Effect of Thickness and Translucency on Color Change and Masking Ability of Ceramic Materials used for Laminate Veneers

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ABSTRACT

This study evaluated the effect of the thickness and translucency of lithium disilicate-based glass ceramics on resin composite substrates on color change and masking effect. Laminate veneers were fabricated using IPS e.max CAD (A1) blocks with two different light transmittance values (High translucent [HT], Low translucent [LT]). Slices of two different thicknesses (0.3 mm, 0.5 mm) were obtained (n=10) and laminate veneers were cemented on the resin composite substrates of two different shades (A2, A3.5). The color change (ΔE values) was evaluated with the CIELab color system using a spectrophotometer, while the masking effect was calculated. The data were analyzed using independent-samples t-test and two-way analysis of variance. The ceramic thickness and translucency had a significant effect on final color and masking. When HT was used, and the laminate veneer thickness decreased (0.3 mm), the masking effect in ΔE values were lower (p<0.05). The ΔE values (>3.7) were clinically unacceptable. With the increase in thickness, translucency of porcelain laminate veneers decreases showing better color masking ability. Veneer thickness seems to be more effective on the restoration's masking ability than the shade of the substrate and translucency. Cinically, in case a 0.5-mm or thinner laminate veneer is planned, tooth color, resin cement and ceramic type should be considered.

INTRODUCTION

Owing to novel ceramic materials and cementation agents used in dentistry, it has become possible to fabricate restorations that imitate the natural tooth tissue.[1] Furthermore, superior aesthetic results, especially in the case of anterior restorations, could be achieved employing advanced adhesive systems using all-ceramic products with high color stability and biocompatibility.[3]

Porcelain laminate veneers are preferred for the aesthetic rehabilitation of teeth with discoloration, misalignment and deformity, with high overall success rates.[4-6] Additionally, these restorations are used according to a minimal invasive approach with the aim of preserving the tooth tissue, with minimal or no preparation, achieving the the aesthetic expectations of patients.[7]

Aesthetics play a major role in evaluating the success of porcelain laminate veneers.[8] Color is one of the most important factors affecting the aesthetics of laminate veneer restorations and their compatibility with natural teeth.[9] Factors affecting the final color of porcelain laminate veneers include the color of the tooth, the type, thickness, light transmittance and color of the porcelain that is used along with thickness and color of the resin cement.[8,10,11]

Due to the translucent nature of glass ceramics used in the production of porcelain laminate veneers, tooth color may be reflected from behind the restoration, which adversely affects the result, especially when very thin laminate veneers are indicated.[12] Appropriate resin cement color and ceramic thickness are critical factors in the rehabilitation of a dark tooth with laminate veneers.[2,13] In order to overcome this problem and mask dark colored teeth, new generation resin cements and ceramics have been produced.[10]

In line with this information, the aim of this study was to investigate the effect of the thickness and light transmittance of lithium disilicate-based glass ceramics applied with neutral colored cement on differently colored resin composite substrates simulating tooth color, on color change and masking. The first null hypothesis tested was that the thickness and light transmittance of laminate veneers would have no effect on masking ability and color change. The second null hypothesis was that the color difference between the final color after cementation and the color of the blocks used (A1) would result in a clinically acceptable value (<3.7).

MATERIALS AND METHOD

The brands, types, chemical compositions, manufacturers and batch numbers of the materials used in this study are listed in Table 1.

PREPARATION OF COMPOSITE RESIN SUBSTRATES

In order to achieve standardization in the production of composite resin substrates that simulate the tooth color, a metal brass mold with ellipsoid cavities of 4 mm in depth and 12 mm x 14 mm in diameter were produced. The nanohybrid composite resin material Filtek Z550 (3M ESPE, St. Paul, MN, USA) with the colors A2 and A3.5 was used to obtain the resin

Table 1. Materials and details used in the study.

The Brands	Types	Chemical Compositions	Manufacturers	Batch Numbers
IPS e.max CAD HT A1 C14	Lithium disilicate-based glass ceramic block	%57-80 SiO_2, %11-19 Li_2O, %0-13 K_2O, %0-11 P_2O_5, %0-8 ZrO_2, %0-8 ZnO, %0-5 Al_2O_3, %0-5 MgO, %0-8 pigment	Ivoclar Vivadent, Schaan, Lichtenstein	Y45611
IPS e.max CAD LT A1 C14	Lithium disilicate-based glass ceramic block	%57-80 SiO_2, %11-19 Li_2O, %0-13 K_2O, %0-11 P_2O_5, %0-8 ZrO_2, %0-8 ZnO, %0-5 Al_2O_3, %0-5 MgO, %0-8 pigment	Ivoclar Vivadent, Schaan, Lichtenstein	Y16102
Filtek Z550	Nanohybrid composite resin	Bis-GMA, Bis-EMA, UDMA, PEG-DMA, TEGDMA, Modified zirconia/silica doldurucu (%81.8)	3M ESPE, St. Paul, MN, USA	NC01550 N989790 N954930
Variolink Esthetic LC	Composite resin cement	10-<25% YbF3, 3-<10% UDMA, 3-<10% 1,10-decandiol dimethacrylate, initiator, stabilizer, pigment	Ivoclar Vivadent, Schaan, Lichtenstein	Y44437
Acid gel	Hydrofluoric acid	9% HF acid	Ultradent Products, South Jordan, UT, USA	BHWRX

Bis-GMA, Bisphenol-A glycidyl methacrylate; UDMA, Urethane dimethacrylate; Bis-EMA, Ethoxylated Bisphenol A dimethacrylate; YbF3, ytterbium trifluoride; PEG-DMA, Polyethylene glycol dimethacrylate; TEGDMA, Triethylene glycol dimethacrylate: HF, hydrofluoric acid.

composite substrates. The resin composite material was applied to the metal mold avoiding air bubble formation. Then, a smooth surface was created by placing transparent tape (Mylar Strip SS White, Philadelphia, PA USA) and cement glass on the top surface and polymerized for 40 seconds with a photopolymerization device (Valo cordless, Ultradent, South Jordan, UT, USA). After preparing 40 specimens of A2 and 40 specimens of A3.5 resin composite substrates, the samples were randomly divided into 8 groups (n=10). The schematic view of the experimental groups is shown in Figure 1.

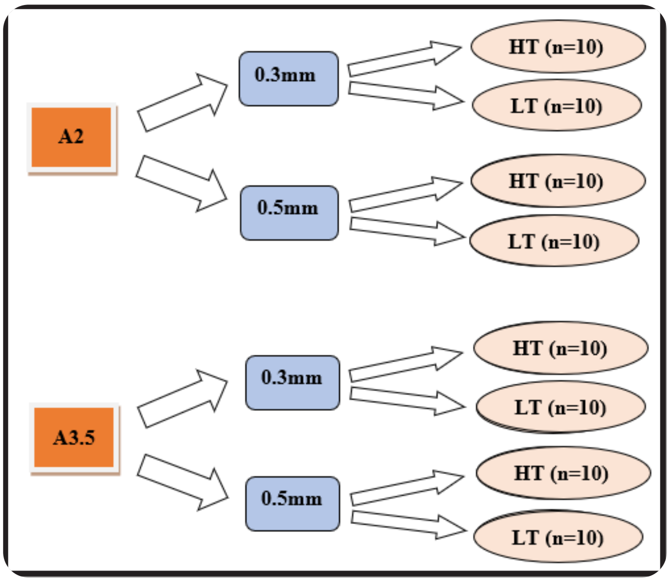

Figure 1: Schematic view of the experimental groups.

PREPARATION OF LAMINATE VENEERS

For this study, IPS e.max CAD A1 blocks (Ivoclar Vivadent, Schaan, Lichtenstein) with two different light transmittance values were used: High translucent (HT) and Low translucent (LT). Thin slices of two different thicknesses (0.3 mm and 0.5 mm) and a 12 mm x 14 mm dimensions were obtained from the blocks using a low-speed diamond cut-off wheel (Struers MOD10; Buehler, Lake Bluff, IL, USA) under constant water cooling (n=10). The thickness of the sliced laminate specimens was measured with a digital micrometer (293-230 MDC-MX; Mitutoyo Corporation, Tokyo, Japan), and a total of 80 laminate veneers were manufactured. They were then randomly divided into groups according to their translucency degree (HT and LT) and thickness (0.3 mm and 0.5 mm) to be cemented onto resin composite substrates in two shades. The laminate veneers that were obtained with smooth surfaces were crystallized in a crystallization furnace (Programat P-310, Ivoclar Vivadent, Schaan, Lichtenstein) in accordance with the manufacturer's instructions. Glaze consisting of powder-liquid (IPS Ivocolor Glaze Paste, Ivoclar, Vivadent, Schaan, Lichtenstein) was applied to one surface of the crystallized laminate samples with the help of a brush and fired in accordance with the manufacturer's instructions.

CEMENTATION OF CERAMICS ONTO SUBSTRATES WITH RESIN CEMENT

Prior to cementation, the non-glazed surfaces of the specimens were treated with 9% hydrofluoric acid (Ultradent Porcelain Etch, South Jordan, USA) for 20 seconds, water-rinsed and air-dried. Next, silane (Monobond Plus; Ivoclar Vivadent, Schaan, Lichtenstein) was applied for 60 seconds followed by an adhesive bonding agent (Adhese Universal; Ivoclar Vivadent, Schaan, Lichtenstein) on the surface of the composite resin substrates for 20 seconds, air dried for 5 seconds and photo-polymerized for 10 seconds. A photo-polymerized resin cement (Variolink Esthetic LC; Ivoclar Vivadent, Schaan, Lichtenstein) was homogeneously applied onto the surface of the specimens. Then in order to standardize the cement thickness, 1 kg (9.8 N) force was applied for 20 seconds onto the specimens with a dynamometer device (Algol NK-100, Taiwan) during the cementation [2]. After removing the force, light was applied for 2 seconds, the excess cement was removed, after which each surface was photopolymerized for 10 seconds.

COLOR MEASUREMENTS

All color measurements in this study were performed by the same calibrated researcher on a white background (L^* = 91.9, a^* = –1.6, b^* = 0.7) with a digital spectrophotometer (Spectroshade Micro II; MHT Optic Research AG, Niederhasli, Switzerland) to ensure standardization.[14] The calibration process was repeated after measuring each specimen. Each specimen was measured three times, and the mean values calculated.

In this study, two different ΔE values were obtained,[15,16] The shade of the resin composite substrates was measured before cementation (L1, a1, b1). After cementation, the final color of the laminate veneers was measured (L2, a2, b2). The color difference between the color values of the resin composite substrates before cementation and the final color values of the laminate veneers after cementation was calculated according to the following formula:

$$\Delta E = \sqrt{(\Delta L *)2 + (\Delta a *)2 + (\Delta b *)2}$$

With these ΔE values, the effect of the thickness and light transmittance of the laminate veneers on masking effect was evaluated. At the same time, the ΔE values of the final colors of the cemented laminate veneers according to the shades in the Vitapan Classical scale were also recorded. Color change was also evaluated with these ΔE values. In this study, the clinically acceptable ΔE value for color difference was set as 3.7.[4,17]

Data were statistically analyzed using the statistical analysis software SPSS 22.0 for Windows (SPSS Inc., Chicago, IL). The conformity of the data to normal distribution was evaluated with histograms, Q-Q plots and Shapiro-wilk test. The homogeneity of the variances was tested with Levene's test. The effects of thickness and light transmittance on the ΔE values were evaluated with independent-samples t-test and two-way analysis of variance (ANOVA). The significance level was accepted as $p<0.05$.

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RESULTS

When A2 substrates were used, the mean total ΔE values were found as 13.06 at the thickness of 0.3 mm and 16.71 at the thickness of 0.5 mm, which showed a statistically significant difference in terms of masking effect (p<0.05). When the A3.5 substrate was used, the mean total ΔE values were found to be 18.96 at the thickness of 0.3 mm and 23.11 at the thickness of 0.5 mm, and there was a statistically significant difference in terms of masking effect (p<0.05) *(Table 2)*.

When the A2-colored substrate was used, the mean total ΔE values were found as 13.89 at the light transmittance of HT and 15.88 at LT, and there was a statistically significant difference in masking. When the A3.5 substrate was used, as the mean total ΔE values were found as 19.88 at HT and 22.19 at LT, and there was a statistically significant difference in masking effect *(Table 3)*.

The final colors of all combinations provided ΔE values above the clinically acceptable limit according to the shades on the Vitapan Classical scale (ΔE>3.7).

Considering the mean values of ΔE according to the shades corresponding to the scale, significant difference was observed between the 0.3 mm and 0.5 mm thicknesses of the A2-HT, A2-LT and A3.5-HT combinations (p<0.05). In the A3.5-LT combination, there was no significant difference between the specimens of the thickness of 0.3 mm and 0.5 mm (p=0.397) *(Table 4)*.

Considering the mean values of ΔE according to the color corresponding to the scale, there was a significant difference between the HT and LT light transmittance values according to the A1 color in the A2-0.3 mm combination and according to the B1 and C1 colors in the A3.5-0.3 mm combination (p<0.05). In the other comparisons, there was no significant difference based on light transmittance (p>0.05) *(Table 5)*.

DISCUSSION

This study investigated the effects of the thickness and light transmittance of lithium disilicate-based glass ceramics when bonded with neutral colored cement on resin composite substrates of different shades simulating tooth color on color change and masking effect. The results obtained in the study showed that the thickness and translucency of the laminate veneers cemented onto both the A2- and A3.5 resin composite resin substrates had a significant effect on color change and masking. Likewise, the color difference between the final color of all combinations after cementation and the color of the blocks used (A1) was above the clinically acceptable level (ΔE>3.7). Thus, both null hypotheses were rejected.

Today, the popularity of laminate veneers has increased in the design of patients' smiles and the aesthetic and functional rehabilitation of anterior teeth.[5,6] With the right indication, selection of materials and correct application of the technique, laminate veneers can provide aesthetic results by mimicking the translucency of the natural tooth structure.[4,10] Aesthetics

Table 2. Masking ΔE values of laminate veneers by thickness (n=10).

Substrate Color	Thickness	HT Mean± SD	LT Mean± SD	Total Mean± SD	*p*
A2	0.3mm	11.03±1.83	15.08±1.18	13.06±2.56	<0.001
	0.5mm	16.74±1.26	16.67±0.45	16.71±0.92	
A3.5	0.3mm	16.60±1.52	21.32±1.65	18.96±2.86	<0.001
	0.5mm	23.16±1.44	23.07±1.64	23.11±1.50	

A2 A3.5 substrate color; 0.3mm 0.5mm laminate thickness; HT LT laminate light transmittance. SD: standard deviation.

Table 3. Masking ΔE values of laminate veneers by light transmittance (n=10).

Substrate Color	Light Transmittance	0.3mm Mean± SD	0.5mm Mean± SD	Total Mean± SD	*p*
A2	HT	11.03±1.83	16.74±1.26	13.89±3.30	<0.001
	LT	15.08±1.18	16.67±0.45	15.88±1.19	
A3.5	HT	16.60±1.52	23.16±1.44	19.88±3.66	<0.001
	LT	21.32±1.65	23.07±1.64	22.19±1.83	

A2 A3.5 substrate color; 0.3mm 0.5mm laminate thickness; HT LT laminate light transmittance. SD: standard deviation

Table 4. Color change ΔE values according to thickness for all combination groups according to the colors in the scale (n=10).

Combinations	ΔE with A1 Mean± SD	ΔE with B1 Mean± SD	ΔE with C1 Mean± SD	Final Color
A2-0.3mm-HT	4.23±0.41	4.64±0.59	5.05±1.28	A1
A2-0.5mm-HT	6.86±0.92	6.46±0.73	9.54±0.79	B1
p	<0.001	<0.001	<0.001	
A2-0.3mm-LT	5.53±1.00	5.19±0.86	7.89±1.06	B1
A2-0.5mm-LT	6.87±0.32	6.17±0.41	9.00±0.58	B1
p	0.001	0.004	0.009	
A3.5-0.3mm-HT	6.72±1.10	6.72±1.30	4.47±0.78	C1
A3.5-0.5mm-HT	6.54±0.76	5.35±0.67	6.93±1.20	B1
p	0.681	0.008	<0.001	
A3.5-0.3mm-LT	6.61±0.56	5.69±0.30	5.88±1.06	B1
A3.5-0.5mm-LT	7.16±0.66	5.87±0.60	7.03±1.36	B1
p	0.060	0.397	0.049	

Combination: A2 A3.5 substrate color; 0.3mm 0.5mm laminate thickness; HT LT laminate light transmittance. SD: standard deviation

Table 5. Color change ΔE values according to light transmittance for all combination groups according to the colors in the scale (n=10).

Combinations	ΔE with A1 Mean± SD	ΔE with B1 Mean± SD	ΔE with C1 Mean± SD	Final Color
A2-0.3mm-HT	4.23±0.41	4.64±0.59	5.05±1.28	A1
A2-0.3mm-LT	5.53±1.00	5.19±0.86	7.89±1.06	B1
p	0.001	0.107	<0.001	
A2-0.5mm-HT	6.87±0.92	6.46±0.73	9.54±0.79	B1
A2-0.5mm-LT	6.87±0.32	6.17±0.41	9.00±0.58	B1
p	0.995	0.288	0.098	
A3.5-0.3mm-HT	6.72±1.10	6.72±1.30	4.47±0.78	C1
A3.5-0.3mm-LT	6.61±0.56	5.69±0.30	5.88±1.06	B1
p	0.788	0.035	0.004	
A3.5-0.5mm-HT	6.54±0.76	5.35±0.67	6.93±1.20	B1
A3.5-0.5mm-LT	7.16±0.66	5.87±0.60	7.03±1.36	B1
p	0.068	0.082	0.870	

Combination: A2 A3.5 substrate color; 0.3mm 0.5mm laminate thickness; HT LT laminate light transmittance. SD: standard deviation plays a major role in evaluating the success of porcelain laminate veneers. Color is one of the most important factors that affect the aesthetics of these restorations and in ensuring that they are compatible with natural teeth.[9] Considering difficulties that clinicians may experience in the aesthetic rehabilitation of teeth with porcelain laminate veneers, in deciding on the amount of preparation and in material selection, in our study, laminate veneer thickness, optical properties, the thickness and color of the resin cement, and the color of the tooth, affecting the final color of the restoration, were considered as a whole.

Lithium disilicate-based ceramic materials with favorable aesthetic properties are frequently used for laminate veneer restorations.[13] In studies evaluating the color properties of laminate veneers, it has been observed that light-colored blocks were frequently preferred, and the A1 color was the most commonly used shade among such light colors.[2,6,18] In our study, IPS e.max CAD high and low translucent blocks in the A1 color were preferred. The thickness of the laminate veneer restoration is limited by the tissue removed from the tooth surface. Additionally, our aim should be to make the minimum preparation on the tooth.[19] In order to achieve good adhesion, the veneers should be bonded to the enamel, and the developing technology allows the production of porcelain laminate veneers as thin as 0.2 mm.[20] In line with this information, 0.3-mm and 0.5-mm-thick laminate veneers were used in our study.

In similar studies in the literature, it was seen that the thickness of composite resin substrates simulating tooth color was at least 4 mm.[6,13] In our study, which aimed to imitate the *in vitro* aesthetic rehabilitation of dark-colored teeth that we may encounter in the clinic, A2- and A3.5-colored, 4-mm-thick substrates prepared from nanohybrid resin composite material were used.[19,21]

Currently, photo-polymerized resin cements are recommended for luting of anterior restorations due to their improved color stability than other cements.[22] In our study, the neutral color of a resin cement was preferred, aiming to minimize the effect of the resin cement on the final color.

Significant differences in the masking ΔE values were found among the groups in this study. With both substrate colors, when the laminate veneer thickness decreased (0.3 mm) and at high light transmittance (HT), the masking ΔE values were low *(Tables 2 and 3)*. This result was in agreement with those reported in other studies.[6,16] Given the insufficiency of masking ability with thinner restorations, this was an expected result. With both resin composite substrate shades, laminate veneer thickness was found to be more effective on masking ability than light transmittance *(Tables 2* and 3).

In our study, 0.3-mm-thick laminate veneers produced from high translucent blocks were the group most affected by substrate color. When these laminate veneers were cemented to the A2 resin composite substrate, the final color was A1 (ΔE>3.7). When the A3.5-colored composite resin was cemented to the substrate, the final color was obtained as C1 (ΔE>3.7).

Sari *et al*. reported that it is impossible to mask a substrate with a large color difference with a ceramic that is only 0.3 mm thick.[11] In our study, the masking effect ΔE values for the 0.3-mm-thick laminate veneers cemented with the neutral colored cement were found to be 11.03 and above on average. This value was well-above the clinically acceptable limit. At the same time, the final colors of the combinations using the 0.3 mm thickness were A1, B1 and C1, which are lighter colors than the color of the substrates. Again, in the same aforementioned study, contrary to the results of our study, it was stated that there was no statistically significant difference in masking between the specimens at a thickness values of 0.3 mm and 0.5 mm.[11] The reason for all these results may have been that the block material they used was Vitablocks Mark II, and the authors measured the color values of the 0.3-mm-thick ceramics by placing them onto the substrate without using cement.

The results of this study revealed that varying thickness and translucency values of ceramics affect the color change in ΔE values, and thus, the final color of laminate veneers. This result was in agreement with those reported in other studies.[2,10] The final colors of all combinations provided ΔE values above the clinically acceptable limit according to the colors A1, B1 and C1 on the Vitapan Classical scale (ΔE>3.7). The combination closest to the color of the blocks used (A1) was A2-0.3mm-HT. The final color of the A3.5-0.3mm-HT combination was C1. The final colors of all other combinations were B1. The reason for these results could be attributed to decrease in laminate veneer thickness (0.3 mm) and the use of high translucent block (HT) which helped mask the dark color of the substrates less, and the b* values of the final color of these restorations were higher.

Turgut *et al*. reported that the ΔE values of 0.5-mm-thick laminate veneers, which were cemented with neutral colored cement onto A3.5-colored composite resin substrates, were above 3.7 according to the A1 color in the scale.[2] This finding was similar to our finding. In the study of Omar *et al*., 0.5-mm-thick laminate veneers obtained from 3M2-colored blocks were cemented on 3M2-colored teeth with light colored cement, and the color difference between the obtained color and the 3M2 color was examined, where ΔE was found to be lower than 3.7.[15] This result may have been reached because they conducted their study by choosing the same substrate color as the block color they were using.

Azer *et al*. stated that when a 2-mm-thick laminate veneer was used, the final color of the restoration was not affected by the substrate. The color changes at the thickness value of 1.5 mm were visible only with instruments, and the color difference was clinically noticeable at the thickness of 1 mm.[23] Similarly, when the final colors were evaluated according to the findings of our study, it was concluded that there was a clinically unacceptable color difference in comparison to the color of the blocks that were used, since laminate veneers much thinner than 1 mm were used (ΔE>3.7).

In this study, the use of prefabricated CAD-CAM materials was simulated, and the results also indicated possible color changes that the clinician may prefer when a change in the final color is planned. The limitations of this study were the flat surface preparation of the fabricated samples so that the measurements could provide more accurate results. Additionally, only glass porcelain blocks were used for the laminate veneers. Other available systems may differ in terms of color matching and masking capabilities. Further studies are required to investigate the clinical color matching and masking abilities of ceramic restorations.

Based on the results of this study and color measurements, a table was created to help clinicians determine the amount of preparation and to see the effects of substrate color, ceramic thickness and light transmittance on the final restoration color, which would be used as a guideline to avoid repeated restorations due to colour mismatch of laminate veneers after luting them on resin composites.

CONCLUSIONS

From this study, the following conclusions could be made:

1. Porcelain laminate veneers show better color masking ability as their thickness increases and light transmission decreases accordingly. Restoration thickness seems to have a higher effective on the masking ability of the substrate than translucency.
2. The thickness and light transmittance of porcelain laminate veneers affect the final restoration color. Although the final colors of all combinations were close to A1, B1 and C1, they provided ΔE values above the clinically acceptable limit. For this reason, if a 0.5-mm-thick or thinner laminate restoration is planned, care should be taken in material selection considering tooth color, resin cement type and color and ceramic type and their interaction.
3. Color changes after cementation are different from each other in laminate veneers with different light transmittance and thickness values. The clinician should also consider the final color of the restoration after cementation while choosing the ceramic type. Resin cements with trial paste may be preferred for checking the final color.

DISCLOSURE

The authors declare that they have no conflict of interest.

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