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A comparative study of translucency and color perception in monolithic zirconia and lithium disilicate veneers☆,☆☆

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ABSTRACT

Ceramic laminate veneers which are a conservative approach to restoring anterior teeth, combining minimal preparation and esthetics. This study aims to evaluate the impact of the thickness of monolithic zirconia laminate veneers on their optical properties and color perception, comparing them to lithium disilicate. A total of 60 laminate veneers were prepared using two ceramic materials, divided into three groups for each material ($n = 10$) with thicknesses of 0.5, 0.7, and 1.0 mm. CIELab color parameters of the veneers were measured using a spectrophotometer and translucency parameters were calculated. The veneers were cemented onto uniform dies and final L, a, b values of the restorations were measured. The color difference between the different thicknesses was calculated using the CIEDE2000 formula. Two-way ANOVA and Bonferroni HSD post hoc tests were conducted to compare the color parameters ($\alpha = 0.05$). The results showed that both material type ($p < 0.001$) and thickness ($p < 0.001$) influenced translucency values. The translucency values of zirconia veneers were significantly lower than those of lithium disilicate. The color differences ($\Delta E00$) resulting from thickness changes (0.5–1.0 mm) were near or below the perception threshold for lithium disilicate, but distinct for zirconia restorations. In conclusion, monolithic zirconia veneers demonstrated lower translucency compared to lithium disilicate. Changing the material thickness affected the translucency of both materials, but not the color perception only for zirconia.

The presented manuscript is not derived from any dissertations or theses.

1. Introduction

The visible color of a tooth restored with a laminate veneer is determined by the diffuse reflectance of light from the dentin through the outer restorative material. Following the primary color attributes, translucency is the most important optical property influencing the dental restoration's esthetic outcome [1]. Translucency is defined as the property of a material that scatters light in all directions as

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it passes through it [2] and it is inversely related to material thickness.

Nowadays, with developing technology and rising life standards, dental materials have progressed, and esthetic expectations have increased. The development of adhesive systems has allowed treatments to be performed with minimal loss [3,4]. Ceramic laminate veneers offer a combination of minimal tooth preparation and improved esthetics. Thus they are a conservative alternative to ceramic crowns for the restoration of anterior teeth [5,6].

Obtaining satisfactory esthetic results with minimal tooth preparation can be challenging [7]. Laminates are used to conceal tooth discoloration with minimal preparation [8]. However, obtaining acceptable esthetics with feldspathic ceramics requires a minimum ceramic thickness of 1.0–2.0 mm, which may involve extensive tooth reduction [9–13]. In severe cases, a zirconia substructure can be considered, but this compromises esthetics [14]. Alternatively, high-translucent monolithic zirconia can be used to achieve minimal thickness and sufficient masking ability [15,16].

Porcelain fracture is the most common reason for laminate veneer failure [17]. Y-TZP is a strong and durable material, but it has limited translucency and is prone to chipping or delamination of the superstructure porcelain [18]. To address these issues, monolithic high translucent zirconia restoratives have been developed. The fracture toughness of monolithic cubic ultra-translucent zirconia is lower than Y-TZP but still higher than Lithium Disilicate (LiSi) [19]. Monolithic zirconias allow for thinner restorations with improved esthetics and stronger structures.

Paravina et al. [20] concluded a study to evaluate the color difference thresholds for dental ceramics and they found the $\Delta E00$ values corresponding to 50 % perceptibility and acceptability were 0.8 and 1.8, respectively. In the study, the color differences resulting from thickness change for two dental ceramics were calculated and categorized according to these thresholds.

The clinical use of highly translucent monolithic zirconia is increasing due to its improved strength compared to glass-matrix ceramics and better esthetic properties than Y-TZP [15]. Zirconia ceramics become more translucent as the thickness increases [21]. However, the effect of zirconia veneer thickness on color perception has not been fully clarified. This study aims to evaluate the impact of zirconia veneer thickness on optical properties and color perception compared with LiSi. The null hypotheses are as follows: (I) the translucency rates of laminate veneers made from two types of ceramics are similar; (ii) translucency is not affected by material thickness; and (iii) the final restoration color is not affected by material thickness.

2. Methods

2.1. Preparation of the models

A maxillary right central incisor acrylic tooth (#11) (Frasaco, Germany) was prepared for each design of laminate veneer restoration. Three designs were used involving a reduction of the labial surface depth of 0.5, 0.7, and 1 mm for groups 1, 2, and 3, respectively, with a 1.5 mm reduction from the incisal edge with the incisal palatal shoulder (Fig. 1). Depth marker burs were used to determine the cutting depth. The base of the grooves on the labial surface was marked with a lead pencil to check the amount of tooth reduction. A chamfer bur was then used to level all the grooves on the tooth surface.

The prepared acrylic teeth were digitized with a dental lab scanner (Ceramill Map 400, Amann Girrbach, Kobach, Austria). A digital light processing (DLP) 3D printer (NextDent 5100, 3D Systems, NextDent B·V., in Soesterberg, Netherlands) was used to fabricate resin abutments. A total of 60 abutments were fabricated, with 20 abutments for each design, using a micro-filled hybrid resin (NextDent C&B MFH, N 1.5). The models in each group were scanned and then randomly distributed to restoration material groups, such as zirconia and lithium disilicate.

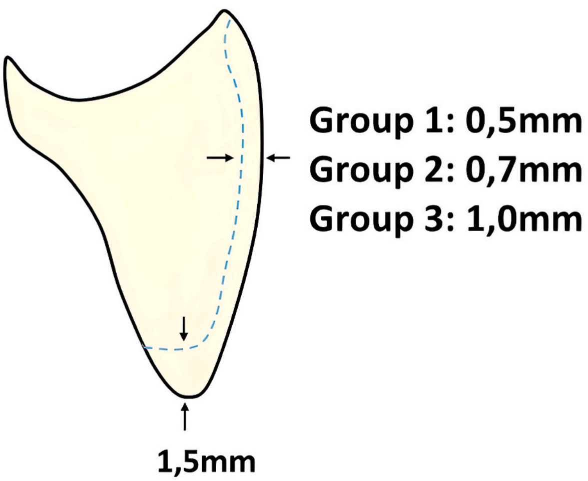

Fig. 1. Schematic drawing of preparation design for laminate veneer restorations.

2.2. Veneer production

Veneers were designed using CAD–CAM design software (Exocad Dental CAD; Exocad, Darmstadt, Germany). The cement gap thickness was set as 40 μm, with a 1 mm distance from the margin for all restorations. Restoration thicknesses were set as 0.5, 0.7, and 1.0 mm for groups 1, 2, and 3, respectively. The veneers were then produced using a milling machine (Ceramill Motion 2, Amann Girrbach, Kobach, Austria).

Thirty veneers were milled from pre-sintered zirconia (KATANA Zirconia STML A1, Noritake, Miyoshi, Japan). All zirconia veneers were positioned in the same manner for milling to ensure that each veneer included the same layers of the multilayered zirconia disc. The zirconia veneers were then sintered in a furnace (Austromat 674i; Dekema Dental-Keramiköfen, Freilassing, Germany) for 6 h and 42 min using a standard sintering program at 1530 °C, as recommended by the manufacturer. In a similar manner, thirty LiSi veneers were milled from LiSi (IPS e. max CAD HT A1, Ivoclar Vivadent, Schaan, Liechtenstein) and underwent crystallization firing (Programat P510, Ivoclar Vivadent, Schaan, Liechtenstein), following the manufacturer's recommendations.

After production, all veneers were manually polished with rubber diamond points (ST102 HP, R1020HP, R1040HP. Edenta AG, Au/SG, Switzerland). The thickness of the veneers was checked and verified using a digital caliper (Digimatic Caliper IP67, Mitutoyo, Tokyo, Japan).

2.3. Translucency measurement

Each veneer was placed on black (L = 1.6, a = 1.2, b = −1.0), and white (L = 92.6, a = −1.2, b = 2.9) resin abutments for translucency measurement. Glycerin was used as a medium between the die and veneer. The CIELab values of the materials over the black (Lb, ab, bb) and white (Lw, aw, bw) abutments were measured with a spectrophotometer (SpectroShade Micro II, MHT, Verona, Italy). In accordance with the manufacturer's recommendation, the white calibration procedure was performed at each session. The entire labial surface of the teeth was selected in the device menu for measurement, each veneer was measured two times, and average values were taken. All color readings were performed with the same setup by the same operator to ensure standardization. The measurement values were used to calculate the translucency parameter (TP_{00}) using the following formula [22]:

$$TP00 = [(L'_B - L'_W / K_L S_L)^2 + (C'_B - C'_W / K_C S_C)^2 + (H'_B - H'_W / K_H S_H)^2 + RT\,(C'_B - C'_W / K_C S_C)\,(H'_B - H'_W / K_H S_H)]^{1/2}$$

2.4. Cementation

The tooth surfaces of laminate veneers were prepared for cementation according to the manufacturer's recommendations. Zirconia veneers were air abraded with silica-modified 110 μm diameter aluminum oxide particles (Rocatec Plus, 3 M ESPE, St. Paul, MN). LiSi veneers were etched for 20 s (K-etchant gel, Kuraray Noritake Dental), rinsed, and dried. Subsequently, the surfaces were treated with a conditioning agent (Ceramic Primer Plus, Kuraray Noritake Dental). A translucent resin cement (Panavia V5 Clear, Kuraray Noritake Dental) was applied to each veneer, placed on a resin die (L = 77.1, a = 1.4, b = 18.4), and seated with finger pressure for 1 min. The excess cement was then removed, and the restoration was light cured for 20 s from labial and palatal surfaces.

After cementation, final L, a, b values of the restorations were measured twice by a spectrophotometer, and the average value was taken. The color difference between the veneers of different thicknesses was calculated with the CIEDE2000 formula [23].

Table 1
TP_{00} values of tested groups and post hoc test results.

	Thickness			Test Statistics†	
	1 mm	0,7 mm	0,5 mm		
	$\overline{X} \pm ss$	$\overline{X} \pm ss$	$\bar{x} \pm ss$	*F*	*p*
Material					
Zirconia	$12{,}78 \pm 0{,}74^{xA}$	$13{,}62 \pm 0{,}81^{yA}$	$15{,}33 \pm 0{,}76^{zA}$	18,031	**<0,001**
LiSi	$18{,}15 \pm 1{,}11^{xB}$	$20{,}37 \pm 0{,}79^{yB}$	$21{,}85 \pm 1{,}38^{zB}$	37,03	**<0,001**
Test Statistics‡					
F	154,805	243,651	227,939		
P	**<0,001**	**<0,001**	**<0,001**		
Thickness effect: *F* = 18,046 *p* = 0,053 **Material effect:** *F* = 214,679 *p* = **0,005**					
Thickness x Material effect: *F* = 2891 *p* = 0,064					

$\bar{x}$: mean, *ss*: Standard deviation, *M*: Median, *IQR*: Inter Quartal Range, * Two-way Analysis of Variance, †:Between-group comparisons for thickness values, superscripts A and B indicate groups that differ significantly in each measurement. Groups with the same superscripts are similar.‡:Comparisons between within-group measurements in each group (thickness), superscripts x, y, and z indicate differences in material measurements.

2.5. Statistical analysis

Statistical analyses were performed using TURCOSA Cloud (Turcosa Analytics, Turkey) statistical software. The Kolmogorov-Smirnov test and Levene's test were conducted to verify the normal distribution and had homogeneous variances of the TP values. Two-way ANOVA and Bonferroni post hoc tests were used to identify the statistical difference in the TP values among the three groups. For all tests, a p-value of less than 0.05 was considered statistically significant.

Post hoc power analysis was performed using Minitab 18 (Minitab LLC, State College, PA) to confirm that the sample size was large enough to detect significant differences. The statistical power was calculated to be 1.00 for TP with an α error of 0.05, indicating that the sample size used in this study was sufficient.

3. Results

The results of the two-way ANOVA indicate that the TP values were affected by both the type of material ($p < 0.001$) and the thickness ($p < 0.001$) (Table 1). According to results of the Bonferroni post hoc test, the TP value of the zirconia specimens was significantly lower than that of the LiSi specimens for all thicknesses ($p = 0.005$; Fig. 2).

In Fig. 2, a negative correlation between translucency and material thickness can be observed for both ceramic materials. Increasing the material thickness from 0.5 to 1 mm resulted in a significant increase in translucency ($p < 0.001$).

The descriptive statistics for the L, a, b values of laminate veneers after cementation are presented in Table 2. The change in L, a, b values caused by a thickness variation was greater for zirconia than lithium disilicate.

Table 3 shows the ΔE00 values, which were calculated with the CIEDE2000 formula. ΔE00 values give a numerical expression of the color difference between cemented restorations of various thicknesses. Additionally, their relationship to the thresholds described by Paravina [20] is stated.

4. Discussion

The null hypothesis was partially rejected based on the findings. The translucency values of laminate veneers made from the two ceramics were not similar. Additionally, the translucency of the restoration was affected by the thickness of material. The final color of the zirconia restorations was also affected by the thickness of the material. Moreover, the change of thickness from 0.5 to 1.0 mm resulted in a color difference (ΔE00) for LiSi veneers. However, the color difference was even more distinct for zirconia restorations [24].

Shirani and Kolakarnprasert evaluated the translucency differences between the layers of multilayer zirconia and reported no difference [25,26]. Therefore, in the study, optical measurements of the restoration surface were performed as a whole. The mean translucency of 1.0 mm thick enamel was reported to be 18.7 [1]. In this study, the translucency of 1 mm thick LiSi was measured similarly to enamel. Zirconia veneers showed lower translucency and hence could not be taken to mimic natural enamel.

Spink et al. [27] reported that absolute translucency is the most accurate measurement for evaluating the light transmission of dental ceramics. The study concluded that the contrast ratio was not appropriate for describing the light transmission of materials with

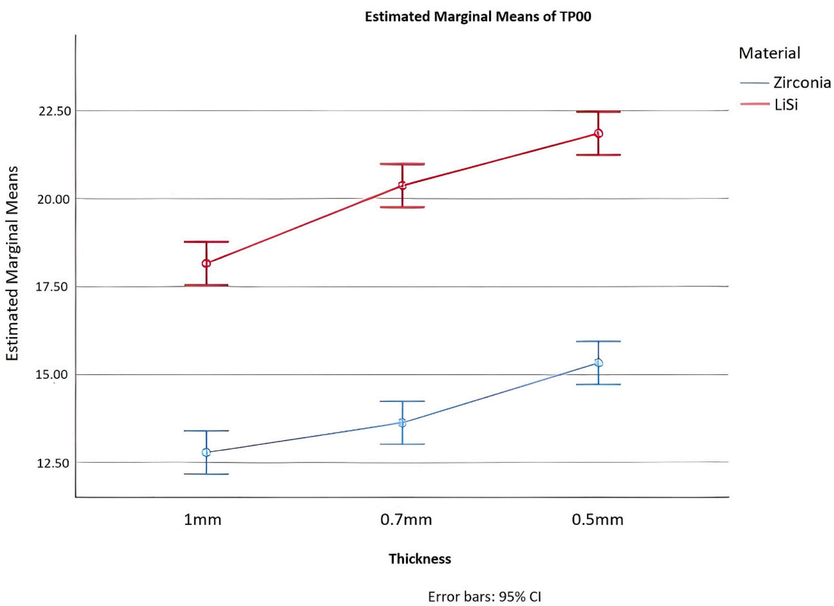

Fig. 2. Graphical representation of the TP_{00} values of different thicknesses of zirconia and LiSi veneers.

Table 2
Mean L, a, b values and standard deviation of cemented laminate veneers.

Group	L	a	b
0.5 mm zirconia	77.55 ± 0.75	0.37 ± 009	15.76 ± 0.72
0.7 mm zirconia	76.18 ± 0.78	0.34 ± 0.09	17.09 ± 0.45
1.0 mm zirconia	73.96 ± 0.63	0.23 ± 0.23	17.68 ± 0.37
0.5 mm LiSi	73.88 ± 0.82	1.89 ± 0.15	17.76 ± 0.46
0.7 mm LiSi	73.62 ± 0.84	2.03 ± 0.26	18.12 ± 0.21
1.0 mm LiSi	72.53 ± 1.71	1.54 ± 0.27	17.94 ± 0.55

Table 3
The color difference between the varying thicknesses (mm) of veneers.

Groups	ΔE_{00}	Status[a]
Katana 0.5–0.7	1,36	Perceptible
Katana 0.7–1.0	1,66	Perceptible
Katana 0.5–1.0	2,96	Inacceptable
Emax 0.5–0.7	0,31	Non-perceptible
Emax 0.7–1.0	0,76	Non-perceptible
Emax 0.5–1.0	0,83	Perceptible

[a] <0.8 Below the perceptibility threshold, 0.8–1.8 Perceptible, >1.8 Inacceptible.[20].

less than 50 % translucency. Therefore, contrast ratio values were not considered in this study.

This study included actual anatomic restorations instead of flat specimens to obtain a more accurate resemblance to clinical situations. The spectrophotometer employed was adjusted to provide an average value of the whole labial surface, allowing for the consideration of the effect of surface shapes of restorations.

To the authors' knowledge, in the literature, there was no information available on the effect of thickness changes on the color perception of zirconia. The CIEDE2000 formula is recommended for measuring color differences because it is more accurate than the CIELAB formula and better reflects how humans perceive color. The CIEDE2000 formula also provides a better fit for the perceptibility and acceptability thresholds of color differences [20,24,28]. Therefore, this study aimed to evaluate the effect of thickness change on the color of zirconia and lithium disilicate restorations using the CIEDE2000 color difference formula.

The color values of the veneers were affected by the material and veneer thickness (Table 3). The L* values, which measure brightness, were higher for zirconia and tend to decrease for both materials with increasing thickness. This tendency is consistent with the findings of Shokry et al. [29] and can be explained by the absorption of light by thicker specimens, resulting in lower reflection. Zirconia showed lower a* values compared to LiSi, indicating a more greenish color. The a* values for both materials were inversely related to thickness. When comparing veneers of the same thickness, the b* values of LiSi were slightly higher than those of zirconia, indicating a more yellowish color. Thicker zirconia restorations tended to have higher b* values, which means more yellowish color. Kim et al. [30] also reported decreased b* values for thinner monolithic zirconia ceramic restorations, which is in line with the findings of this study.

To obtain successful esthetic results, the color values of the prepared teeth and designated final restoration should be considered, as well as factors like the veneering material, thickness, and the color of the luting cement. Although lower translucency is an esthetic disadvantage for zirconia, its masking ability also presents an advantage. High translucent zirconia can provide satisfactory esthetic results when used as a monolithic or core material for laminate veneers [31,32].

Based on the findings of this study, it is recommended that high translucent zirconia veneers be preferred due to higher masking ability at smaller thicknesses. On the other hand, when more translucency is intended lithium disilicate veneers would be superior even at higher thicknesses.

A limitation of this study was that all the veneer restoration materials and all prepared teeth models were single-shaded. Another limitation was only one type of zirconia was included. Different zirconia materials with various crystal compositions and translucency rates may yield different results. Further studies should include the translucency of different shades of highly translucent monolithic zirconia veneers and the masking ability of varying shades of abutment teeth.

5. Conclusion

Within the limitations of this study, the follows conclusions drawn.

1. High translucent monolithic zirconia veneers showed a significantly lower translucency rate compared to lithium disilicate veneers ($p < 0.001$).
2. Material thickness had a significant effect on translucency for both groups ($p < 0.001$).
3. Material thickness affected the final color of zirconia restorations, while the effect of thickness change on lithium disilicate restorations was near or below the perception threshold.

Data availability statement

Data associated with this study been deposited into a publicly available repository https://drive.google.com/drive/folders/1mbn5ABFwuZ2W5qKRjGLD7P379nh95U3?usp%20=%20sharing.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Hasan Murat Aydoğdu: Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Investigation, Data curation, Conceptualization. **Pınar Bolpaça Yıldız:** Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Damla Güneş Ünlü:** Supervision, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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