Dental Research Journal

Original Article

The minimum thickness of a multilayer ceramic restoration required for masking dark background

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ABSTRACT

Background: Masking dark tooth structure or darkness of oral cavity with ceramic restorations is an important concern. The aim of this study was to determine the minimum thickness of a multilayer all-ceramic restoration (IPS-emax Press) required for a proper masking in these situations.
Materials and Methods: In this experimental *in vitro* study, 36 multilayer ceramic disks of IPS e.max Press (IvoclarVivadent, Schaan, Liechtenstein) with the diameter of 13 mm were prepared and allocated in six groups of different core/veneer thicknesses: 0.4/0.4 mm (G1), 0.5/0.5 mm (G2), 0.6/0.6 mm (G3), 0.8/0.7 mm (G4), 1.0/0.8 mm (G5), and 1.1/0.9 mm (G6). For backgrounds, the standard black tile of spectrophotometer (B) was used to stimulate the darkness of oral cavity, and an opaque ceramic (OC) of IPS-emax Press (OC) was fabricated to determine the masking ability. CIELAB values of all disks on B and OC backgrounds were measured, and ΔE was calculated between two backings. One-way ANOVA and *post hoc* tukey test were used to analyze the data. ΔE ≤3.3 and $P < 0.05$ were considered, respectively, as the clinically acceptable limit and the level of statistical significancy.
Results: The mean ΔE between B and OC of groups 4 (2.83 ± 0.80) and 5 (1.46 ± 0.36) were within the range of the clinically acceptable color difference (ΔE ≤3.3); thus these groups could properly mask the black background. A trend was existed in the results as by increasing the thickness, ΔE was decreased.
Conclusion: A thickness of 1.5 mm of a multilayer ceramic restoration (IPS e.max Press) is required to mask a dark discoloration.

Key Words: Color, masking, multilayer ceramic, spectrophotometer, tooth discoloration

Received: 25-Sep-2020
Revised: 18-Oct-2021
Accepted: 23-Dec-2021
Published: 27-Apr-2022

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INTRODUCTION

Producing a restoration with closest appearanc simillar to natural teeth is a practical challenge, which dentists and dental technicians are commonly faced to. Color assessment is a complex psychophysiologic procedure that depends on different factors.[1] Color of an individual tooth is primarily determined by dentin, and enamel is the layer that can affect that color through its translucency and thickness. In the other word, reflected and transmitted light from enamel and dentin, which are hard structures in a tooth, results in the ultimate color. Achieving proper tooth-like optical charectristics by dental materials is a major issue in dentistry. Ceramics are materials with close optical

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www.ncbi.nlm.nih.gov/pmc/journals/1480

How to cite this article: Shadman N, Ebrahimi SF, Shoul MA, Kandi SG, Rostami S. The minimum thickness of a multilayer ceramic restoration required for masking dark background. Dent Res J 2022;19:31.

behavior to natural tooth,[1] and a good choice for treatments in esthetic zone. However, providing an excellent color match compatible with surrounding dentition by means of these materials is still a concern.[2,3] On the other hand, the psychological impact of esthtetics has an important role in overall patient acceptance.[4,5]

While restoring a tooth with severe discoloration, placing a "through and through" restorations, or closing a large diastema where enough tooth structure does not exist for providing a base to reflect and transmit the light, shade matching is a major step to gain an acceptable color. In such situations, the ability of a ceramic restoration for masking the darkness has importance,[6] and it can be hard to achieve a successful esthetic outcome, without a shadowing in restoration, unless the beneath dark structure is well covered.[7] Therefore, determining the minimum thickness of a ceramic restoration which is not affected by a black background would be useful in clinical treatments. It has been suggested that the glass-ceramic should be at least 2.0 mm thick,[8-10] and zirconia which is a semi-translucent material should have a thickness of 0.8 mm to render sufficient masking ability.[11]

To mitigate the effect of any background's color on the overall color, an opaque ceramic (OC) layer can be used as the core of a bilayer structure in a ceramic restoration.[12]

There are several factors determining the final esthetic properties of an all-ceramic restoration *in vivo*: color and thickness of the ceramic, different ceramic layers' properties (such as core and veneer shade and opacity), thickness and color of luting cement, and color of remaining tooth structure or background.[13]

In addition, some intrinsic characteristics such as opalescence, fluorescence, and translucency of ceramic in combination with the size of crystal particles have an important influence on the final color.[14]

Superior esthetics, adequate strength, wear resistance, and chemical durability are the factors which have made the lithium disilicate glass-ceramics a popular choice for anterior and posterior restorations.[15] High-opaque lithium disilicate copings can bond chemically with resin cements and might be better to use in preparations with compromised retention and stability in comparison with zirconia.[11] IPS e.max Press ceramic (IvoclarVivadent, Schaan, Liechtenstein) is a lithium silicate glass-ceramic with proper esthetic features and strength which can be used in extremely thin anterior veneers.[16]

Determination of the masking ability of aceramic restoration in black oral cavity is defined by measuring the color difference (ΔE) when the restoration is placed over two different backgrounds: a dark background (1) and an opaque background which fabricated from the same material but with enough thickness to be completely opaque.[2] The masking ability can be determined using the following formula: [9,17]

$$\Delta E^*_{lab} = \sqrt{(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2} \quad (1)$$

Spectrophotometer is a popular device used for color matching with standard, objective, and accurate measurements which show the colors with numerical expressions.[7] Actually, it is used to determine CIE (Commission Internationale de l'Eclairage) L*a*b* color coordinates by spectral reflectance measurements. L*, a*, and b* are, respectively, representatives of lightness, greenness-redness, and yellowness-blueness.[18]

When there is no color difference (ΔE = 0), the masking ability of the system is perfect. The visually acceptable color difference, for dental applications, is when ΔE ≤3.3.[9]

Masking ability of IPS e.max press (including core and veneer) for dark abutment or darkness of the oral cavity has not been established previously.

The purpose of this *in vitro* study was to determine the minimum thicknesses of a multilayer all-ceramic restoration (IPS e.max Press) required for masking black background while including a high opaque (HO) core for masking the underlying black background and an A1 shade veneering layer to provide some translucency-simulating tooth enamel.[19] The null hypothesis was that all the ceramic samples would properly mask the black background.

MATERIALS AND METHODS

Fabrication of ceramic specimens

In this experimental *in vitro* study, 36 multilayer ceramic disks of IPS e.max Press ingots were made by heat-press technique (*n* = 6). The baseline thickness was 0.4 mm for core and of 0.4 mm for veneer (Group 1). Other specimens had increased core/veneer thickness of 0.5/0.5 mm (Group 2), 0.6/0.6 mm (Group 3), 0.8/0.7 mm (Group 4), 1.0/0.8 mm (Group 5), and 1.1/0.9 mm (Group 6) according to the manufacturer's instruction. HO shade was selected to fabricate the ceramic core layer according to the manufacturer's recommendation for masking heavily dark abutments. To obtain the desired thicknesses, cores' wax patterns were fabricated by PixCera machine (Perfactory, Gladbeck, Germany). Series containing three wax patterns were invested in an investment ring with a phosphate-bonded investment (Ivoclar Vivadent, Schaan, Liechtenstein) after attachment of a 3 mm-diameter sprue to each of the patterns. The rings were bench set for 60 min and placed into a burn out furnace (Ivoclar Vivadent, Schaan, Liechtenstein) for 120 min. The specimens were then heat pressed in an EP600 furnace (Ivoclar Vivadent, Schaan, Liechtenstein), air-cooled, divested by blasting with 80 μ glass beads at 4 bar pressure, and ultrasonically treated in an acidic cleaning liquid (Invex, Ivoclar Vivadent, Schaan, Liechtenstein).

The thickness of cores was measured using a digital caliper with 0.01 mm resolution (Mitutoyo Digimatic, Kawasaki, Japan) and was adjusted if needed with 350, 600, and 1500 grit silicon carbide paper (Matador Wasserfast, Germany) under running water.

According to the manufacturer's instruction, the so-called "veneer" layer was a combination of a thin layer of IPS e.max Deep Dentin (0.2 mm, A1 shade) and a more translucent layering material on top. Custom-made brass molds with 13 mm internal diameter and 1, 1.2, 1.4, 1.7, 2, and 2.2 mm thicknesses were used to obtain a uniform thickness of samples. These molds were fabricated 0.2 mm thicker than the desired final thicknesses to compensate the veneer layers shrinkage and polishing process. In the next step, the core disks were inserted in the molds, and a thin layer of deep dentin was directly applied first. Then, the more translucent layer (A1 shade of IPS e.max ceram layering material), which was a mixture of 50% translucent and 50% translucent incisal shades, was applied as the last veneering layer using hand vibration and condensation. Excess moisture was removed with a tissue. After firing, the thickness was measured using a digital caliper with 0.01 mm resolution (Mitutoyo Digimatic, Kawasaki, Japan). Whenever needed, they were adjusted to the desired thickness with silicone carbide (350, 600, and 1500 grit) paper as mentioned above, and an auto-glazing process was performed at 730°C. Details of core/veneer thicknesses of study groups are clarified in Table 1.

Later, the disks were immersed in IPS e.max Press Invex liquid for 20 min (<1% hydrofluoric acid) and cleaned with an ultrasonic cleaner (DENTSPLY NeyTech, CA, USA) for 10 min and then cleaned with airborne-particle abrasion using 100 μ Al2O3 powder at 2 bar pressure (BEGO, ZiroDent Dentalhandel GbR., Cologne, Germany). Finally, etching of the disks was done using IPS ceramic etching gel (4.5% hydrofluoric acid) for 20 s. Afterward, all specimens were cleaned in an ultrasonic bath (Ultrasound Vita-Sonic II, Vita Zahnfabrik, Germany) for 5 min and dried.

Fabrication of backgrounds

Two backgrounds; black (B), and OC backgrounds from the selected IPS e.max ceramic were prepared.

For OC background, a 4 mm-thick specimen (core: 2, veneer [0.2 deep dentin and 1.8 opaque layer]: 2) was fabricated. The OC background had the same diameter as the specimens. The spectrophotometer's standard black tile (B) was used as a black background. Finally, inherent CIELAB values were measured using spectrophotometer. The sufficient thickness to mask a dark background was determined by calculating the of specimens between the B and OC backings.

Spectrophotometric analysis

The color measurements were performed using a Gretag Macbeth ColorEye 7000A spectrophotometer (Color Eye 7000 A, Model C6; Gretag Macbeth, New Windsor, NY, USA). This spectrophotometer has two measuring modes; specular component included and specular components excluded. In the present study, the specular excluded configuration was applied to compensate for errors caused by surface glaze. Before each measurement, the spectrophotometer was calibrated using the calibration tile supplied by the manufacturer.

Table 1: Core/veneer thicknesses (mm) of study groups

Groups	Thickness (mm)			
	Core	Veneer		Total
		Deep dentin	More translucent layer	
1	0.4	0.2	0.2	0.8
2	0.5	0.2	0.3	1.0
3	0.6	0.2	0.4	1.2
4	0.8	0.2	0.5	1.5
5	1.0	0.2	0.6	1.8
6	1.1	0.2	0.7	2.0

The ceramic specimens were placed individually on each of the backgrounds (B and OC). A drop of distilled water was placed between the disks when they were combined so that a good optical contact was possible during the spectrophotometric measurement.[20,21] The difference between two backgrounds for each thickness ΔE is determined by measuring CIELAB values by a spectrophotometer (formula 1). CIELAB coordinates provide a numerical description of the color's position in a three-dimensional color space.

"Critical thickness" is the minimum ceramic thickness required for masking the black background, which is determined through the clinically acceptable ΔE range (ΔE ≤ 3.3). It is a cutoff point, which does not need any statistical analysis.

Mean ΔE values in six groups were statistically evaluated by one-way ANOVA and Tukey *post hoc* tests. $P < 0.05$ was considered statistically significant. To make a statistical analysis, SPSS 21 software (SPSS Inc., Chicago, Il, USA) was used.

RESULTS

The mean CIELAB color values and mean ΔE values of specimens placed on both backgrounds are shown in Tables 2 and 3.

ΔE of Groups 4, 5 and 6 was within the range of the clinically acceptable color difference (ΔE ≤ 3.3) and could mask the black background, so the critical thicknesses for masking the black backing was 1.5 mm. A trend existed in the results as by increasing the thickness, ΔE is decreased.

DISCUSSION

According to the results of our study, the minimum thickness of a multilayer ceramic restoration (IPS e.max Press) sufficient for masking dark background was 1.5 mm. Thus, our null hypothesis that all the specimens with different thicknesses can mask the black background was rejected.

Masking metal post and cores and discolored structures is a challenging situation while placing a ceramic restoration.[11] The result of a study in 2020 shows that low translucent (LT) heat-pressed lithium disilicate ceramic discs with 1, 1.3, and 1.6 mm thickness could not properly cover the metal substrate and thicknesses more than 1.6 mm or ceramics with higher opacity is needed for masking metal.[15]

Using a multilayer ceramic restoration including an opaque core for masking the underlying discoloration or darkness and also a veneering layer to give some

Table 2: Chromatic values of ceramic specimen under different backgrounds (mean±standard deviation)

Groups	Core/veneer thickness (mm)	Background	L	a*	b*
1	0.4/0.4	OC	76.03±0.81	−1.34±0.10	10.23±0.52
		B	72.14±1.27	−1.81±0.85	6.49±0.90
2	0.5/0.5	OC	75.85±0.68	−1.37±0.09	10.27±0.71
		B	72.27±1.18	−1.77±0.12	6.88±0.95
3	0.6/0.6	OC	75.37±0.52	−1.44±0.04	9.84±0.79
		B	72.38±0.65	−1.85±0.03	6.89±0.53
4	0.8/0.7	OC	75.45±0.66	−1.32±0.12	10.50±0.98
		B	73.53±0.85	−1.68±0.10	8.47±1.17
5	1.0/0.8	OC	75.22±0.29	−1.31±0.11	9.14±1.59
		B	74.29±0.30	−1.58±0.13	8.06±1.38
6	1.1/0.9	OC	73.97±0.89	−1.29±0.15	9.94±0.47
		B	72.85±0.76	−1.64±0.16	8.67±0.37

OC: Opaque ceramic background, B: Black background

Table 3: ΔE of ceramic specimen under different backgrounds (mean±standard deviation)

Groups	Core/veneer thickness (mm)	ΔL	Δa	Δb	ΔE
1	0.4/0.4	−3.88±0.58	−0.46±0.07	−3.73±0.55	5.41±0.76
2	0.5/0.5	−3.57±0.64	−0.40±0.05	−3.39±0.62	4.94±0.88
3	0.6/0.6	−2.99±0.44	−0.41±0.05	−2.94±0.40	4.22±0.56
4	0.8/0.7	−1.91±0.80	−0.35±0.03	−2.03±0.36	2.83±0.80
5	1.0/0.8	−0.93±0.27	−0.27±0.04	−1.08±0.27	1.46±0.36
6	1.1/0.9	−1.1±0.34	−0.35±0.07	−1.26±0.42	1.72±0.53

translucency in combination with an opaque luting cement to enhance the masking ability would be so beneficial.[19]

It is reported that using a 1-mm layer of IPS-emax Press lithium disilicate on a translucent zircinia core can improve the masking ability of the restoration in case of covering dark backgrounds.[22] A recent study reported that using a high-opaque lithium disilicate coping with porcelain veneer (core/veneer thickness: 0.8/1 mm) has a statistically similar ΔE value in comparison with zirconia-based structures,[11] while Awad *et al*.[23] and Arif *et al*.[24] declared that lithium disilicate has more translucency than zirconia-reinforced lithium disilicate.

Little changes in thickness and color of resin cement and opaque and translucent layers of ceramic can clearly alter the final shade in a multilayered ceramic restoration.[8,9,25] It has been reported that, if the thickness of the restoration is between 1.0 and 2.0 mm, the color of cement has the least effect on final shade rather than other variables.[8,26,27]

While we did not investigate the impact of luting cement on masking ability of ceramic restorations, Pires[14] and Bacchi[11] took into account this important factor in their studies. Laís *et al*. compared the masking ability in different thicknesses of LT and HO types of lithium disilicate placed on composite resin and metal alloy substrates with the translucent shade of variolink II resin cement using spectrophotometry and reported that the color, type, and thickness of ceramic and using a cement have a significant influence on the resultant color. They concluded that the thickness of 1.5 mm HO ceramic is enough to omit the showing of a metal substrate.[14] In the current study, we used opaque core with translucent veneer ceramics that 0.8 mm core with 0.7 mm veneer showed proper masking ability for black background.

In addition, a study in 2020 reported that zirconia and zirconia plus LT lithium disilicate veneers with 1.8 mm thickness can successfully mask the metal-underlying substrate using white opaque resin cement.[7]

Human eye cannot distinguish the ΔE lower than 1.1. and the ΔE ranged from 1.1 to 3.3 can be detected; however, it is clinically accepted, while ΔE more than 3.3 is not.[28-30]

By lots of improvements in mechanical and optical properties and fabrication techniques of ceramics, heat-pressed lithium disilicate-reinforced glass-ceramics (IPS e.max Press) have become very public due to the material's favorable mechanical and esthetic properties. IPS e.max Press has also the ability of bonding to tooth structure. Its fabrication technique (lost wax) is more practical than layering technique and leads to an excellent adaption of the restoration. Lithium disilicate ceramics are considered as reinforced glass ceramics. The glassy phase provides light transmission and ability of bonding to resin cements, and the crystals of lithium disilicate give strength to the material.[4] The resultant chemical composition of this ceramic would make it a suitable material compatible with anterior and posterior zones.[11] There is an optical compatibility between the glassy matrix and the crystalline phase which makes the lithium disilicate-reinforced glass-ceramics high translucent esthetic ceramics. Additionally, in case of treating severe discolored teeth, various opacities and colors of ceramic, provide the opportunity of achieving desired color.[31]

For IPS e.max Press, it is recommended by the manufacture to use the HO1 shade for masking background discoloration and achive A1-shade as the desired color.

To stimulate the clinical situation, the shade we selected for the veneering layer was a mixture of translucent and translucent Incisal (50%–50%). Deep dentin wash firing is recommended by the manufacture for masking the opacity of the HO1 core which was applied before the more translucent veneering layer.

The thickness of most ceramic restorations made by computer-aided design/computer-aided manufacturing (CAD/CAM) can be around 0.4-mm that is a minimally invasive veneer restoration.[32] In the study by Alfouzan *et al*. in 2020, it was claimed that 0.4-mm is the minimal thickness for e.max that could provide good esthetic results on teeth with minimal discoloration.[33]

Lots of improvement are achieved in ceramic restorations such as new zirconia based materials, new resin-based luting cements, novel CAD-CAM technologies which may result in better esthetic outcomes in practice. Therefore, more studies specially well-designed randomized controlled trials are needed to make comprehensive conclusion about choosing the best material and techniques in complicated clinical situations.

CONCLUSION

Within the limitation of our study, the minimum thicknesses of a multilayer ceramic restoration (IPS e.max Press) required for masking dark backgrounds or darkness of the oral cavity was 1.5 mm (core/veneer: 0.8/0.7).

Acknowledgment

The authors thank Kerman University of Medical Sciences for financial support and Dr. Raad for statistical analysis.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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