 and 1.5) of porcelain veneers constructed from two pressable ceramics and luting agent (translucent and opaque shade) on their color masking ability.

## Materials and Methods

For this study, two pressable ceramics were used: lithium disilicate reinforced (IPS e.max-Ivoclar vivadent) and leucite reinforced (Cergo-Dentsply). Fifteen ceramic discs were manufactured from each ceramic and divided into three groups, according to the thickness (0.5, 1, 1.5 mm), using an adjustable standardized metallic matrix (11 mm diameter). Porcelain discs were fabricated by the lost wax and heat-press techniques, according to the manufacturer's recommendations. The specimens were then ground on the veneer side using 220-, 400-, and 600-grit sandpaper under water cooling to standardize the surfaces, followed by polishing with silicone points and glazing according to the manufacturers' recommendations.

To simulate the color of a dark underlying dental structure, background discs, color C3, with 20 mm diameter and 5 mm width, were made from resin composite (Tetric N-Ceram, Ivoclar Vivadent AG, Schaan, Liechtenstein), using a silicone mold, made of Putty consistency Polyvinylsiloxane (Coltene).

The luting agents (Rely veneer TR and A3Opaque) were applied and pressed onto the surface between the resin composite disc and a glass plate using a digital veneer calliper producing a cement thickness of 0.02 mm. It was then light cured for 60 s.

The analysis of the color was done using a spectrophotometer. The parameters  $L^*$ ,  $a^*$  and  $b^*$  were first measured for the background resin disc and these readings were kept as base values. Then, the color parameters were noted for all the ceramic discs, one by one, by keeping them on the background disc with translucent luting agent as well as on the background disc with opaque luting agent layer.

The measure of the total difference of color between two objects is described by  $\Delta E$ . The formula used to calculate the  $\Delta E$  is:

$$\Delta E_{ab^*} = \left[ (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2},$$

where  $\Delta L^* = L^*_2 - L^*_1$ ,  $\Delta a^* = a^*_2 - a^*_1$  and  $\Delta b^* = b^*_2 - b^*_1$ .

## Statistical Analysis

To compare the differences between the groups, obtained results were statistically analyzed. Data was described in mean and standard deviation (SD). Two way ANOVA was used for multiple group comparisons followed by Tukey HSD test to assess any significant difference between the individual groups.  $P$  value of 0.5 or less was considered for statistical significance.

**Table 2** The mean and standard deviation of  $\Delta E$  values of different thicknesses of Cergo with translucent (TR) and opaque (O) cement shades

Type of Cement		Thickness (mm)			P value
		0.5	1	1.5	
Translucent cement	Mean	17.012 <sup>a</sup>	18.962 <sup>b</sup>	20.356 <sup>c</sup>	$P < 0.001^{**}$
	SD	0.770273	0.284289	0.663611	
Opaque cement	Mean	19.004 <sup>b</sup>	20.052 <sup>c</sup>	20.806 <sup>c</sup>	
	SD	0.773162	0.386419	0.437641	

\*\* Indicates highly significant difference between groups ( $P < 0.001$ )

Same superscript alphabets indicate statistically homogenous subgroups ( $P > 0.05$ )

## Results

The measure of the total difference of color between two objects is described by  $\Delta E$ . The  $\Delta E$  values were calculated for all groups by keeping the base values of C<sub>3</sub> shade resin composite disc ( $L^*$ : 56.69,  $a^*$ : 0.78,  $b^*$ : 8.73). The mean and standard deviation of  $\Delta E$  values of different groups of both materials are listed in Tables 1 and 2; Fig. 1. The highest mean  $\Delta E$  values were exhibited by IPS-emax 1.5 mm thickness group with opaque resin cement and lowest mean  $\Delta E$  values were exhibited by Cergo 0.5 mm thickness group with translucent resin cement.

From the results it was found that there was a statistically significant difference between the groups of IPS-emax ( $P < 0.001$ ) and Cergo ( $P < 0.05$ ) with respect to the  $\Delta E$  values.

There was no statistically significant color difference between 1 mm with translucent cement and 0.5 mm with opaque cement in both materials and between 1 and 1.5 mm with opaque cement in both materials.

$\Delta E$  values above 3.7 are visually detected. Figure 2 depicts the color differences  $\Delta E$  between 0.5 and 1.0 mm thicknesses of both materials with translucent and opaque shade cement. Only Cergo with translucent cement shows visually detectable color difference. Figure 3 depicts the color differences  $\Delta E$  between 0.5 and 1.5 mm thicknesses of both materials with translucent and opaque shade cement. All groups show visually detectable color difference.

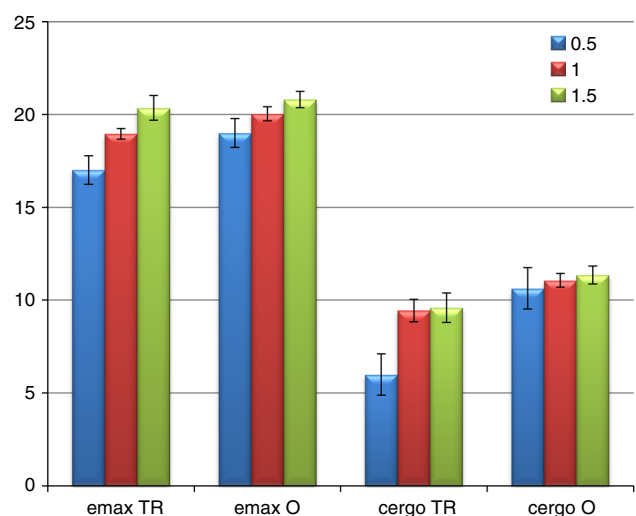
## Discussion

In modern era, patients demand not only healthy functional dentition, but also an esthetic smile [10]. Tooth colour depends upon a series of factors including: the thickness and morphology of the enamel, presence of staining and the amount of any dentine exposed. Tooth staining has a multi-factorial aetiology and may be either extrinsic or intrinsic. Extrinsic staining results from chromogens in the diet and environmental processes including coffee, tea, red

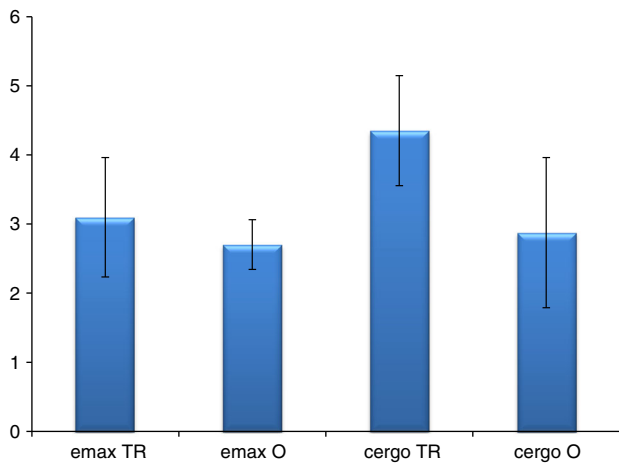
wine and smoking. Intrinsic staining results from an alteration of the structural or compositional characteristics of hard tissue, for example, fluorosis, tetracycline stains. As tooth ages or undergoes a disease process, a reduction in the size of the pulp chamber with laying down of secondary or tertiary dentine changes the colour of a tooth. Additionally, as enamel is thinned by the processes of abrasion and erosion, the tooth appears increasingly yellow [10].

Both bleaching and veneering are common methods of treating discolouration [11]. Although generally considered to be a safe procedure bleaching has many reported side effects including tooth sensitivity, furthermore the final results are often unpredictable [10]. Resin composite veneers can be used to mask tooth discolorations and/or to correct unaesthetic tooth forms and/or positions [1]. However, such restorations still suffer from a limited longevity, because resin composites remain susceptible to discoloration, wear and marginal fractures, reducing the aesthetic result in the long term [2].

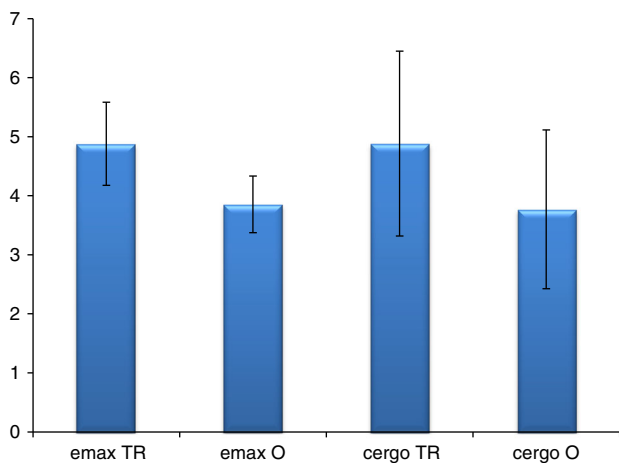
The popularity of porcelain veneers stems from their superior optical properties, translucency, and minimally



**Fig. 1** The mean and standard deviation of  $\Delta E$  values of different thicknesses OF IPS-emax and Cergo with translucent (TR) and opaque (O) cement shades



**Fig. 2**  $\Delta E$  between 0.5 and 1.0 mm thicknesses OF IPS-emax and Cerigo with translucent (TR) and opaque (O) cement



**Fig. 3**  $\Delta E$  between 0.5 and 1.5 mm thicknesses of IPS-emax and Cerigo with translucent (TR) and opaque (O) cement

invasive preparation of natural tooth structure. The survival rate for feldspathic porcelain laminate veneers for over 20 years was reported to be 96 % [12]. Typically, ceramic veneers are used to alter the color or shape of anterior teeth such as discolored or hypoplastic teeth, fractured incisors or teeth where the morphology or alignment is causing poor aesthetics [13]. Preparations for ceramic veneers, which are typically very conservative, allow the preparation to remain within enamel. This reduces the risk of pulpal injury and gives a more predictable adhesion than when bonding to dentine [13].

Porcelain Laminate Veneers present a significant aesthetic challenge due to the various interactions of the elements involved, manifested in the ultimate colour and translucency of the restoration [12]. Factors such as the degree of opalescence, translucency, fluorescence, surface

texture and shape properties, ceramic brand and batches, number of ceramic firings, and the condensation technique may affect the final shade of the ceramic. In this in vitro investigation, the null hypothesis that the colour masking ability of a simulated porcelain laminate veneer restoration would not be influenced by the change in thickness of the porcelain material, or the change of shade of the resin luting agent was rejected.

This study simulated a clinical situation in which veneers are not individual layers of ceramic, but rather comprise a complete unit, with a background simulating the tooth shade, the luting agents, and the ceramic layers. The influence of the type of luting agent used and the different ceramic thicknesses, which can vary clinically, were evaluated to verify their influence on color parameters.

The choice of using a chromatic background was intended to simulate a typical clinical condition in which a dark underlying dental structure is present and a ceramic veneer restoration is planned. C3 shade is one of the darker shades and hence, it was used for chromatic background.

In this study, varying thicknesses of the ceramics influenced the color parameters evaluated, overall presenting higher  $\Delta E$  values when thicker veneers were used, regardless of the luting agent. Ceramics with 1.0 and 1.5 mm thickness had an increased  $L^*$  parameter resulting in lighter ceramic specimens, promoting higher masking of the darkened background. These results were in agreement with other investigators (Volpato et al. [3], Cubas et al. [6], Dozic et al. [7], Kürklü et al. [12], Vichi et al. [14]).

The shade of luting agent also had an effect on the color masking ability of the veneers. The use of an opaque luting agent resulted in higher  $\Delta E$  values when compared to the translucent cement [15]. Öztürk et al. [16] in his study, concluded that resin cement shade has a significant effect on the ceramic opacity.

A limitation of this study is that only two ceramic systems were compared. Other available systems for laminate veneers may differ in the color masking abilities. Only one luting agent with only two shades were used. It has been shown that different resin cements in same shade labels have different color values. Although in vitro studies simulate clinical reality and may be a clue as to how these restorations will perform clinically, randomized controlled trials are necessary to investigate the magnitude of color alterations and their differences under clinical conditions. Studies that analyze ceramic restorations as a unit composed of dental substratum, luting agent, and ceramic thickness could help in understanding the factors involved in producing the final color of a ceramic restoration. Such information would be useful for establishing a guideline for clinical practice and could help to determine the need for tissue reduction associated with product selection, to

increase the capacity of different ceramic systems in masking dental color substratum, and to assist in optimizing shade selection.

## Conclusion

The thickness of a ceramic material can affect its translucency and color, therefore presenting higher capacity for masking a dark substrate when fabricated with higher thickness. The veneers with opaque shade of luting agent have a higher ability to mask the background color variations as compared to the veneers of equivalent thicknesses with translucent shade of luting agent. A similar color masking, of a dark dental substructure, can be obtained by using a 0.5 mm veneer with an opaque shade of luting agent rather than using a 1.0 mm veneer with a translucent shade of luting agent, thus being more conservative. Thus, depending on the color variations on the dental substructure, an appropriate choice of the ceramic thickness as well as luting agent shade is important for optimum esthetic results.

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