

# Effect of Ceramic and Composite Thickness on Masking of Discoloration

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**Objectives** Color of ceramic veneers is affected by the thickness and translucency of ceramics as well as the color of the underlying tooth structure. This study aimed to assess the effect of ceramic and composite systems with two different thicknesses on masking of a substrate with C4 color shade.

**Methods** In this in vitro, experimental study, 90 discs measuring 8 mm in diameter and 0.8 mm and 1.2 mm in thickness were fabricated from IPS e.max Press ceramic with high (HO) and low (LT) translucency, and IPS Empress Direct composite with A1 enamel and dentin shades. The samples were separately placed over a C4 substrate, and the CIE L\*a\*b\* color parameters and color change ( $\Delta E$ ) were measured for the seven groups using a spectrophotometer. Data were analyzed using one-way ANOVA, Tukey's HSD test, and two-way ANOVA.

**Results** Type of material had no significant effect on  $\Delta E$  ( $P=0.086$ ), and the  $\Delta E$  of ceramic and composite was the same while the mean  $\Delta E$  in 0.8 mm bilayer samples was significantly higher than that of 1.2 mm bilayer samples ( $P=0.002$ ). The interaction effect of type of material and thickness on  $\Delta E$  was not significant ( $P=0.113$ ).

**Conclusion** The masking ability is not influenced by the type of material, but thickness of material and degree of translucency affect it. None of the tested materials could completely mask the underlying color, and selection of a material for this purpose should be based on clinical conditions.

**Keywords** Ceramics; Composite Resins; Tooth Discoloration

## Introduction

The appearance of dentition is of concern to a large number of people seeking dental treatment, and the color of teeth and restorations is of particular cosmetic importance. There has been a recent increase in interest in correction of tooth staining and discoloration.<sup>1</sup> A beautiful smile plays an important role in facial esthetics. Individuals with mal-shaped or discolored teeth often try not to smile. Discoloration of the anterior teeth can negatively impact on smile esthetics, and is among the main reasons behind many dental visits.<sup>2</sup>

The treatment of tooth discoloration varies depending on its intrinsic or extrinsic etiology. Precise assessment of the cause of tooth discoloration is essential for more accurate diagnosis and more efficient treatment planning. Extrinsic discolorations are superficial and can be removed by routine prophylaxis. Intrinsic discolorations, however, can only be corrected by tooth bleaching techniques.<sup>3,4</sup>

Demand for whiter teeth is increasing. The available options for this purpose include removal of superficial stains, bleaching, micro-abrasion, macro-abrasion, and veneering and porcelain crowns. Considering the fact that a large number of patients do not consent to reduction of their sound tooth structure as part of tooth preparation for a crown, many dental clinicians opt for more conservative approaches such as dental veneering in order to preserve the tooth structure as much as possible. Porcelain crowns are often preferred for severely discolored teeth.<sup>5-8</sup>

To minimize the background color effect, a layering technique is applied by generally using opaque shade

composite resin as a baking material. In this case, the material translucency and color are considered as important factors.<sup>9</sup> Composite resin thickness is one of the factors affecting translucency.<sup>10</sup>

IPS e.max Press is a 70% lithium disilicate glass ceramic fabricated with the Press technology. Silicon dioxide is its main component. It also contains lithium oxide, potassium oxide, magnesium oxide, zinc oxide, aluminum trioxide and some other oxides. Its fabrication process yields completely homogenous ingots with different degrees of translucency, colors and shades. According to the manufacturer, thin veneers with 0.3 mm thickness can be fabricated from these ingots.<sup>11</sup>

IPS Empress Direct is a composite resin, which ideally mimics the appearance of natural teeth. It contains coarse barium glass fillers measuring 0.7  $\mu\text{m}$  in size, fine barium glass particles measuring 0.4  $\mu\text{m}$  in size, prepolymers measuring 1-10  $\mu\text{m}$  in size, 150 nm spherical mixed oxides and 100 nm ytterbium trifluoride as fillers. It has enamel, dentin and translucent shades and has optimal strength and surface properties.<sup>11</sup>

Considering the existing controversy and limitations of previous studies, this study aimed to answer the question whether IPS e.max Press ceramic and IPS Empress composite in 0.8 mm and 1.2 mm thicknesses can mask a discolored substrate. The null hypothesis was that changing the thickness of IPS e.max Press ceramic and IPS Empress composite would have no significant effect on masking of a discolored substrate.

## Methods and Materials

In this *in vitro*, experimental study, bilayer disc-shaped samples were fabricated from IPS e.max Press ceramic (Ivoclar Vivadent AG, Schaan, Liechtenstein) with 0.8 mm and 1.2 mm thicknesses in high (HO) and low (LT) translucencies in the following combinations: 0.4 LT+0.8 HO, 0.6 LT+0.6 HO, and 0.4 LT+0.4 HO. Disc-shaped samples were also fabricated of IPS Empress Direct composite with 0.8 mm and 1.2 mm thicknesses in enamel and dentin translucencies as single layer 1.2 mm and 0.8 mm dentin and bilayer samples including 0.4 enamel+0.8 dentin and 0.4 enamel+0.4 dentin all from A1 shade. The overall color change ( $\Delta E$ ) was measured against a substrate with C4 color shade ( $L^*=54.9$ ;  $a^*=2.9$ ;  $b^*=25.7$ ), which is the darkest shade of Vita classical shade guide, and is used to simulate severe discoloration.<sup>9</sup> The color parameters were then compared with A1 shade. Ten samples were fabricated for each group (a total of 90, Table 1). The sample size was calculated according to a pilot study.

**Table 1-** Study groups (n=10)

Material	Manufacturer	Translucency	Thickness (mm)
Ceramic	Ivoclar Vivadent AG (Schaan, Lichtenstein)	HO	0.4
			0.6
			0.8
		LT	0.4
			0.6
			0.8
Composite	Ivoclar Vivadent AG (Schaan, Lichtenstein)	Enamel	0.4
			0.8
		Dentin	0.4
			0.8
			1.2
			1.2

Disc-shaped samples were fabricated from the A1 shade of the two systems with 8 mm diameter and the aforementioned thicknesses. In the e.max group, HO and LT translucencies were used. Samples were fabricated as bilayer with 0.8 and 1.2 mm thicknesses.

To fabricate the dark substrate, discs with 8 mm diameter and 2 mm thickness were fabricated from the C4 shade of IPS e.max ceramic by the lost wax and heat press technique according to the manufacturer's instructions to simulate the middle third of a tooth with severe discoloration.

First, discs with the desired dimensions were fabricated from inlay pattern resin (Dent Duralay, Aria Teb mfg, Iran). Using acrylic discs, a mold was fabricated using very high density condensation impression material (Speedex Putty; Coltene, Switzerland). Next, wax discs with the desired thickness ( $\pm 0.05$ ) were fabricated in the mold, sprued, and invested according to the manufacturer's instructions. A sprue with 4 mm length and 45° to 60° angle was used. In each ring, 6 to 7 discs were invested such that the distance between each two discs was at least 3 mm. For investment, 100 g of the investment powder was mixed with 14 mL of liquid (Cergofit Speed; Ivoclar Vivadent) and 13 mL of distilled water. They were first hand-mixed under vacuum for 60 seconds. The investment material was poured into the ring on a vibrator and allowed 30 seconds to set. They were then placed in a burnout

furnace at 85°C for 45 minutes. The press program was selected for IPS e.max Press. The ring was placed at the center of the heated press furnace (Programat EP 300; Ivoclar Vivadent). After completion of each cycle, the investment ring was removed from the furnace and allowed to cool down to room temperature. The samples were divested and the discs were immersed in IPS e-Invex liquid (Ivoclar Vivadent), which contains <1% hydrofluoric acid and were then rinsed with water.

In Empress Direct composite group, single-layer samples with 0.8 mm and 1.2 mm dentin thicknesses and bilayer samples in enamel and dentin translucencies with 0.8 mm and 1.2 mm thicknesses and core thickness (dentin) of 0.4 mm and 0.8 mm were fabricated. For this purpose, molds with adequate depth were used. The molds were filled with the respective composite. Celluloid tapes were placed beneath and on top of each sample and the composite was compressed between two glass slabs to create a smooth surface. The samples were then light-cured for 40 seconds using a light curing unit (Demetron LC, Kerr, Orange, CA, USA) with a light intensity of 600 mW/cm<sup>2</sup>.

The samples were then polished with 250, 400 and 600-grit abrasive papers under running water. Before glazing, the respective thicknesses were checked with 0.05 mm accuracy using a digital caliper with 0.01 mm accuracy (Mitutoyo, Japan). Ceramic samples were then glazed on only one side. For e.max samples, the paste and liquid of glaze (IPS e.max Ceram) were mixed and applied on one surface of the samples. It was then heated to 403°C and dried for 6 minutes. The temperature was then increased to 770°C at a rate of 60°C/minute. The samples remained in vacuum for 90 minutes. All samples were then rinsed with water and dried. They were then stored in screw-top containers at room temperature until the measurement of color parameters.

The color parameters were measured with a spectrophotometer (Xrite; USA) and il-Share software using the CIE L\*a\*b\* color space (reflectance mode, 360-750 nm wavelength, 10 nm intervals). The aperture size was 4 mm and the observation angle was 10° with 0.45° geometry and D65 light source. Each ceramic sample was placed over a C4 substrate. Eye drop was used as a medium to decrease the effect of air on light reflection. The samples were placed against a standard white background ( $L^*=100$ ) and measurement of color parameters was carried out at the center of each disc. Thus, a total of 10 measurements were made in each group. Before the measurements, the device was calibrated using a white tile. In the CIE L\*a\*b\* system, L\* indicates lightness, a\* indicates redness-greenness and b\* indicates blueness-yellowness. The L\*, a\* and b\* values of different thicknesses and translucencies of ceramic and composite samples were determined using a spectrophotometer. The  $\Delta E$  of the samples when placed over the substrate and their color difference with A1 shade

were calculated using the formula below:

$$\Delta E = [(L_1^* - L_0^*)^2 + (a_1^* - a_0^*)^2 + (b_1^* - b_0^*)^2]^{1/2}$$

Where  $L_0^* a_0^* b_0^*$  indicated the background color or color of shade tabs and  $L_1^* a_1^* b_1^*$  indicated the color of samples over the substrate.

The normal distribution of data was evaluated using the Kolmogorov-Smirnov test. The Levene's test was applied to assess the equality of variances. One-way ANOVA was used to compare the mean  $\Delta E$  of the seven groups. The Tukey's HSD test was used for pairwise comparisons. Two-way ANOVA was applied to assess the effect of type of material and its thickness on  $\Delta E$ .

## Results

The Kolmogorov-Smirnov test revealed that data in the seven groups were normally distributed ( $P > 0.05$ ). Table 2 presents the mean  $\Delta E$  of the seven groups.

The Levene's test confirmed the equality of variances ( $P > 0.05$ ). Comparison of the mean  $\Delta E$  of the groups by one-way ANOVA revealed a significant difference

( $P = 0.012$ ). The 0.4 LT+0.8 HO ceramic and 0.8 dentin composite groups seemed to have lower  $\Delta E$  and better masking ability but since the thicknesses were not the same in the two groups, the effect of material and thickness could not be determined. Table 3 presents the results of pairwise comparisons of the groups by the Tukey's HSD test. As shown, 0.4 LT+0.8 HO and 0.8 dentin groups had higher masking ability than the 0.4 LT+0.4 HO group. Also, 0.4 LT+0.8 HO group had lower  $\Delta E$  than 0.6 LT+0.6 HO and 0.4 dentin+0.4 enamel groups. Moreover, 0.8 dentin group had lower  $\Delta E$  and higher masking ability than 0.6 LT+0.6 HO and 0.4 dentin+0.4 enamel groups.

**Table 2-** Mean  $\Delta E$  of the seven groups

Group	Mean	Standard deviation	Minimum	Maximum
0.4 HO+0.4 LT	5.0710	1.56809	3.59	8.43
0.8 HO+0.4 LT	3.5740	1.05554	2.59	5.65
0.6 HO+0.6 LT	5.0370	1.00263	4.15	7.3
1.2 dentin	4.4660	1.47552	2.14	7
0.8 dentin	3.5800	1.50885	2.15	7.24
0.4 dentin+0.4 enamel	5.1200	0.88243	3.47	6.07
0.8 dentin+0.4 enamel	4.5100	0.81235	3.22	5.48

**Table 3-** Pairwise comparisons of the groups by the Tukey's HSD test

Group I	Group J	Mean difference	P value
0.4 HO+0.4 L	0.8 HO+0.4 LT	1.49700	0.008
	0.6 HO+0.6 LT	0.034	0.951
	1.2 dentin	0.605	0.273
	0.8 dentin	1.49100*	0.008
	0.4 dentin+0.4 enamel	-0.049	0.929
	0.8 dentin+0.4 enamel	0.561	0.309
	0.8 HO+0.4 LT	0.6 HO+0.6 LT	-1.46300*
1.2 dentin		-0.892	0.108
0.8 dentin		-0.006	0.991
0.4 dentin+0.4 enamel		-1.54600*	0.006
0.8 dentin+0.4 enamel		-0.936	0.3
0.6 HO+0.6 LT	1.2 dentin	0.571	0.3
	0.8 dentin	1.45700*	0.01
	0.4 dentin+0.4 enamel	-0.083	0.88
	0.8 dentin+0.4 enamel	0.527	0.339
1.2 dentin	0.8 dentin	0.886	0.11
	0.4 dentin+0.4 enamel	-0.654	0.236
	0.8 dentin+0.4 enamel	-0.044	0.936
0.8 dentin	0.4 dentin+0.4 enamel	-1.5400*	0.006
	0.8 dentin+0.4 enamel	-0.93	0.094
0.4 dentin+0.4 enamel	0.4 dentin+0.4 enamel	1.5400*	0.006

Two-way ANOVA evaluated the effect of type of material (ceramic and composite) and thickness (0.8 mm and 1.2 mm) on  $\Delta E$  and showed that type of material had no significant effect on  $\Delta E$  ( $P = 0.086$ ) but the effect of thickness on  $\Delta E$  was significant such that 0.8 mm bilayer samples had a higher mean  $\Delta E$  than 1.2 mm bilayer samples ( $P = 0.002$ ). The interaction effect of type of material and thickness on  $\Delta E$  was not significant ( $P = 0.113$ ). In other words, in both ceramic and composite samples, the mean  $\Delta E$  of 0.8 mm bilayer group was higher than that of 1.2 mm bilayer group.

## Discussion

This study assessed the effect of ceramic and composite systems with two different thicknesses on masking of a

substrate with C4 color shade. Samples were made of A1 color shade, which is highly popular. Different translucencies were also evaluated to better simulate the clinical setting. IPS e.max Press ceramic and IPSS Empress Direct composite are among the most commonly used ceramic and composite systems and therefore, were selected for evaluation in this study. Use of veneering with a minimum thickness of 0.5 mm is often recommended to preserve the enamel wherever possible.<sup>5</sup> The minimum recommended thickness for a veneer at the middle third of a tooth is averagely 0.8 mm.<sup>12</sup> Thus, 0.8 mm and 1.2 mm thicknesses of ceramic and composite were fabricated in this study. The substrate color (2 mm-thick disc) was C4 in order to simulate the most severe discoloration.<sup>13</sup> Color measurements were made using a spectrophotometer and CIE L\*a\*b\* system, which are commonly used for clinical

measurement of color parameters.<sup>14</sup> Our results showed that type of material had no significant effect on  $\Delta E$  ( $P=0.086$ ) and the  $\Delta E$  of ceramic and composite was the same while the mean  $\Delta E$  in 0.8 mm bilayer samples was significantly higher than that of 1.2 mm bilayer samples ( $P=0.002$ ). The interaction effect of type of material and thickness was not significant ( $P=0.113$ ). The results also showed that the degree of translucency of ceramic significantly affected its masking ability such that by an increase in thickness of HO layer, a significant reduction occurred in  $\Delta E$ , indicative of its optimal masking ability. Zhou et al. evaluated the masking ability of IPS e.max with HO translucency and reported that it had higher masking ability when used in 0.6 mm and 0.8 mm thicknesses (<sup>15</sup>). In line with our study, Shono and Nahedh found that by an increase in thickness of IPS e.max Press, Vita VM7 and NRPA ceramics from 1 to 1.5 mm, the mean  $\Delta E$  decreased and the masking ability of ceramics increased.<sup>16</sup> Hilgert et al. demonstrated that increasing the ceramic veneering thickness from 0.4 mm to 0.7 mm and 1 mm decreased its  $\Delta E$  and improved its masking ability.<sup>17</sup> Vichi et al. showed that by increasing the thickness of IPS Empress Ceramic from 1 to 1.5 mm, its masking ability increased, but further increase to 2 mm had no significant effect on  $\Delta E$ .<sup>18</sup> In contrast to our findings, Ozturk et al. concluded that increasing the thickness (by 1 mm for the core and from 0.5 to 1 mm or 1.5 mm for the veneering) increased the  $\Delta E$  of IPS e.max and DC-Zircon ceramics and decreased their masking ability.<sup>19</sup> Shokry et al. revealed that increasing the thickness of IPS Empress and In-Ceram Spinel ceramics increased their mean  $\Delta E$  and decreased their masking ability.<sup>20</sup>

Our findings showed that increasing the thickness of LT layer of ceramic or enamel layer of composite did not have a significant effect on  $\Delta E$ . Evidence shows that optical properties of the veneering and core materials as well as the thickness of material are among the main factors affecting the masking ability of ceramic systems.<sup>21</sup> Thus, increasing the thickness of a material, which does not contain high levels of opaquer, has no significant effect on its masking ability. The percentage of alumina, aluminum trioxide and lithium disilicate in the composition of ceramics can significantly affect their masking ability and optical properties as well.

In the present study, the  $L^*$  value increased by an increase in thickness (especially the core thickness). Volpato et al. reported an increase in  $L^*$  value following an increase in thickness of IPS Empress samples from 1.5 mm to 2.5 mm. They explained that increasing the thickness increases the reflection of light from the ceramic surface.<sup>22</sup> However, this result also depends on the background substrate and changing the background may alter the results.

Assessment of  $\Delta E$  of composite groups revealed that  $\Delta E$  of 0.8 mm single layer composite samples was lower than that

of other samples; thus, they had better masking ability. In line with our findings, Kim et al. reported that 0.5 mm and 1 mm thicknesses of Z350, Amelogen Universal, Esthet-X, Charmfil and Aelite Universal masked a C4 substrate while 1 to 2 mm thickness was required to mask a black background.<sup>23</sup> In contrast to our findings, Miotti et al. compared the masking ability of 0.5 mm, 1 mm and 1.5 mm thicknesses of IPS Empress Direct, Charisma Diamond and Filtek Z350 XT to mask a severely discolored substrate using the incremental technique and showed that only Z350 CT could mask the background color (irrespective of thickness and translucency).<sup>12</sup> Darabi et al. compared the translucency and masking ability of five composites with different thicknesses against a black background and reported that  $\Delta E$  of 1.5 mm thickness of all samples, except for one type of composite, was within the unperceivable range. No change in translucency was noted when 1.5 mm thickness of these composites was used. Thin samples (<1 mm thickness) could not mask the background.<sup>24</sup> This finding was in contrast to our result. Controversy in the results of studies may be due to different opacities of different composite resins.<sup>25, 26</sup>

Assessment of single layer composite samples with 0.8 mm and 1.2 mm thicknesses revealed that the mean  $\Delta E$  of the group with 0.8 mm thickness was lower than that of 1.2 mm thickness, which indicated higher similarity to A1 shade. The mean  $\Delta E$  of the aforementioned two groups was also compared with the substrate color (C4) and the results showed that the mean  $\Delta E$  of the samples with 1.2 mm thickness was less than that of samples with 0.8 mm thickness. No significant difference was noted between the two thicknesses of composite in terms of  $L^*$  parameter.

Optical properties of esthetic dental materials depend on the function of constituents and fillers present in the composition of composites. Barium glass fillers present in enamel and dentin composite and spherical mixed oxides play a role in optimal surface properties.<sup>11</sup> Since there is no ideal restorative material to perfectly mask the underlying color, in the present study,  $\Delta E$  of the samples against a C4 substrate was compared with the color of shade tabs with a value close to that of A1 Vita (A2, B1, C1, D2). The results showed that  $\Delta E$  in all samples was close to B1. The e.max ceramics with higher core thickness could better simulate B1 compared with other ceramic samples. Empress Direct composite samples with higher thickness of dentin could also better simulate B1, except for 0.8 mm single layer samples, which better simulated B1 than those with 1.2 mm dentin thickness. Moreover, 0.8 mm dentin, 1.2 mm dentin and 0.4 enamel+0.4 dentin composite samples and 0.6 TL+0.6 HO ceramic samples better simulated D2 color shade. In general, by an increase in thickness of HO in ceramic samples and dentin in composite samples, B1 and D2 shades were better simulated.

In the present study, the  $L^*$ ,  $a^*$  and  $b^*$  parameters of

ceramic and composite samples were compared with A1 and C4. The results revealed no significant difference between these values and the corresponding values of Vita shade tab. In contrast, Zhang et al. showed that alumina porcelain samples with A2 shade and 0.6 mm thickness had about 5.02-unit difference with the corresponding Vita shade tab value.<sup>24</sup> Douglas and Przybylska attributed this difference to very high amount of L\* while Lee et al. mentioned the reason to be the difference in translucency of ceramics and shade tabs as well as the properties of the substrate used.<sup>28, 29</sup>

In the present study, the samples were glazed to better simulate the clinical setting. Since the control of glaze on the surface of samples is difficult, it may cause variations in the results. Heffernan et al. discussed that the amount of glaze was not equal on visual examination. Moreover, despite the significant difference in contrast ratio of glazed and unglazed samples,  $\Delta E$  was  $<0.06$ , which was not clinically perceivable.<sup>30</sup>

The masking ability of ceramic veneers is ideal when there is no color change in the black or white background ( $\Delta E=0$ ). In such conditions, veneers have color stability against black and white backgrounds.  $\Delta E < 3.3$  is often considered clinically acceptable.<sup>31, 32</sup> In the present study,  $\Delta E$  of ceramic samples in all comparisons was  $>2.5$  and only a few samples had a  $\Delta E > 5$ . Thus, although IPS e.max Press in the aforementioned thicknesses was relatively successful, it had differences with all shade tabs. The same result was obtained regarding  $\Delta E$  of composite samples.

Considering all the above, although color improvement in

terms of L\*, a\* and b\* color parameters was mathematically significant in our study, some differences still existed visually. Some other factors related to shade tab parameters produced by different manufacturers need to be assessed. According to the guideline of the American Dental Association, a difference around 2  $\Delta E$  units may be present between different shade tabs.<sup>33</sup> In general, it may be concluded that ceramic and composite yielded similar results in terms of color improvement, and increasing the thickness (especially dentin or HO) improved the color while increasing the thickness of LT layer had no effect on color improvement. Thus, the null hypothesis was rejected. Future studies are required to compare the masking ability of ceramics and composites. Also, the effect of aging on the masking ability of restorative materials and resin cements should be evaluated. Use of spectroradiometer may yield more accurate results regarding the color change.

## Conclusion

The masking ability of e.max ceramic and Empress Direct composite is affected by the thickness and degree of translucency. IPS e.max samples with higher core thickness had higher capability in masking the substrate color. Empress Direct composite samples with higher dentin thickness had higher masking ability as well.

## Conflict of Interest

No Conflict of Interest Declared ■

## References

- Vogel RI. Intrinsic and extrinsic discoloration of the dentition. A review. *J Oral Med.* 1975;30(4):99-104.
- Heymann HO, Swift Jr EJ, Ritter AV. *Sturdevant's Art & Science of Operative Dentistry-E-Book*: Elsevier Health Sciences 2018; chap:9;p:274.
- Watts A, Addy M. Tooth discoloration and staining: a review of the literature. *Br Dent J.* 2001;190(6):309-16.
- Summitt JB, Robbins JW, Hilton TJ, Schwartz RS. *Fundamentals of operative dentistry: a contemporary approach*: Quintessence Pub 2014. chap:16; page:4-15
- Pablo J Atria, Isabel Lagos, Camila S Sampaio. In vitro evaluation of surface roughness, color stability, and color masking of provisional restoration materials for veneers and crowns. *Int J Comput Dent.* 2020;23(4):343-50.
- Basegio MM, Pecho OE, Ghinea R, Perez MM, Della Bona A. Masking ability of indirect restorative systems on tooth-colored resin substrates. *Dent Mater.* 2019;35(6):e122-30.
- Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. *J Dent.* 2000;28(3):163-77.
- Korkut B, Yanikoğlu F, Günday M. Direct composite laminate veneers: three case reports. *J Dent Res Dent Clin Dent Prospects.* 2013;7(2):105-11.
- Ikeda T, Sidhu SK, Omata Y, Fujita M, Sano H. color and translucency of opaque-shade and body-shade of resin composite. *Eur J Oral Sci.* 2005;113:170-3.
- Kamishima N, Ikeda T, Seno H. color and translucency of resin composite for layering techniques. *Dent Mater J.* 2005; 24: 428-32.
- Vivadent I. Scientific Documentation IPS d. SIGN Ivoclar Vivadent AG, FL-9494, Schaan, Liechtenstein. 2003
- Miotti L, Santos I, Nicoloso G, Pozzobon R, Susin A, Durand L. The Use of Resin Composite Layering Technique to Mask Discolored Background: A CIELAB/CIEDE2000 Analysis. *Oper Dent.* 2017;42(2):165-74.
- Shadman N, Kandi SG, Ebrahimi SF, Shoul MA. The minimum thickness of a multilayer porcelain restoration required for masking severe tooth discoloration. *Dent Res J(Isfahan).* 2015;12(6):562-8.
- Güler AU, Güler E, Yücel AÇ, Ertaş E. Effects of polishing procedures on color stability of composite resins. *J Appl Oral Sci.* 2009;17(2):108-12.
- Zhou SY, Shao LQ, Wang LL, Yi YF, Deng B, Wen N. Masking Ability of IPS e. max all-ceramics system of HO series. *J Int Soc Prev Community Dent.* 2019;9(6):646-51.
- Shono N, Nahedh HA. Contrast ratio and masking ability of three ceramic veneering materials. *Oper Dent.* 2012;37(4):406-16.
- Hilgert L, Araujo E, Baratieri L, Edelhoff D, Gernet W. Influence of stump shade, ceramic thickness and translucency on the color of veneers. *Dent Mater J.* 2009;25(5):e9.
- Vichi A, Ferrari M, Davidson CL. Influence of ceramic and cement thickness on the masking of various types of opaque posts. *J Prosthet Dent.* 2000;83(4):412-7.
- Ozturk O, Uludag B, Usumez A, Sahin V, Celik G. The effect of ceramic thickness and number of firings on the color of

- two all-ceramic systems. *J Prosthet Dent.* 2008;100(2):99-106.
- 20.Shokry TE, Shen C, Elhosary MM, Elkhodary AM. Effect of core and veneer thicknesses on the color parameters of two all-ceramic systems. *J Prosthet Dent.* 2006; 95(2):124-9.
- 21.Chu FC, Chow TW, Chai J. Contrast ratios and masking ability of three types of ceramic veneers. *J Prosthet Dent.* 2007 Nov;98(5):359-64.
- 22.Volpato CÂM, Monteiro S, de Andrada MC, Fredel MC, Petter CO. Optical influence of the type of illuminant, substrates and thickness of ceramic materials. *Dent Mater.* 2009;25(1):87-93.
- 23.Kim SJ, Son HH, Cho BH, Lee IB, Um CM. Translucency and masking ability of various opaque-shade composite resins. *J Dent.* 2009;37(2):102-7.
- 24.Darabi F, Radafshar G, Tavangar M, Davaloo R, Khosravian A, Mirfarhadi N. Translucency and masking ability of various composite resins at different thicknesses. *J Dent Shiraz Univ Med Sci.* 2014;15(3):117-22.
- 25.Villarreal M, Fahl N, DE SOUSA A, De Oliveira OB. Direct esthetic restorations based on translucency and opacity of composite resins. *J Esthet Restor Dent.* 2011;23(2):73-87.
- 26.Ryan E-A, Tam LE, McComb D. Comparative translucency of esthetic composite resin restorative materials. *J Can Dent Assoc.* 2010;76:a84.
- 27.Zhang F, Heydecke G, Razzoog ME. Double-layer porcelain veneers: effect of layering on resulting veneer color. *J Prosthet Dent.* 2000;84(4):425-31.
- 28.Douglas RD, Przybylska M. Predicting porcelain thickness required for dental shade matches. *J Prosthet Dent.* 1999;82(2):143-9.
- 29.Lee Y-K, Cha H-S, Ahn J-S. Layered color of all-ceramic core and veneer ceramics. *J Prosthet Dent.* 2007;97(5):279-86.
- 30.Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM, Vargas MA. Relative translucency of six all-ceramic systems. Part I: core materials. *J Prosthet Dent.* 2002;88(1):4-9.
- 31.Kim HS, Um CM. Color differences between resin composites and shade guides. *Quintessence Int.* 1996;27(8):559-67.
- 32.Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. *Dent Mater.* 2004;20(6):530-4.
- 33.Affairs ADACoS. Dental shade guides-acceptance program guidelines. Chicago: American Dental Association 2001: p:4

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