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Investigation of Color Change of Different Restoration Thickness, Background Color and Resin Cement Shade on CAD/CAM Glass Ceramic Materials

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Abstract

The aim of this study is to investigate the color change of different restoration thicknesses, backgrounds and resin cement colors on lithium disilicate and zirconium reinforced lithium silicate materials *in vitro*. In this study, IPS emax CAD (LT C14) and Celtra Duo (LT C14) are used as full ceramic materials, and Variolink Esthetic LC (warm, neutral) used as resin cement and Tokuyama Estelite Sigma Quick (A3, A2) is used as composite materials. A total of 160 samples in the form of 40 pieces of 5 × 5 0.4 mm thick 40 pieces of 5 × 5 0.6 mm thick square discs from each of the all-ceramic materials in block form were obtained using a water jet device (DWJ1525-FA; Dardi International Corporation, Nanjing, China). Glass ceramic samples produced in 2 different thicknesses were cemented on 2 different backgrounds with 2 different resin types of cement. Color measurements of the samples before and after cementation were performed on a grey background with spectrophotometer Vita EasyShade V (Vita Zahnfabrik, Bad Sackingen, Germany) and color parameters (L*, a*, b*, ΔE) were calculated according to the CIE Lab (Commission Internationale de L'Eclairage) system. Average values for each group (ΔE) were not affected by ceramic type, material thickness, background color, resin cement color, and the interaction of these four variables ($p > 0.05$). When the triple interactions between the groups were examined, there were no statistically significant differences ($p > 0.05$). In the evaluation of pairwise interactions between two groups (material type-material thickness, material type-background color, and thickness of material-background interactions) statistically significant differences ($p < 0.05$) were seen. **Clinical Implications:** The material type, thickness, background and cement color used did not cause any statistically significant color change in lithium disilicate and zirconium-reinforced lithium silicate glass ceramic materials ($p > 0.05$).

Keywords

CAD/CAM, Color, Laminate Veneer, Resin Cement

1. Introduction

The development of dental materials and new technologies has increased the popularity of aesthetic dentistry and the provision of anterior group aesthetics in the treatments has become important for both the patient and the physician. [1] [2]

In modern dentistry, it is important to ensure color harmony between the natural tooth and the restoration.3 In order for the restoration to resemble the natural tooth appearance, tooth form, color and surface properties must be carefully controlled. [3] [4] [5] Among the restorative materials, all ceramics are materials that can best reflect the natural tooth appearance since their optical properties are very similar to dental tissues. [6] [7] [8] All-ceramic restorations, on the other hand, are frequently used in prosthetic dentistry due to their aesthetic properties, high resistance to discoloration and biocompatibility. [9]

The final color of ceramic restorations depends on the luting cement and the color of the background tooth as well as factors related to the ceramic material. [3] [4] [9] [10] [11] [12] Luting cement, these are the materials that provide the connection between the tooth to be restored and the restoration and are used when the resultant color of the restoration is desired to be changed. [3] [13] [14] Endodontically treated teeth are seen to change color, especially in the cervical area. When considering a full ceramic crown, the crown and color of the ceramic material or changing the color of the cement should be considered in order to eliminate these stains. [6] [13] [15] [16]

Ceramics are translucent and offer aesthetic properties close to natural tooth appearance, and they are also affected by the color of the tooth and cement forming the background. [4] [6] [11] [14] [16]

Two hypotheses have been established regarding this issue. The first hypothesis suggests the color change of 0.4 mm thick lamina restorations cemented using different colored backgrounds and resin cements will differ from 0.6 mm thick lamina restorations; while the second hypothesis suggests that the zirconium-reinforced lithium silicate glass ceramics will show lower ΔE values than lithium disilicate glass ceramics.

2. Material and Methods

This study, IPS e.max CAD (Ivoclar, Vivadent, Schaan, Liechtenstein) and Celtra Duo (Sirona Dentsply, Milford, DE, USA) glass ceramic blocks were preferred. A total of 160 samples, 80 from each ceramic group, were used. The blocks selected with a thickness of 14 mm, A1 color and low translucency (LT) were prepared in such a way that they were 0.4 mm and 0.6 mm thickness.

5 × 5 mm in size, 0.4 and 0.6 mm thickness with smooth surface LDS (IPS e.g. max CAD; Ivoclar Vivadent, Schaan Liechtenstein) and ZLS (Celtra Duo; Sirona Dentsply, Milford, DE, USA) samples were crystallized in a porcelain furnace according to the manufacturer's recommendations (Program P-310; Ivoclar Live, Schaan, Liechtenstein). A metal mold was prepared for the preparation of the substructure samples, which will represent the prepared teeth, with dimensions of 5 × 5 mm and a thickness of 2 mm. Composite materials of two different (A3, A2) colors (Estelite Sigma Quick, Tokuyama Dental, Tokyo, Japan) were used to create the substructures. A total of 160 smooth substructure samples with 5 × 5 mm dimensions and 2 mm thickness were prepared for the substructure samples representing the prepare female, with 80 pieces in each group of two different colors.

A total of 160 glass ceramic samples were applied to two different colored substructure samples with two different colors (neutral, light) adhesive resin cement (Variolink Esthetic LC, Ivoclar Vivadent, Schaan, Liechtenstein) using the light polymerization device Valo Grand (Ultradent Products, South Jordan, UT) was polymerized for 10 s in standard mode (1000 mW/cm^2) according to the manufacturer's instructions. After the polymerization of the adhesive resin cement had been completed, all specimens were removed from the molds.

Color measurements of all samples cemented on substructures were performed on a gray background [17] [18] with reference to previous studies using the VITA EasyShade V (Vita Zahnfabrik, Bad Sackingen, Germany) color device. Before the color measurement of each sample, the spectrophotometer was calibrated. The color of each sample was measured three times with a spectrophotometer, and the L*a*b* values in each measurement were recorded. In order to calculate the ΔE value, the average L*a*b* values of these three recorded measurements were taken.

Patients usually prefer light colors such as A1, B1 when having laminate restorations. For this reason, the L*a*b* values of the A1 color were used as a reference in this study. For this purpose, the L*a*b* values were measured with a spectrophotometer by selecting the A1 color from the Vitapan Classical (Vita Zahnfabrik, Bad Sackingen, Germany) color scale in accordance with the manufacturer's recommendations, and these L*a*b* values were used as reference values to calculate ΔE. ΔE is calculated to numerically express the harmony of the two colors to be compared. The degree of color change is expressed by ΔE. The following formula is used to calculate the color change: ΔE = [(ΔL) 2 + (Δa) 2 + (Δb) 2] 1/2. The values ΔL, Δa and Δb in this formula indicate the differences between the CIE L*a*b* color parameters of the two samples. Dec. ΔE was calculated using the L*a*b values measured and averaged after cementation and the L*a*b values of the A1 color taken as a reference [19].

The data are collected by IBM SPSS Statistics V. 23 (IBM, Armonk, NY, USA) were analyzed with the package program. The Kolmogorov-Smirnov test was used to check whether the data showed normal distribution or not. Whether the ΔE values differ according to the material, thickness, background and cement were examined by Analysis of Variance (ANOVA) in a 2 × 2 × 2 × 2 × 2 factorial layout. Tamhane's T2 test, one of the multiple comparison tests, was used to determine the average differences of the factors that were significant as a result of the Variance Analysis. The significance level was determined as $p < 0.05$.

3. Results

According to the analysis of variance; mean values (ΔE) for each group are not affected by ceramic type, material thickness, background color, resin cement and interaction of these four variables ($p > 0.05$). When the triple interactions between the groups were examined, it was seen that there was no statistically significant difference ($p > 0.05$).

In the evaluation of the bilateral interactions between the groups, it was seen that material type-resin cement, material thickness-resin cement, and background color-resin cement interactions did not show any statistically significant difference ($p > 0.05$). Material type-material thickness, material type-background color, and material thickness-background interactions showed statistically significant differences ($p < 0.05$) (**Table 1**).

Table 1. Comparison of ΔE values according to material, thickness, background and cement.

	sd	Mean of Squares	F	Significance (p)
Material	1	59.811	34.925	**<0.001**
Thickness	1	20.859	12.180	**<0.001**
Background	1	67.511	39.421	**<0.001**
Cement	1	4.060	2.370	0.126
Material * Thickness	1	35.118	20.506	**<0.001**
Material * Background	1	119.754	69.926	**<0.001**
Cement * Cement	1	0.242	0.141	0.708
Thickness * Background	1	56.149	32.786	**<0.001**
Thickness * Cement	1	0.049	0.029	0.866
Background * Cement	1	0.185	0.108	0.743
Material * Thickness * Background	1	1.931	1.127	0.290
Material * Thickness * Cement	1	2.418	1.412	0.237
Material * Background * Cement	1	0.320	0.187	0.666
Material * Background * Cement	1	0.221	0.129	0.720
Material * Thickness * Background * Cement	1	2.194	1.281	0.260

According to Tamhane's T2 multiple comparison test results for bilateral interactions, the main effects of the materials on the mean ΔE values were found to be statistically significant ($p < 0.001$). While the mean value was 2.73 ± 1.32 in Celtra Duo (Sirona Dentsply, Milford, DE, USA) material, the mean value was higher in IPS e.max CAD (Ivoclar, Vivadent, Schaan, Liechtenstein) material as 3.96 ± 2.30.

The main effects of thicknesses were found to be statistically significant. ($p < 0.001$). While the mean value for 0.4 mm thickness was 3.71 ± 2.36, the mean value for 0.6 mm thickness was 2.99 ± 1.40. The color change obtained at 0.6 mm thickness is lower.

The background main effect was also found to be statistically significant ($p < 0.001$). While the mean value was 2.70 ± 1.24 on the A2 background, the mean value was 4.00 ± 2.33 on the A3 background.

The main effects of cements were not statistically significant ($p > 0.05$). While the mean value was 3.19 ± 1.90 in light cement, it was 3.51 ± 2.04 in neutral cement.

The interaction of material and thickness has a significant effect on the ΔE value ($p < 0.001$). The mean value for Celtra Duo-0.4 mm is 2.63 ± 1.35, while it is 2.84 ± 1.31 for Celtra Duo-0.6 mm. It was obtained as 4.79 ± 2.67 for IPS e.max CAD-0.4 mm and 3.13 ± 1.49 for IPS e.max CAD-0.6 mm. The average value obtained in the 0.4 mm application of IPS e.max CAD material was higher than the others. There is no difference between other material and thickness interactions. The comparison of the ΔE values of the interaction between the material and the thickness is shown in **Table 2**.

Background interaction with material has a significant effect on ΔE ($p < 0.001$). The mean value was 2.95 ± 1.40 for Celtra Duo-A2, 2.52 ± 1.22 for Celtra Duo-A3, 2.44 ± 1.02 for IPS e.max CAD-A2 and 5.47 ± 2.24 for IPS e.max CAD-A3. The average value obtained with the application of IPS e.max CAD material on the A3 floor was higher than the others. There is no difference between other material and background interactions. A comparison of material and background interaction ΔE values is shown in **Table 3**.

Table 2. Comparison of material and thickness interaction ΔE values.

Material	Thickness	
	0.4 mm	**0.6 mm**
Celtra Duo	2.63 ± 1.35^{a}	2.84 ± 1.31^{a}
E.max CAD	4.79 ± 2.67^{b}	3.13 ± 1.49^{a}

Table 3. Comparison of material and background interaction ΔE values.

Material	A2 background	A3 background	Total
Celtra Duo	2.95 ± 1.40^{a}	2.52 ± 1.22^{a}	2.70 ± 1.24
E.max CAD	2.44 ± 1.02^{a}	5.47 ± 2.24^{b}	4.00 ± 2.33

Thickness and background interactions were also statistically significant ($p < 0.001$). When 0.4 mm thickness was applied on the A2 background, the mean value was 2.47 ± 1.23, while it was 4.95 ± 2.58 on the A3 background. The mean value obtained when 0.6 mm thickness was applied on A2 background was 2.93 ± 1.23 while it was 3.04 ± 1.57 on A3 background. The highest mean value was obtained on A3 background of 0.4 mm thickness. The comparison of thickness and background interaction ΔE values is shown in **Table 4**.

There is no difference between other bilateral interactions. The mean and standard deviation values of the groups are shown in **Table 5** and illustrated in **Figure 1**.

Table 4. Comparison of thickness and background interaction ΔE values.

Background	0.4 mm tickness	0.6 mm tickness
A2	2.47 ± 1.23^{a}	2.93 ± 1.23^{a}
A3	4.95 ± 2.58^{b}	3.04 ± 1.57^{a}

The letters indicate the differences between the groups. ($p < 0.05$)

Table 5. Descriptive statistics of ΔE values and multiple comparison results by material, thickness, background and cement.

			Materyal		
Thickness	Background	Cement	Celtra	E-Max	Total
		Light	1.98 ± 1.04	2.66 ± 0.86	2.32 ± 0.99
	A2	Nötral	2.30 ± 1.56	2.92 ± 1.31	2.61 ± 1.44
		Total	2.14 ± 1.30	2.79 ± 1.09	2.47 ± 1.23^{A}
		Light	2.82 ± 1.07	6.80 ± 2.13	4.81 ± 2.62
0.4 mm	A3	Nötral	3.41 ± 1.37	6.77 ± 2.46	5.09 ± 2.59
		Total	3.11 ± 1.23	6.78 ± 2.24	4.95 ± 2.58^{B}
		Light	2.40 ± 1.11	4.73 ± 2.65	3.57 ± 2.33
	Total	Nötral	2.85 ± 1.54	4.84 ± 2.75	3.85 ± 2.42
		Total	2.63 ± 1.35^{a}	4.79 ± 2.67^{b}	3.71 ± 2.36
		Light	3.65 ± 0.93	1.99 ± 0.51	2.82 ± 1.12
	A2	Nötral	3.87 ± 1.07	2.20 ± 1.06	3.03 ± 1.34
		Toplam	3.76 ± 0.98	2.10 ± 0.82	2.93 ± 1.23^{A}
		Light	2.00 ± 0.98	3.59 ± 1.40	2.79 ± 1.43
0.6 mm	A3	Nötral	1.85 ± 0.85	4.73 ± 0.89	3.29 ± 1.70
		Total	1.92 ± 0.89	4.16 ± 1.28	3.04 ± 1.57^{A}
		Light	2.83 ± 1.26	2.79 ± 1.31	2.81 ± 1.27
	Total	Nötral	2.86 ± 1.40	3.47 ± 1.61	3.16 ± 1.52
		Total	2.84 ± 1.31^{a}	3.13 ± 1.49^{a}	2.99 ± 1.40
		Light	2.82 ± 1.29	2.32 ± 0.77	2.57 ± 1.08
Total	A2	Nötral	3.08 ± 1.53	2.56 ± 1.22	2.82 ± 1.39
		Total	2.95 ± 1.40^{A}	2.44 ± 1.02^{A}	2.70 ± 1.24

Continued

	Light	2.41 ± 1.08	5.20 ± 2.41	3.80 ± 2.32
A3	Nötral	2.63 ± 1.37	5.75 ± 2.08	4.19 ± 2.35
	Total	2.52 ± 1.22^{A}	5.47 ± 2.24^{B}	4.00 ± 2.33
	Light	2.61 ± 1.19	3.76 ± 2.29	3.19 ± 1.90
Total	Nötral	2.86 ± 1.45	4.16 ± 2.33	3.51 ± 2.04
	Total	2.73 ± 1.32	3.96 ± 2.30	3.35 ± 1.97

a-b: No difference between material and thickness interactions with the same letter; A-B: No difference between material and background interactions with the same letter; A-B: No difference between thickness and background interactions with the same letter.

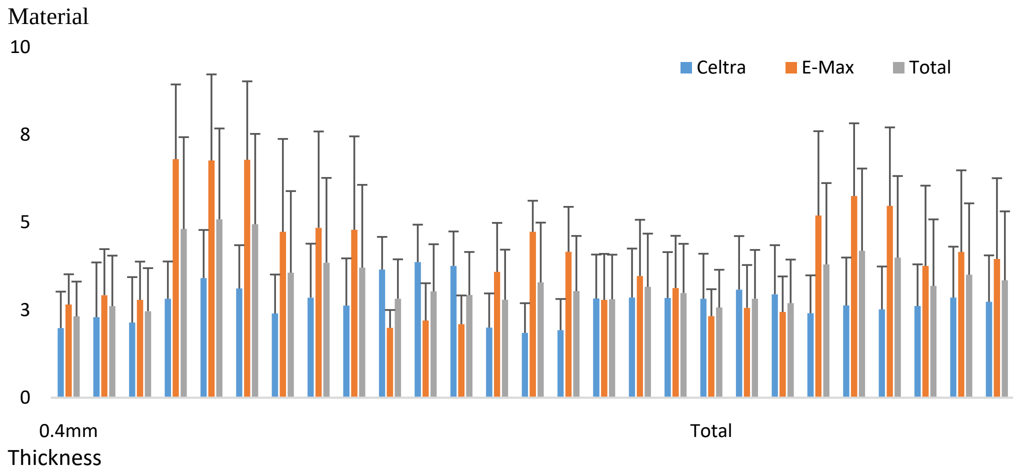

Figure 1. Graph of mean and standard deviation by material, thickness, background and cement.

4. Discussion

In this study, in the evaluation of ceramic laminate restorations, the resin cement used to cement the material, the background color representing the tooth, and the ceramic restoration were considered as a whole. The samples used in our study were prepared with the methods applied in similar studies in the literature and in accordance with the instructions of the manufacturers. [20] [21]

According to the results of our study, the first hypothesis of our study was rejected because there was no statistically significant difference between the ΔE changes of materials with 0.4 and 0.6 mm thickness, which were cemented using different backgrounds and resin cements. According to the statistical evaluation results, our second hypothesis was also rejected because there was no significant difference between the color changes of ZLS and LDS materials.

Resin-containing ceramics and reinforced ceramics, which can be produced in accordance with CAD/CAM production, are used as an alternative to feldspathic porcelain in the construction of lamina restorations, which are preferred today due to their superior aesthetic appearance. Two types of glass ceramics have been introduced to the market to provide adequate mechanical strength without affecting the aesthetic result of the restoration; lithium disilicate and zirconia reinforced lithium silicate ceramics. [22]

The most important features of these materials are the translucency of the enamel; they can imitate the reflection of light from their surfaces, absorption and scattering within the material. In addition, 2 different glass ceramic materials with the same light transmittance (LT, A1) were preferred in this study, since they have advantages such as the obtained color harmony and stable structure, such as not changing in long-term use [23] [24] [25]

The type and thickness of the ceramic restoration are two important parameters in light transmission. The clinical success of light-cured adhesive resin cements is determined by the adequacy of the light source and the amount of light that can pass through the restoration and reach the resin cement. [26] Studies show that the thickness of the restorative materials has a great effect on the final color of the restoration. [13] [27] [28] Peixoto *et al.* stated that most of the colors showed a significant decrease in light transmission and this decrease was related to the thickness rather than the color of the samples. [29]

The thickness of the laminate restorations is determined by the limit of the tissue removed from the tooth, and the ideal connection is to remain limited to the enamel for a good bonding. [30] In line with this information, the samples in our current study were prepared in 0.4 mm and 0.6 mm thickness in accordance with the minimally invasive concept.

The determining factors for the final color of restorations are; the color of the underlying tooth, the type of restorative material and the color and composition of the resin-based cementation. In this research, the use of composite material as a background helps to ensure that the results are more reliable by creating a standard color, unlike extracted natural teeth.

In the studies where the effect of the underlying tooth color on the final color of ceramic laminate restorations was evaluated [3] [6] [30] [31] [32], samples of composite resin material were used as substructure material in order to represent the tooth in accordance with this study.

It has been shown that the final color of ceramic restorations is not only determined by the color of the ceramic material, but also the color of the cement. [17] [18] [33]-[40]

According to the existing literature, the effect of resin cement on color can be investigated by calculating the color difference between background + ceramic and background + ceramic + resin cement. [30] [41] In this study, since there were samples with restoration thickness less than 2 mm (0.4 mm and 0.6 mm), dual cure resin cements showed clinically noticeable color change in the long term due to their amine content, so 2 different colors (light, neutral) light cure resin cement that do not contain amine compounds (Variolink Esthetic LC; Ivoclar, Vivadent, Schaan, Liechtenstein) was preferred.

It shows that white opaque cementing agents (WO, Bleach) provide significantly greater color change in the final color of the ceramic, which is always clinically detectable. In another study, it was stated that the use of resin cement in WO (opaque) color was more effective in masking discolored teeth. 181 Similar results were obtained in the study of Aiquahtani *et al.* [30]. Two different colors of resin cement (WO and A3) made the ceramic samples lighter than the control group, while the other three different colors of resin cement (A1, TR and B0.5) made the ceramic samples darker than the control group.

In this study, there was no significant difference in the ability of resin cement to mask different materials of different thicknesses. ($p > 0.05$). Think that this is due to the fact that opaque color cement was not preferred in this study and the resin cements used were neutral and light in color.

In studies in the literature, researchers have reported that Vita Easyshade (Vita Zahnfabrik, Bad Sackingen, and Germany) is one of the most reliable and sensitive devices for measuring tooth color and the color of porcelain restorations. [42]. In this thesis, Vita Easyshade V (Vita Zahnfabrik, Bad Sackingen, Germany) spectrophotometer device was used for the measurement of color change values.

The limitations of this study are that only LT, A1 lithium silicate and derived glass ceramic materials and A2, A3 were investigated in the background. In addition, composite resin teeth were used as the background instead of the natural tooth. Therefore, the optical properties of artificial teeth are different from natural teeth. The effect of different ceramic materials on different backgrounds should be considered in future research. Further studies are required to investigate the effect of a wider range of colors. Another limitation of this study is that the samples were compared only in color and were not subjected to mechanical tests evaluating the brittleness of 0.4 mm and 0.6 mm materials.

5. Conclusions

The following results were obtained within the limitations of this study;

1) There was no statistically significant difference between the ΔE values of Celtra DUO and IPS e.max CAD glass-ceramic blocks prepared with 0.4 mm and 0.6 mm thickness of lamina samples ($p > 0.05$).

2) When comparing different colors of the tested composite resin and resin cement, no statistically significant difference was found for the color parameters of CIE L* a* b* between various combinations of all-ceramic specimens regarding color change ($p > 0.05$).

3) Material type-material thickness, material type-background color, and material thickness-background interactions showed statistically significant differences ($p < 0.05$).

4) Since there is no statistically significant difference between the samples prepared with 0.4 mm and 0.6 mm thickness, a lamina restoration of this thickness can be applied clinically reliably in terms of optical properties, but for lamina restorations to be prepared at this thickness, the mechanical properties of the material should be supported by further studies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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