Evaluation of Translucency Parameter of Four Different Glass-ceramic Materials of Two Thicknesses with Two Finishing Protocols: An In Vitro Study

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Abstract

Objective: The objective of this study is to examine the translucency of four different glass-ceramic materials; IPS e.max Press, CeraMotion, Rosetta SP and Celtra press using different finishing protocols; glazing solely or by both polishing and glazing. **Materials and methods:** 80 ceramic samples were prepared and divided into four groups (n=20) according to the material used. Each group was subdivided into two subgroups (n=10) according to the thickness of the restoration; 1 mm or 2 mm, which were further divided into two divisions according to the used finishing protocol; subdivision 1 samples were subjected to glazing only, while subdivision 2 were subjected to both polishing and glazing (n=5). Translucency parameters were measured using VITA Easyshade. **Result:** The present findings showed no statistically significant difference in translucency parameters among different ceramic materials. However, different material thicknesses and finishing protocols demonstrated a statistically significant influence on the translucency parameters (p-value < 0.001). **Conclusion**: Material thickness and finishing protocols have a direct impact on the translucency parameters of the ceramic restorations.

Keywords: translucency, zirconia, lithium disilicate, aesthetics, finishing, ceramics

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Introduction

Ceramic restorations are frequently used to satisfy patients' high esthetic demands since they successfully mimic the appearance of the tooth substance and are made of biocompatible materials. [1] Dental restorations of normal shape, function, and look imitating the appearance of genuine teeth are the most challenging objectives of a restorative dentist, which has a positive impact on the patient's self-esteem. In addition to their superb color and translucency, matching natural tooth structure, all-ceramic materials have become more popular as an alternative to metal-ceramic restorations. [2,3]

Lithium disilicate glass-ceramic, one of many ceramic materials currently available on the market, is able to exhibit both favorable esthetic and mechanical qualities. It was first introduced in 1988 as IPS™ Empress 2 (Ivoclar Vivadent, Lichtenstein). Later on, after much refinement within its micro-structure, an all-ceramic IPS e.max system was launched in 2005. It is noteworthy that the IPS e.max press has flexural strength that is two to three times stronger than that of IPS™ Empress 2. [4] Afterwards, zirconia-reinforced lithium silicate (ZLS) was introduced on the market with the intention of simultaneously providing advanced aesthetic properties. [5,6] In addition, ZLS has a special micro-structure that precisely mimics the spectrum of natural sunlight. It consists of a significant proportion of very fine-grained lithium silicate crystals, together with a high glass content, which gives the material its ideal optical properties. [7]

Furthermore, translucency parameters can be altered by different material thicknesses. Several previous studies have extensively examined the correlation between the type of ceramic material, its thickness, and translucency. They have demonstrated that the translucency of glass-ceramic and zirconia ceramics increases as the thickness decreases, although the extent of this variation is dependent on the specific material type. [8,9,10]

Not only the material choice and thickness that impact the esthetic outcome of a restorative treatment, but also the choice of an appropriate finishing protocol can have a significant influence on the translucency of dental ceramic materials. Translucency can be defined as a state halfway between perfect transparency and opacity. The dispersion of light, ceramic size and composition, refractive index, number of firings, porosity, and thickness are a few parameters that affect how translucent ceramics are. [11,12] Studies have also shown that polishing and glazing can restore translucency after grinding or sandblasting. However, excessive grinding or the use of coarse abrasives can cause irreversible damage to the ceramic material. [13]

Therefore, the aim of this in vitro study was to examine the translucency of four different glass-ceramic materials; IPS e.max Press, CeraMotion, Rosetta SP and Celtra press at two thicknesses (1 mm and 2 mm) using different finishing protocols; by glazing or by both polishing and glazing.

2. Material and Methods

2.1. Sample Grouping

80 ceramic specimens were divided into 4 groups according to ceramic material (n=20): group (A): Lithium disilicate glass-ceramic (IPS e-max Press) with chemical structure SiO_2 57 – 80%, Li_2O 11 – 19% and other 1-32% (Ivoclar Vivadent, Amherst, NY), group (B): Lithium disilicate glass-ceramic (CeraMotion) with chemical structure SiO_2, Al_2O_3, Li_2O, P_2O_5, K_2O, ZnO, ZrO_2 (Dentaurum GmbH and Co, Ispringen, Germany), group (C): Lithium disilicate glass-ceramic (Rosetta SP) with chemical structure

SiO_2, Al_2O_3, Li_2O (HASS Corporation, Germany) and group (D): Zirconia reinforced lithium silicate (CeltraPress) with chemical structure (ZrO_2 10%, SiO_2 59.0% Li_2O 14.8 % and other 16.2%) (Dentsply, USA). Each group was subdivided into two subgroups (n=10) according to the thickness of the samples (1 mm or 2 mm) which were further divided into two divisions according to the used finishing protocol; subdivision 1 was subjected to glazing only, while subdivision 2 was subjected to both polishing and glazing (n=5).

2.2. Sample Preparation

2.2.1 Designing of Specimens

Digital 3D software (ExoCAD, Darmstadt, Hessen, Germany) was used in order to accurately design specimens of 1 and 2 mm thickness and 10 mm diameter with the required shape selected using the insert object tool. The design was adjusted and saved as an STL file.

2.2.2 Fabrication of Castable Resin Discs

The STL file designed on 3D builder software was exported to a 3D printer (3D printer, ANYCUBIC, Shenzhen Anycubic Technology Co., Ltd, China) to fabricate the resin discs using castable resin (Savoy Castable LCD Green, MAKTech 3d). The 3D printed specimens were washed and cured using a wash and cure machine (ANYCUBIC, Shenzhen Anycubic Technology Co., Ltd, China), for 6 minutes. All specimens' dimensions were checked using a digital caliper.

2.2.3.Fabrication of Ceramic Discs

Each castable resin disc was sprued, invested and pressed according to the manufacturer's instructions for each ceramic material. A sprue diameter of 2.5 - 3.5 mm was attached to the edge of the resin disc and then attached to the ring (100 g). All rings were poured with the investment material (Bellavest SH, BEGO Bremer Goldschlägerei Wilh, Germany) according to manufacturer instructions using a vacuum mixer for 9 minutes and left to set for 12 minutes. The ring former was then removed and the investment was placed upside down in a burnout furnace at 850 °C for 45 minutes to preheat the investment and allow gasses to escape with no residues.

2.2.4. Heat pressing and Devesting

Pressing and firing were then carried out in the Program at ep 3010 furnace (Ivoclar Vivadent, Schaan, Liechtenstein) according to each manufacturer. The plunger size and a suitable program were selected with a starting temperature of 700°C, with a heating rate of 45°C/min and a holding time of 30 minutes. Pressing was done for 3 minutes at a pressure of 2.7 bar. After cooling down, the plunger was used to determine where to cut the investment. The investment was broken down carefully, and then discs were removed by devesting using airborne particle abrasion (50µm Al_2O_3 at 1 bar, 30 PSI).

2.3. Finishing protocols

After devesting all of the specimens, sprues were removed and the specimens of each material were subgrouped into glazed or polished and glazed subgroups.

2.3.1 Glazed Subgroup

The glazing of the specimens was done according to the manufacturer's instructions for each material. Half of the specimens were glazed on only one surface with a clear glaze and the other surface was kept untouched. Checking the dimensions of all specimens after glazing was performed using a digital caliper to ensure the absence of any dimensional changes.

2.3.2 Polished and Glazed Subgroup

For the other half of the specimens, polishing was done using a low-speed straight handpiece mounted to an adaptor. The polishing protocol was done using diapro rubber polishing cups (EVE Ernst Vetter GmbH, Pforzheim, Germany) with two grits medium and fine for 40 seconds for each grit. Then glazing was performed similarly to the procedure described in the aforementioned subgroup.

2.4. Measurement of Translucency

All samples were measured for translucency on a black and white background using a VITA easyshade spectrophotometer device (Bad Sackingen, Germany).

Each specimen was measured 3 times separately on the glazed surface with the tip of the device touching the specimen according to the manufacturer's instructions. The L, a and b coordinates were tabulated and then the mean was calculated for each separate coordinate. The VITA easy shade device was re-calibrated every 10 measurement cycles. The translucency parameter (TP) was calculated using the following equation: $TP = [(Lb\ Lw)^2 + (ab\ aw)^2 + (bb\ bw)^2]^{½}$. Where L* stands for lightness, a* stands for red/green coordinates, b* stands for yellow/blue coordinates, (b) stands for black background and (w) stands for white background.

2.5. Statistical Analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution, using the Shapiro-Wilk test and Kolmogorov–Smirnov test. Data showed parametric distribution. Comparison of main and simple effects was done utilizing one-way ANOVA followed by Tukey's post hoc test for independent variables and paired t-test for repeated measurements. P-values were adjusted for multiple comparisons utilizing Bonferroni correction. The significance level was set at $p < 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

3. Results

3.1. Effect of the Material on the Translucency Parameter

The results showed that there was no significant difference between the mean values of the translucency of the different groups ($p=0.286$). The highest value was found in Celtra Press (11.83±5.01), followed by CeraMotion (11.81±4.15), then Rosetta SP (11.60±4.86), while the least value was observed in IPS e.max press (11.37±4.54). The Mean and standard deviation (SD) values of the translucency parameter (TP) for the different materials are presented in table (1)

Table (1): Mean, standard deviation (SD) values of translucency parameter (TP) for different materials.				
Translucency Parameter (TP) (mean ± SD)				p-value
IPS e.max press	CeraMotion	Rosetta SP	Celtra press	
11.37 ± 4.54^{A}	11.81 ± 4.15^{A}	11.60 ± 4.86^{A}	11.83 ± 5.01^{A}	**0.286ns**

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant (p≤0.05) ns; non-significant (p>0.05).

3.2. Effect of Different Material Thicknesses

Mean and standard deviation (SD) values of the translucency parameter (TP) for different thicknesses are presented in table (2). 1 mm thick samples (16.04±1.87) had a significantly greater translucency value than 2 mm thick samples (7.27±0.60) ($p<0.001$).

Table (2): Mean, standard deviation (SD) values of translucency parameter (TP) for different thicknesses.		
Translucency Parameter (TP) (mean±SD)		p-value
1 mm	2 mm	
16.04±1.87	7.27±0.60	<0.001*

*; significant (p≤0.05) ns; non-significant (p>0.05).

3.3. Effect of Finishing Protocols

Polished and glazed samples (12.07±4.96) had significantly higher translucency values than glazed samples (11.23±4.22) ($p<0.001$). Mean and standard deviation (SD) values of translucency parameter (TP) for different finishing protocols were presented in table (3)

Table (3): Mean, standard deviation (SD) values of translucency parameter (TP) for different finishing protocols.		
Translucency Parameter (TP) (mean±SD)		p-value
Glazed only	Polished and glazed	
11.23±4.22	12.07±4.96	<0.001*

*; significant (p≤0.05) ns; non-significant (p>0.05).

3.4. Interaction Between Different Variables.

Mean and standard deviation (SD) values of the translucency parameter (TP) for different material thicknesses and finishing protocols within other variables were presented in table (4).

3.4.1. <u>IPS e.max press:</u>

- **<u>1 mm:</u>**

Glazed samples (15.35±1.53) had a higher value than polished and glazed samples (14.71±5.48) yet the difference was not statistically significant (p=0.807).

- **<u>2 mm:</u>**

Polished and glazed samples (7.80±0.30) had a significantly higher value than glazed samples (7.22±0.31) (p=0.018).

3.4.2. <u>CeraMotion:</u>

- **<u>1 mm:</u>**

Polished and glazed samples (16.44±0.33) had a higher value than glazed samples (16.41±0.91) yet the difference was not statistically significant (p=0.936).

- **<u>2 mm:</u>**

Glazed samples (7.93±0.65) had a higher value than polished and glazed samples (7.78±0.18) yet the difference was not statistically significant (p=0.631).

3.4.3 <u>Rosetta SP:</u>

- **<u>1 mm:</u>**

Polished and glazed samples (17.29±0.08) had a significantly higher value than glazed samples (14.54±0.75) (p<0.001).

- **<u>2 mm:</u>**

Glazed samples (7.05±0.05) had a significantly higher value than polished and glazed samples (6.64±0.09) (p<0.001).

3.4.4. <u>Celtra press:</u>

- **1 mm:**

Polished and glazed samples (17.62±0.05) had a significantly higher value than glazed samples (15.33±0.07) ($p<0.001$).

- **2 mm:**

Polished and glazed samples (7.48±0.25) had a significantly higher value than glazed samples (6.67±0.53) ($p=0.015$).

Table (4): Mean, Standard deviation (SD) values of translucency parameter (TP) for different finishing protocols within other variables.

Material	Thickness	Translucency parameter (TP) (mean±SD)		p-value
		Glazed only	Polished and glazed	
IPS e.max press	1 mm	15.35±1.53	14.71±5.48	0.807ns
	2 mm	7.22±0.31	7.80±0.30	0.018*
CeraMotion	1 mm	16.41±0.91	16.44±0.33	0.936ns
	2 mm	7.93±0.65	7.78±0.18	0.631ns
Rosetta SP	1 mm	14.54±0.75	17.29±0.08	<0.001*
	2 mm	7.05±0.05	6.64±0.09	<0.001*
Celtra press	1 mm	15.33±0.07	17.62±0.05	<0.001*
	2 mm	6.67±0.53	7.48±0.25	0.015*

*; significant ($p\leq0.05$) ns; non-significant ($p>0.05$).

4. Discussion

Ceramics are biocompatible materials that have great color stability. That's why they can be used with minimal risk in the oral cavity. However, ceramics are brittle materials that are easily broken. They are typically strengthened with particles, supported by metal, or made entirely of polycrystalline material to avoid this weakness which can affect their optical properties. There are numerous ceramic products and systems on the market that can be used in dentistry. [1] Therefore, our study aimed to examine the effect of material thickness and finishing protocols on the translucency parameter of four different ceramic materials; Lithium disilicate glass-ceramic (IPS e.max press, CeraMotion, Rosetta SP) and Zirconia-reinforced lithium silicate (ZLS) (Celtra LiSi press by Dentsply).

In the context of our study, the thicknesses used were 1, and 2 mm, which was done similarly in a previous study by Chaiyabutr et al. in 2011. Our choice of these thickness were to mimic the thickness of glass ceramics which is between 1- 2 mm depending on the amount of preparation and restoration surface. [14] Additionally, different finishing protocols can be applied to glass ceramics. Glazing involves giving the finished restorations a glass-coated surface that is both esthetically pleasing and hygienic. It is considered the best method for creating a smoother surface. [15] Glazing sprays and pastes are recognized as alternatives to glaze powder and liquid techniques for performing crystallization and glaze firing in one step. However, studies claim that manual polishing techniques, as opposed to glazing techniques, can produce smoother surfaces. [16]

The current findings revealed that there is no significant effect on translucency regarding the material. However; Celtra press had the insignificantly highest translucency value, followed by CeraMotion then Rosetta SP while IPS e.max press had the lowest value regardless of the finishing protocol used. Celtra Press might have the highest value due to its uniform, fine, rod-like crystalline structure with an average crystal size of roughly 0.5 mm. It also has a homogeneous structure and smaller crystal particles than lithium disilicate glass-ceramic, which typically has crystals of about the same size. [17]

Regarding the material thickness; the thickness of the ceramic material in our study showed that 1 mm thick samples (16.04±1.87) had a significantly higher translucency value than 2 mm thick samples (7.27±0.60). A statistically significant difference was noticed between the two thicknesses ($p<0.001$). Ilie and Stawarczyk in 2014 found that the smaller the thickness of glass ceramic the better the translucency value. They experienced the highest translucency with 0.5 mm thickness of the ceramic. [8] It can be justified that reducing material thickness decreases the amount of light absorption. In fact, the thickness of the specimen as well as the scattering and absorption all affect how much of the incident light is reflected, absorbed, and transmitted. [18]

Similarly, the finishing procedure, polished and glazed samples had significantly higher translucency values than glazed samples. In fact, light direction is changed when light transmits through a roughened surface. It is assumed that glaze application alone does not ensure that all defects on an excessively rough surface will be entirely filled in; the existence of bubbles and unfilled regions may account for the observed poor optical performance. That's why the polishing procedure enhanced the translucency of the ceramic material. [19]

In our study, all different glass-ceramic materials have higher translucency parameters. Polished and glazed Celtra press showed the highest translucency parameter, which was consistent with a similar study where ZLS was more polishable than LDS. In contrast to the LDS material surface, which displayed needle-shaped crystals and an average crystal size of about 1.5 mm with the scanning electron microscopy, the ZLS material surface had a uniform, fine, rod-like crystalline structure. The smaller color change of polished ZLS than polished LDS may be explained by the smaller crystal particles and homogeneous structure of ZLS. The greater translucency of ZLS than LDS may be due to the larger crystal dimension of LDS and higher firing temperature, which hinder light transmission and reduce the translucency. [20]

The present study has a number of limitations, including The study's in vitro design does not accurately represent intra-oral circumstances. Increased intraoral temperatures might affect the kinetics of a chemical reaction. Hence, further in vivo investigations are needed. Therefore, other environmental factors might give us different results such as tooth substrate, cement, saliva, etc.

Conclusion

To sum up, despite there is no significant difference between different glass-ceramic materials regarding the translucency parameter. The less thickness of a glass-ceramic material, as well as adding the polishing step prior to glazing, results in a better translucency effect of a restoration.

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