Original Articles

Effect of Variations in Translucency of CAD/CAM Lithium-disilicate Ceramic and Abutment Color on Optical Color of Veneer Restoration

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Abstract

This study aimed to evaluate color differences of different translucencies of CAD/CAM lithium-disilicate ceramics on backgrounds with different values. Low translucency (LT) and medium translucency (MT) rectangular-shaped specimens (0.6 mm thickness, shade A1) were fabricated from IPS e.max CAD (EMC; Ivoclar Vivadent) and Amber Mill (AM; HASS). Six specimens of EMC-MT, EMC-LT, AM-MT, and AM-LT were fabricated, resulting in 24 specimens in total. The specimens were placed on six background colors (1M1(reference), 1M2, 2M2, 3M2, 4M2, and 5M2) made of light-cured resin composite (Vita VM LC Base Dentine, Vita Zahnfabrik) using glycerine as a medium. The CIE L*a*b* coordinates were evaluated using a spectrophotometer (Ultrascan PRO, Hunter Lab) and calculated using the CIEDE2000 formula to determine the color difference (ΔE_{00}) and translucency parameter (TP_{00}) of the materials. Mean ΔE_{00} values were statistically analyzed using a two-way analysis of variance (ANOVA) and Bonferroni post-hoc tests (α=0.05), then qualitatively analyzed to consider the perceptibility threshold (PT) and acceptability threshold (AT). Mean TP_{00} values were analyzed by an independent *t*-test (α=0.05). The results revealed that the ΔE_{00} values significantly increased as darker backgrounds were used. The significantly higher ΔE_{00} values of MT compared to LT were presented when EMC specimens were placed on 2M2, 3M2, 4M2, and 5M2 backgrounds. The ΔE_{00} values below AT were found in the specimens placed on the 1M2 background. The TP_{00} values showed that MT had a statistically significant higher value compared to LT in both EMC and AM, and values from AM were higher than EMC. In conclusion, the masking ability of specimens was lower when placed on darker backgrounds. For the 2M2 darker background, IPS e.max CAD in low translucency showed better masking ability than medium translucency. Amber Mill showed more translucency and poorer masking properties than IPS e.max CAD.

Keywords: CAD/CAM block, Ceramic translucency, Ceramic veneers, Color difference, Lithium disilicate ceramic

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Introduction

Ceramic laminate veneer restorations exhibited good clinical long-term success.[1-3] One of the materials used for fabricating ceramic veneers is lithium disilicate. This material has good physical properties and optical characteristics that mimic a natural tooth. Its excellent biomechanical properties allow the thickness of restorations to be minimal in the anterior areas, resulting in the conservation of dental tissues.[4, 5] Studies have shown that restorations fabricated with a lithium disilicate material exhibited very high survival and success rates.[6, 7] Nowadays, computer-assisted design/computer-assisted manufacturing (CAD/CAM) technology has shown to improve clinical predictability with quick and reliable results.[8]

CAD/CAM lithium disilicate ceramic blocks, such as IPS e.max CAD (Ivoclar Vivadent, Liechtenstein) and Amber Mill (HASS, Korea), are the materials that combine both benefits from lithium disilicate and CAD/CAM technology and have been well used in several regions of the world. These materials are available in various translucencies. The translucency levels recommended to fabricate monolithic restoration for veneer were high, medium, and low.[9, 10] Different translucency levels of the lithium disilicate materials might result differently in the final color of the restoration when being restored on abutments with the same color.[11-13] Some challenges for fabricating ceramic veneers are matching the optical color of adjacent natural teeth and creating a life-like restoration. Many factors may influence the optical color of the restorations, such as ceramic translucency, ceramic thickness, abutment color, cement color, and cement thickness.[11-16]

Many studies compared low and high translucency lithium disilicate used for veneers, and it was shown that high translucency lithium disilicate was unsuitable for masking dark color backgrounds. This translucency was more suitable in situations where a small amount of color change from the background was preferred.[11, 13, 17, 18] However, there are limited studies on medium translucency lithium disilicate in shade reproduction or masking ability compared to low translucency lithium disilicate.

Many previous studies have shown that the optical properties of these materials are complex.[11-13] Precisely specified color-matching standards for the ceramic laminate veneers still have not been established. Former studies showed that the traditional color reproduction protocol was unsuitable for all ceramic veneers.[17, 18] There is limited information regarding various translucencies of CAD/CAM lithium disilicate materials on different values of background shades.[19] A previous study has shown that the value of the underlying background probably had a stronger effect than chroma on the final color of restorations.[11] However, in most of the previous studies, background abutments were fabricated from resin materials with shade corresponding to the Vita classic shade guide, therefore, lacking proper order in value.[11, 12]

Therefore, the purpose of this study was to evaluate color differences of veneer restorations when using different translucencies of CAD/CAM lithium disilicate ceramics on backgrounds with different values. The null hypothesis was that the translucency of CAD/CAM ceramic materials and the value of the background would not affect the optical color of veneer restorations, while translucency values would not be different among the medium and low translucent materials.

Materials and Methods

Medium translucency (MT) and low translucency (LT) rectangular-shaped specimens, 0.6 mm thickness, were fabricated from IPS e.max CAD (EMC; Ivoclar Vivadent, Liechtenstein) and Amber Mill (AM; HASS, Korea) size C14, shade A1. Four groups of ceramic specimens were EMC-MT, EMC-LT, AM-MT, and AM-LT, consisting of six specimens in each group, therefore there were 24 specimens in total. The specimens were fabricated by sectioning the ceramic blocks with a water-cooled precision diamond saw (Isomet low-speed saw, Buehler, USA), and polished using a polishing machine (Minitech 233, Presi, France) at 100 rpm for 30 sec under water cooling with 600- and 800-grit SiC paper on both sides. The outer surface of the ceramic specimens was finely polished with a 1200-grit SiC paper. A thickness of 0.6 (±0.05) mm was verified using a digital micrometer (IP-65 Digimatic Micrometer; Mitutoyo, Japan). Crystallization and glaze firing of the specimens were performed simultaneously in a furnace (Programat P700, Ivoclar Vivadent, Liechtenstein), according to the manufacturer's instructions. To simulate the natural variations in the appearance of dentin and to comply with the Vita 3D-Master color organization system (Vita Zahnfabrik, Germany), a light-curing composite material for extraoral application (Vita VM LC Base Dentine, Vita Zahnfabrik, Germany) in shades 1M1, 1M2, 2M2, 3M2, 4M2, and 5M2 was used to fabricate background specimens. The 4 mm thick, rectangular-shaped backgrounds were fabricated using a mold, and polymerized by a light curing unit (Solidilite V, Shofu Dental, USA) according to the manufacturer's instructions. The 1M1 shade was used as a reference background (Fig. 1).

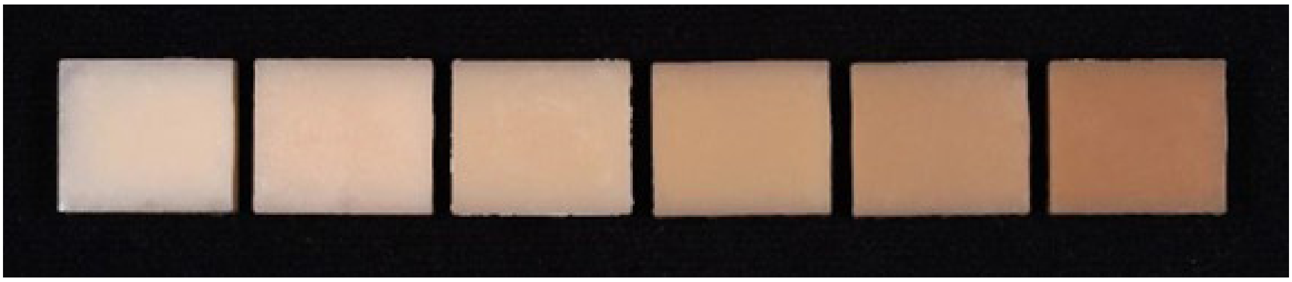

Figure 1 *Different background colors from left to right: 1M1 (reference), 1M2, 2M2, 3M2, 4M2, and 5M2*

All-ceramic specimens were placed on all six different color backgrounds using glycerine as a medium to exclude the effect of cement color and to minimize light scattering between the specimens and the backgrounds (Fig. 2).[20, 21] The color expressed in CIE L*a*b* coordinates was recorded at the center of the specimen using a spectrophotometer (Ultrascan PRO, Hunter Lab, USA) with a 7 mm diameter port on a standard white background under CIE standard illuminant D65, which represented typical daylight. Color coordinates of materials placed on a 1M1 background, a reference, and color coordinates of the materials on other backgrounds were calculated in the CIEDE2000 formula to determine the color difference (ΔE_{00}) values. CIELAB is classically the standard parameter for total color difference between two objects. However, CIEDE2000 (ΔE_{00}) formula was used in this study since it was formulated to improve the correction between perceived and computed color differences. CIEDE2000 is also the most recent international standard recommended by the CIE.[22] In addition, translucency parameter (TP_{00}) values of the lithium disilicate specimens were also calculated from the CIEDE2000 color difference metric by measuring the L*a*b* coordinate differences between the materials positioned over black and white backgrounds. Greater TP_{00} values meant higher translucency of the materials.

Figure 2 *Ceramic specimen over shaded resin composite background*

The ΔE_{00} data was collected and analyzed using the statistical software SPSS version 29 (SPSS, Chicago, IL, USA). Normal distribution was determined by the Shapiro-Wilk test. The homogeneity of variance was tested using Levene's test. Two-way repeated ANOVA and Bonferroni post-hoc multiple comparison tests were used to identify the effect of translucency, abutment color, and their interactions on the mean ΔE_{00} data and to detect significant differences in the mean ΔE_{00} values among the groups.

The P value < 0.05 was considered a statistically significant difference. Additionally, ΔE_{00} data were qualitatively analyzed considering the perceptibility threshold (PT) and acceptability threshold (AT). The PT and AT were set at 0.8 and 1.8, respectively. If the ΔE_{00} value was at or below PT, it represented an excellent match; if the difference was between PT and AT, it represented an acceptable match; and if the difference was above AT, it represented an unacceptable match.[23] The difference in translucency parameter (TP_{00}) values between MT and LT specimens was evaluated and analyzed by an independent *t*-test (α=0.05).

Results

The Shapiro-Wilk test indicated that the data were normally distributed. The mean and standard deviation of the color difference (ΔE_{00}) values of each tested group are shown in Tables 2 and 3. The lowest mean ΔE_{00} value was obtained from EMC-LT placed on a 1M2 background, and the highest mean ΔE_{00} value was demonstrated from AM-MT placed on a 5M2 background. Two-way ANOVA revealed that the color of backgrounds, levels of translucency, and their interactions had statistically significant influences on ΔE_{00} values (P<0.001) of EMC groups (Table 1). On the other hand, for AM groups, only the color of backgrounds had a statistically significant influence on ΔE_{00} values (P<0.001). The translucency and their interaction did not significantly influence ΔE_{00} values (P=0.875 and 0.805, respectively) (Table 1).

According to Bonferroni post-hoc multiple comparison tests, when the background color was 1M2, the ΔE_{00} values between the reference background color 1M1 and the tested background color 1M2 of EMC-LT did not have a statistically significant difference from EMC-MT (P=0.062) (Table 2). For other tested background colors, EMC-LT had a statistically significant lower mean ΔE_{00} value than EMC-MT (Table 2). On the other hand, AM-MT and AM-LT did not have statistically significantly different ΔE_{00} values on any tested background colors (Table 3). Statistically, ΔE_{00} values significantly increased as darker backgrounds were used for both translucencies of EMC and AM (Tables 2 and 3). None of the test groups could provide ΔE_{00} values below PT. The ΔE_{00} values below AT were found in all groups of specimens placed on the 1M2 background color, while specimens placed on other background colors had ΔE_{00} values higher than AT (Fig. 3). The comparison of mean TP_{00} values showed that MT had statistically significantly higher mean TP_{00} values than LT in both EMC and AM groups. The TP_{00} values from AM groups seemed much more elevated than EMC groups (Table 4).

Table 1 *Two-way repeated ANOVA, showing results of the effect of backgrounds (A), translucency (B), and their interactions (A x B) on the mean* ΔE_{00} *values of IPS e.max CAD (EMC) and Amber Mill (AM)*

Source	Sum of Squares	df	Mean Square	F	*P* Value
EMC					
Backgrounds (A)	49.152	4	12.288	1319.433	< 0.001
Translucency (B)	1.389	1	1.389	110.703	< 0.001
A x B	0.488	4	0.122	13.106	< 0.001
AM					
Backgrounds (A)	94.208	4	23.552	3902.473	< 0.001
Translucency (B)	0.041	1	0.041	0.025	0.875
A x B	0.010	4	0.002	0.403	0.805

Table 2 *Mean and standard deviation of* ΔE_{00} *value between EMC specimens placed on 1M1 background (reference) and those placed on 1M2, 2M2, 3M2, 4M2, and 5M2 backgrounds*

Background color	Translucency		*P* Value
	EMC-MT	EMC-LT	
1M2	1.61 (0.13) [a]	1.43 (0.16) [a]	0.062
2M2	2.19 (0.06) [b]	1.99 (0.10) [b]	0.002
3M2	2.64 (0.07) [c]	2.39 (0.11) [c]	< 0.001
4M2	3.11 (0.04) [d]	2.88 (0.09) [d]	< 0.001
5M2	4.52 (0.10) [e]	3.86 (0.07) [e]	< 0.001

Different superscript lowercase letters within columns represent significant differences (P<0.05) between background colors.

EMC, IPS e.max CAD; MT, medium translucency; LT, low translucency.

Table 3 *Mean and standard deviation of* ΔE_{00} *value between AM specimens placed on 1M1 background (reference) and those placed on 1M2, 2M2, 3M2, 4M2, and 5M2 backgrounds*

Background color	Translucency		*P* Value
	AM-MT	AM-LT	
1M2	1.80 (0.08) [a]	1.73 (0.10) [a]	0.251
2M2	2.65 (0.05) [b]	2.64 (0.03) [b]	0.844
3M2	3.04 (0.09) [c]	2.96 (0.05) [c]	0.073
4M2	3.73 (0.05) [d]	3.68 (0.04) [d]	0.073
5M2	5.52 (0.15) [e]	5.47 (0.05) [e]	0.410

Different superscript lowercase letters within columns represent significant differences (P<0.05) between background colors.

AM, Amber Mill; MT, medium translucency; LT, low translucency.

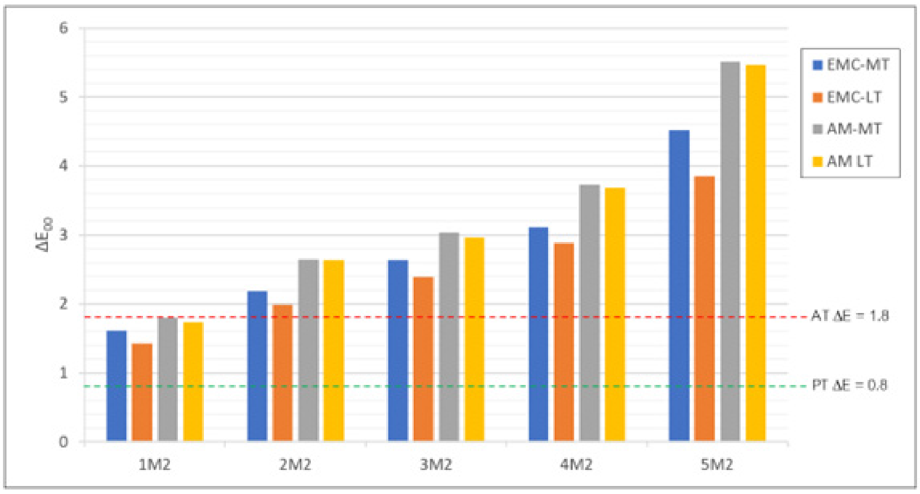

Figure 3 *Graph showing the mean color differences* (ΔE_{00}) *between the reference background color 1M1 and background colors 1M2, 2M2, 3M2, 4M2, and 5M2 of IPS e.max CAD (EMC) and Amber Mill (AM) with medium translucency (MT) and low translucency (LT). The green and red lines indicate the levels of the perceptibility threshold (PT) and acceptability threshold (AT), respectively*

Table 4 *Mean and standard deviation of TP00 value from medium translucency (MT) and low translucency (LT) specimens of both IPS e.max CAD (EMC) and Amber Mill (AM)*

Brand	Translucency		*P* Value
	MT	LT	
EMC	9.00 (0.15)	8.31 (0.08)	< 0.001
AM	19.56 (0.40)	17.98 (0.36)	< 0.001

Discussion

The present study showed that both translucency and background color affected the optical color of veneer restorations for EMC, but AM was only influenced by the background and not by translucency. The MT specimens showed higher TP_{00} values than LT specimens in both EMC and AM. Thus, the null hypothesis was partially rejected. For the color of the background, the results showed an increase in color differences as the background color became darker for both translucencies of EMC and AM. The results agreed with the findings of other studies that changing the abutment tooth color from lighter to darker caused an increase in color difference.[14, 24-26] In this study, when the color of the background was 1M2, all the groups of lithium disilicate specimens in shade A1 with 0.6 mm thickness could mask the 1M2 background color (ΔE_{00} value below AT) (Fig. 3), and both translucencies of the materials showed no significant different ΔE_{00} value from each other (Tables 2 and 3). Therefore, in clinical situations, when a patient has a light color abutment, both MT and LT materials may be chosen to fabricate veneer. However, when the background colors were changed to 2M2, 3M2, 4M2, and 5M2, ΔE_{00} values of all specimen groups were higher than AT, showing the lack of masking ability. Even though the specimens could not mask these backgrounds, for EMC, the LT group showed a significantly lower ΔE_{00} value than the MT group (Table 2). This might imply that when the background color was in shade 2M2 or darker, the LT materials could be used to achieve better masking properties, and possibly giving a more acceptable color match. The result conformed to the TP_{00} values that EMC-LT had significantly lower values than EMC-MT (Table 4), which could mean that EMC-LT was more opaque than EMC-MT and might be the reason why EMC-LT provided a better masking ability compared to EMC-MT. This was similar to previous studies which reported that LT lithium disilicate materials had a lower TP value when compared with other translucencies that were intended for monolithic veneer restorations.[27-29] Other studies also reported that LT materials appeared more opaque than other tested materials and had better masking properties.[11, 26]

On the other hand, for AM groups, AM-MT and AM-LT were not significantly different in the ΔE_{00} values from each other on any tested background color (Table 3). This could mean that AM-LT did not have a superior masking ability than AM-MT, even though the TP_{00} value of AM-LT was also significantly lower than AM-MT. This might be explained by the material's translucency, in which the TP_{00} value of AM showed a much higher value than that of EMC (Table 4). Thus, AM specimens were more translucent, which caused the compromised masking effect of its LT specimens. Conforming to the previous studies, thin veneer was not suitable for dark color backgrounds.[11,25] Other studies that included thicker ceramic also found that thicker ceramic was more opaque and provided better background coverage than thinner ceramic.[20,24,30,31] However, increasing ceramic thickness may not be suitable in some clinical situations, especially for veneers. Other previous studies found that luting cement may help improve the masking ability and make an acceptable shade reproduction.[14,24,32] The results from Igiel *et al.* demonstrated that using a high-value resin cement could help veneer specimens to mask background colors up to shade 3M2.[24]

There were some limitations of the present *in vitro* study. This study only used one shade of lithium disilicate ceramic (shade A1) and did not involve the effect of cement color; therefore, the results may not be relevant to other ceramic colors and colored luting cement. Additionally, one ceramic thickness was studied, and thicker or thinner ceramic may show a different effect on the final optical properties of the restorations. Moreover, this study used resin composite to fabricate the background specimens that might have different optical properties compared to natural teeth. Therefore, further studies are suggested using other shades and thicknesses of ceramic specimens along with the effect of luting cement on natural tooth abutments.

Conclusion

Within the limitation of this study, background colors had influences on optical color of veneer restorations. When the background color was 1M2, a considerably light background color, both medium translucency and low translucency of CAD/CAM lithium disilicate glass-ceramics (IPS e.max CAD and Amber Mill) performed acceptable masking properties. For the background color 2M2 and darker, low translucency IPS e.max CAD showed better masking ability than medium translucency IPS e.max CAD. Amber Mill showed much more translucency and poorer masking properties than IPS e.max CAD.

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