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Original Article

The effect of thickness and cement shade on the color match of different CAD-CAM glass-ceramic materials

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Abstract

Aim: This study aimed to assess the impact of the type and thickness of the ceramic and cement color on the targeted shade of glass-ceramics with various chemical compositions.

Methodology: Thirty ceramic specimens were prepared from leucite-reinforced (GC Initial LRF, GC Group) and lithium-disilicate (IPS e.max CAD, EM Group) materials in three different thicknesses (0.5 mm, 0.7 mm, and 1 mm). Four 4-mm-thick substrates were then made from A3-shaded composite resin material to mimic tooth structure and be utilized for cement application. Four shades (Variolink II: transparent, white, yellow, and bleach) of 0.2-mm-thick resin cement were polymerized over these substrates. Next, the specimens were placed over these substrates, and color measurements were applied with a spectrophotometer (VITA Easyshade V) leading to 24 group combinations (n=5). The color difference (ΔE) readings were obtained in the spectrophotometer's reference shade verification mode by selecting the A2 shade standard. Three-way mixed ANOVA, Tukey HSD, and Bonferroni tests were used for statistical analysis (α=0.05).

Results: The main effects of material, cement, and thickness were found to be statistically significant ($p < 0.05$), as were the interactions of cement×material, cement×thickness, and material×thickness ($p < 0.05$). However, the material×cement×thickness interaction was not found to be statistically significant ($p = 0.568$). Regardless of thickness or cement shade, the GC group had a lower mean ΔE value than that of the EM group ($p < 0.05$). Lower ΔE values were achieved in both materials with a thickness of 1 mm and bleach-shaded cement ($p < 0.05$). The materials with the greatest mean ΔE values were those with the thickness of 0.5 mm and the transparent shade cement combination ($p < 0.05$).

Conclusion: The thickness and shade of the cement used influenced the final color of the glass-ceramic materials with the same shade and translucency but diverse chemical compositions. When compared to the lithium disilicate glass-ceramic material, the leucite-reinforced feldspathic glass-ceramic material displayed lower color difference values and a better color match with the targeted shade.

Keywords: CAD-CAM, cement color, color difference, leucite, lithium disilicate, spectrophotometer

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Introduction

Due to their superior esthetic qualities and good mechanical features, glass-ceramic materials continue to be increasingly in demand. With the development and widespread use of computer-aided design and computer-aided manufacturing (CAD-CAM) systems, it has been possible to produce materials with different compositions that can be used for various indications (1-2). Ceramic laminate veneers have improved aesthetics and are more conservative than ceramic crowns. The increased optical qualities of new generation ceramics make it easier to mimic the translucency of natural teeth (3). However, since less tooth preparation is needed for these types of repairs, it is hard to make laminate veneers look like natural teeth (2, 4).

A key difficulty in esthetics is matching the visual qualities of restorations to those of natural teeth (2, 4). The combination of the color of the tooth, cement shade, and thickness determines the visual behavior of a ceramic restoration (5, 6). As the thickness of ceramic laminate veneers decreases, the translucency increases (7), making color matching more challenging. To eliminate negative impacts, consideration must be given to ceramic color, type, and thickness, as well as the color of the cement. Due to their limited thickness and high translucency, ceramic laminate veneers require careful color matching by clinicians (8-10).

The thickness of the restoration and the resin cement selection is crucial for the optical result of a laminate veneer (11). Because as the thickness decreases the color change effect of the resin cement increases (11). Besides, the color of the underlying tooth structure has an important effect on the final color of the ceramic laminate veneers (12). For dark-colored substrates, using more opaque ceramics and cements or increasing the ceramic thickness is recommended (12, 13).

There are a lot of different silicate-based ceramics that can be made with CAD-CAM technology (14). These differences stem from their distinct crystal formations, which are incorporated in a glass matrix. This produces ceramics such as leucite and lithium disilicate (15). Nonetheless, the silicate ceramic and color values chosen have only a minor impact on the aesthetic outcome. Other key parameters influence the final color of the restoration, and defining them properly is vital for achieving the best potential long-term result when using silicate ceramics (16).

The Commission Internationale de l'Eclairage (CIE) is an organization that provides color and appearance standardization. The CIE established the CIE L*a*b* color system in 1976 (17). One of the most prominent color systems embraces theory based on three separate color receptors (red, green, and blue) inside the eye. The color difference (ΔE) formula is used to calculate the color difference between two objects whose colors are represented by CIE L*a*b coordinates (18, 19).

Although several studies have been conducted on the optical characteristics of ceramic laminate veneers (11-13, 16, 20-26), research comparing the color reproducibility of leucite-reinforced and lithium disilicate glass-ceramic in different thicknesses with the various shades of resin cement used in this study is limited (16). Therefore, the aim of this in vitro study was to investigate the effect of ceramic type, ceramic thickness, and cement color on the targeted color of CAD-CAM glass-ceramic restorations with different chemical compositions. The null hypothesis of this study was that ceramic type, ceramic thickness, and cement color would not affect the targeted color of CAD-CAM ceramic restorations with different chemical compositions.

Materials and Methods

The compositions and materials utilized in this investigation are listed in Table 1. Thirty specimens were sliced with a cutting device (Isomet, Buehler Inc, USA) under water cooling from GC Initial LRF (GC Europe, Leuven, Belgium) and IPS e.max Ceram (Ivoclar Vivadent AG, Schaan, Liechtenstein) in three different thicknesses (0.5 mm, 0.7 mm, and 1 mm). Specimens were ground with silicon carbide abrasive papers from 1,000 to 1,500 grit to ensure surface standardization. The final thickness was measured with a digital caliper (Mitutoyo, Tokyo, Japan). Then, each ceramic material was divided into three different groups in terms of its thickness (n=5).

A 4-mm-thick wax sample was prepared to produce composite backgrounds. Then, a silicon index (Zetaplus, Zhermack, Italy) was obtained from the wax sample. Four 4-mm-thick substrates were produced from A3-colored composite resin material (Mosaic, Ultradent, UT, USA) to imitate tooth structure and to be used to underlie the resin cement. Composite resins were applied to the silicon index incrementally and polymerized for 40 seconds. Then, composite resin specimens were placed inside a second silicon index with a thickness of 4.2 mm, which was prepared in the same manner as the 4-mm-thick silicon index. Four different colors (transparent, white, yellow, and bleach; Variolink II, Ivoclar Vivadent AG) of 0.2-mm-thick light-cure resin cement were applied to each of these composite resin substrates and polymerized by covering a slide. Thicknesses were checked with a digital caliper. Scheme of the test groups were shown in Figure 1. The specimens were placed on these backgrounds, respectively, and a spectrophotometer (Vita EasyShade V, Vita Zahnfabrik, USA) was used to conduct color measurements. A drop of glycerin was applied for optical coupling between the ceramics and the cement surface. In the reference color verification mode of the spectrophotometer, the color difference (ΔE) values were recorded by selecting the A2 color standard of the Vita Classical shade guide system. Average values of three measurements were recorded for each of 24 group combination. The literature indicates that half of observers can spot a 2.6 ΔE color difference, and 5.5 ΔE is considered clinically unacceptable. In this study, these values were accepted as threshold values (27).

Statistical analysis

The Kolmogorov-Smirnov test was used to determine if the data conformed to the normal distribution. SPSS software program v26, (IBM SPSS Inc., Armonk, NY, USA) was used for statistical analysis, and the data were analyzed with the three-way mixed ANOVA, Tukey HSD, and Bonferroni tests (α=0.05).

Results

The results of the three-way mixed ANOVA are presented in Table 2, whereas the means and standard deviations are presented in Table 3. According to the three-way mixed ANOVA, the main effects of the material, cement, and thickness, as well as the cement × material, cement × thickness, and material × thickness interactions, were all statistically significant ($p < 0.05$).

By contrast, the material × cement × thickness interaction was not found to be statistically significant ($p = 0.568$) (Table 2).

Regardless of the thickness and color of the cement, the GC group showed a lower mean ΔE value than the EM group ($p < 0.05$). In the case of both materials, lower ΔE values were obtained with 1-mm-thick and bleach-shaded cement ($p < 0.05$). Moreover, the materials with a thickness of 0.5 mm and a transparent shade cement match exhibited the highest mean ΔE values ($p < 0.05$). In the GC group, only the white, yellow, and bleach-shaded cement with 1-mm-thick ceramic combinations demonstrated color differences below the acceptability threshold (ΔE < 5.5). In the EM group, only the bleach-shaded cement with 0.7-mm and 1-mm thick ceramics were associated with ΔE values below the acceptability threshold (ΔE < 5.5) (Table 3).

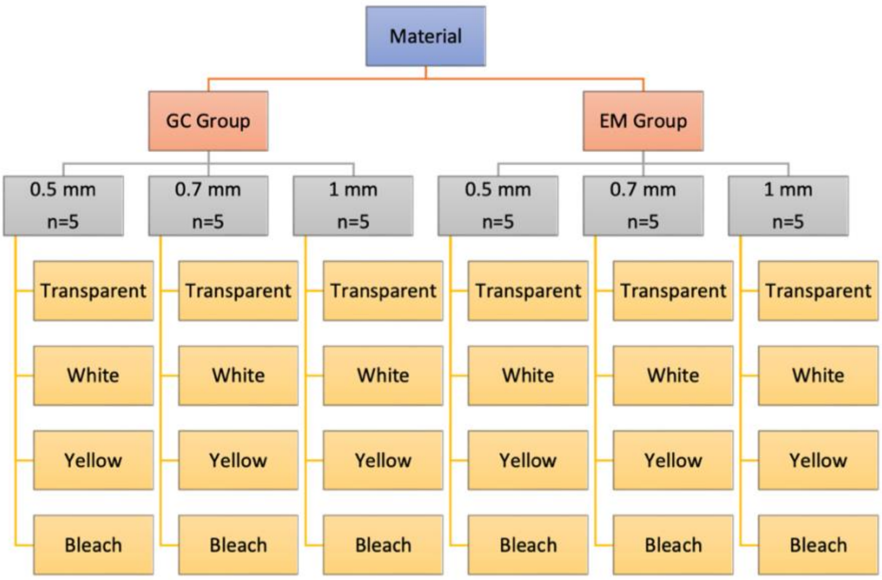

Figure 1. Group scheme of this study

Table 1. Materials and compositions used in this study

Material	Shade	Composition	Manufacturer
GC Initial LRF	A2, Low-translucency	Leucite-reinforced glass ceramic	GC Europe, Leuven, Belgium
IPS e.max CAD	A2, Low-translucency	Lithium disilicate glass-ceramic	Ivoclar Vivadent AG, Schaan, Liechtenstein
Variolink II	Translucent White Yellow Bleach	Light-cure and dual-cure composite resin cement	Ivoclar Vivadent AG, Schaan, Liechtenstein
Mosaic	A3	Universal composite resin	Ultradent, South Jordan, UT, USA

Table 2. Three-way mixed ANOVA results

Effect	df	F	p	Partial Eta Squared
Cement (A)	3	160.010	<.001	.870
Ceramic Type (B)	1	49.123	<.001	.672
Thickness (C)	2	108.596	<.001	.900
A × B	3	214.145	<.001	.899
A × C	6	51.407	<.001	.811
B × C	2	4.711	.019	.282
A × B × C	6	0.807	.568	.063

Table 3. Means, standard deviations, and pairwise comparisons

CERAMIC TYPE	THICKNESS	CEMENT SHADE Translucent	White	Yellow	Bleach	TOTAL
GC GROUP	0.5 mm	6.96±0.18	5.98±0.16	5.80±0.16	7.44±0.29	$6.55^{Θ}$
	0.7 mm	6.50±0.07	5.66±0.18	5.68±0.15	6.32±0.44	$6.04^{β}$
	1 mm	5.50±0.18	5.10±0.14	5.14±0.25	4.82±0.08	$5.14^{λ}$
	Total	**$6.32±0.65^{xA}$**	**$5.58±0.41^{xB}$**	**$5.54±0.35^{xB}$**	**$6.19±1.15^{xA}$**	
EM GROUP	0.5 mm	7.46±0.11	6.84±0.05	6.74±9.05	6.20±0.14	$6.81^{Ω}$
	0.7 mm	7.18±0.18	6.48±0.22	6.70±0.19	5.30±0.39	$6.42^{Σ}$
	1 mm	6.60±0.20	6.18±0.29	6.48±0.26	4.24±0.53	$5.86^{Δ}$
	Total	**$7.08±0.40^{yA}$**	**$6.50±0.34^{yB}$**	**$6.64±0.21^{yB}$**	**$5.24±0.90^{yC}$**	
TOTAL	0.5 mm	$7.21±0.30^{aA}$	$6.41±0.47^{aB}$	$6.27±0.51^{aB}$	$6.82±0.69^{aC}$	6.68^{a}
	0.7 mm	$6.84±0.38^{bA}$	$6.07±0.47^{bBC}$	$6.19±0.56^{aB}$	$5.81±0.67^{bC}$	6.23^{b}
	1 mm	$6.05±0.61^{cA}$	$5.64±0.61^{cB}$	$5.81±0.75^{bB}$	$4.53±0.47^{cC}$	5.51^{c}
	Total	**$6.70±0.66^{A}$**	**$6.04±0.60^{B}$**	**$6.09±0.63^{B}$**	**$5.72±1.12^{C}$**	

* Different lowercase superscript letters indicate a significant difference in the same column (a-c).
* Different lowercase superscript letters indicate a significant difference in the same column (x-y).
* Different uppercase superscript letters indicate a significant difference in the same row (A-C).
* Different superscript symbols indicate a significant difference in the same column ($p < 0.05$).

Discussion

The present in-vitro study evaluated the shade reproducibility of different glass-ceramic materials of the same shade and translucency under various cement shades of three different thicknesses. Based on the findings, the final shade of the ceramics was affected by the ceramic type, thickness, and shade. Therefore, the study's null hypothesis was rejected.

Numerous prior studies have evaluated the colors of ceramic laminate veneers of different thicknesses, different degrees of translucency, different shades of resin cement, and different underlying substrates (11-13, 16, 20-26). Such studies have reported that the thickness, substrate shade, cement shade, and ceramic material all have a significant effect on the final color of the ceramic laminate veneers. Similarly, the final color of the ceramic materials was significantly affected by the ceramic type, thickness, and resin cement shade in the present study. Liebermann et al. (16) reported that the variable with the greatest impact on the ΔE value in their study was the ceramic type. In contrast to the study by Liebermann et al. (16), the variable with the greatest impact on the ΔE value in this study was the thickness, followed by the cement shade and the ceramic type. The types of cement used and the test conditions could explain this difference in findings.

A previous study reported that increasing the thickness of the ceramic from 0.5 mm to 0.7 mm led to a significant decrease in the ΔE value (20), whereas another study found that the substrate color may be concealed using ceramic veneers with a thickness of at least 0.80 mm (28). The mean ΔE value between the targeted A2 shade and the ceramic groups decreased as the thickness increased in the present study. This finding was consistent with the findings of many earlier studies (12, 20, 24). Pires et al. (13) reported that low-translucence lithium disilicate glass-ceramic (IPS e.max CAD) exhibited a higher ΔE value with the target shade when compared with high-opacity lithium disilicate glass-ceramic. In this study, two low-translucency ceramic materials were selected to eliminate the effect of translucency differences on the observed color differences.

Many prior studies have revealed the utilized material and its composition to have a significant effect on the final color of laminate veneers (16, 22, 26, 29). The crystal structure, particularly the crystal size and the interface between the glass phase and the crystals, have been found to affect the refraction and transmission of light (16, 30), which in turn affect the color and final color perception of different leucite and lithium disilicate ceramics (16). It has previously been reported that leucite ceramics are associated with higher translucency, while lithium disilicate ceramic might mask the underlying color better than leucite-reinforced ceramic. Yet, in this study, the leucite-reinforced ceramic exhibited a better color match with the A2 shade as well as better masking ability than the lithium disilicate ceramic. The lack of sufficient information regarding the compositions of various materials prevents further inferences from being drawn regarding the present findings. In addition, the literature contains few comparable studies concerning the CAD-CAM ceramics used in this study (16).

Resin cement can influence the final color of ceramic veneers, with the degree of influence changing according to the resin cement shade (21). Furthermore, it has been reported that the shade descriptions of composite resin cements refer to the entire restoration, not the shade of the resin cement on its own (16). Various studies have also reported the importance of the resin cement shade in relation to the final color of the restoration (12, 13, 16, 20-22, 26, 29). The resin cement shade had a significant effect on the final color in the present study. While the translucent cement shade gave rise to the highest ΔE value, the bleach-shaded cement exhibited the lowest ΔE value with the A2 shade. Similarly, many prior studies have reported that cement systems with opaque properties demonstrate a greater capacity for masking with regard to darkened substrates (12, 20, 31).

The different observed outcomes and effects of the resin cement, thickness, and ceramic types in terms of the color values demonstrate the difficulty facing dentists and dental technicians when determining the appropriate final shade for a patient (16). Thus, the results of this study may facilitate the selection of the appropriate thickness, resin cement shade, and ceramic type for laminate veneer restorations.

The in-vitro test conditions, shape of the specimens (which could not fully imitate oral conditions), and lack of aging of the materials constitute the limitations of the present study. Future studies could focus on the optical effects of different types of cements and materials with various shades and translucencies on the targeted shades of laminate veneer restorations.

Conclusions

Despite the limitations of this study, the following conclusions can be drawn:

- The final color of glass-ceramic materials with the same shade and translucency but with different chemical compositions is affected by the ceramic type, thickness, and color of the utilized cement.
- The utilized leucite-reinforced feldspathic glass-ceramic material exhibited a better color match with the targeted shade as well as lower color difference values when compared with the lithium disilicate glass-ceramic material.
- In the case of a tooth structure with A3 color, increasing the ceramic thickness and using bleach-shaded cement may result in a better color match with the targeted shade.

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