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EVALUATION OF TRANSLUCENCY AND STRENGTH OF TWO GLASS CERAMICS AFTER DIFFERENT SURFACE TREATMENTS

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ABSTRACT

Objective: To investigate the effect of different surface treatments on biaxial flexural strength and translucency of two different glass-ceramics. **Materials and Methods:** Sixty disc-shaped specimens (10 mm x 0.3 mm) were divided into two groups (n=30) according to the type of the ceramic material; lithium disilicate ceramic (IPS e.max CAD), and leucite reinforced ceramic (IPS Empress CAD). Each group was divided into three subgroups (n=10) according to the surface treatment applied; whether hydrofluoric acid etching, sandblasting, or no treatment. Translucency Parameter was measured over black and white backgrounds using dental spectrophotometer VITA Easyshade Compact, while bi-axial flexural strength was measured using a ball on ring fixture test. Data was statistically analyzed by ANOVA and Tukey's post hoc analysis ($\alpha = 0.05$). **Results:** There was a significant difference ($P < 0.05$) in translucency parameter between all surface treatments used for IPS E.max CAD groups, while for IPS Empress CAD there was a significant difference ($P < 0.05$) in translucency between both the control and hydrofluoric acid groups as well as between hydrofluoric acid and sandblasted groups. There was no significant difference in bi-axial flexural strength between different types of surface treatments used for IPS E.max CAD. IPS Empress CAD groups showed a significant difference ($P < 0.05$) only between the control and the hydrofluoric acid groups. **Conclusions:** IPS E.max CAD had higher translucency and biaxial flexural strength. Different surface treatments used affected the flexural strength and translucency negatively in both materials used.

KEYWORDS: Flexural strength, glass ceramics, lithium disilicate, translucency, surface treatments

INTRODUCTION

Esthetic laminate veneers are considered of remarkable clinical performance and demonstrate a breakthrough for esthetic dentistry, especially with the continually evolving materials and techniques. With the increasing call for minimally invasive dentistry, the use of minimum thickness ceramic laminate veneers is becoming of high demand. Nevertheless, attaining ideal esthetics, together with strength and proper bonding, is still considered a challenge [(1-3)]. The reproduction of natural teeth' optical characteristics, specifically the innate translucency found in enamel, is a pivotal factor for the esthetic success of ceramic laminate veneers. Hence, the translucency of ceramic material used is regarded as being a critical factor in controlling the esthetic outcome of the restoration [(4,5)].

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The translucency parameter (TP) is defined as the color difference of a given material thickness over a white and a black background. It can be calculated using either the CIELab formula or the CIEDE2000 formula. CIEDE2000 color difference formula was reported to provide consistently more accurate results than the CIELab formula in the evaluation of translucency and was thus recommended for use for translucency analysis in dentistry [6].

With the growing use of dental CAD-CAM systems, ceramics with different compositions have been introduced to satisfy patients' demands for natural looking restorations. Among the most famous of those ceramics for the fabrication of laminate veneers are both lithium disilicates and leucite re-inforced glass-ceramics that show good flexural strength in addition to their excellent optical properties in terms of translucency which make them both functionally and esthetically pleasing [7-9].

Biaxial flexural strength is related to the long term clinical performance of dental materials [10]. It is regarded to provide more useful data than uniaxial flexural strength since dental materials are subjected to multiaxial loading in the oral cavity [11]. The clinical success of a ceramic restoration depends on its intrinsic properties in terms of flexural strength and translucency. It also depends on the quality and duration of the resin cement-ceramic bonding interface [12]. In a previous study, different surface treatment methods for bonding of lithium disilicate ceramic veneers were tried, and their effect on translucency was studied. It was found out that different surface treatments like sandblasting and laser irradiation negatively affected the translucency of the veneers, especially at lower ceramic thicknesses. It was also found that hydrofluoric acid etching was shown not to affect translucency [13].

Hydrofluoric acid-etching followed by silanization, is considered the gold standard surface treatment for vitreous ceramics. However, this etching is considered by some as controversial[14-16]. However, in a study performed to determine the effect of different surface treatments on surface roughness of IPS Empress 2, it was noted that acid etching had much less effect on increasing surface roughness than air abrasion [17].

Since both flexural strength and translucency are considered to be closely related to the material microstructure [18] and since the effect of hydrofluoric acid etching is becoming controversial [19-22], this study was carried out with the aim to investigate the effect of different surface treatment methods on both biaxial flexural strength and translucency parameter of two different glass-ceramic materials. The null hypothesis was that both the material and surface treatment methods would not affect the biaxial flexural strength or translucency parameter.

MATERIALS AND METHODS

A total of 60 specimens of two all-ceramic materials; lithium disilicate ceramic (IPS e.max CAD, Ivoclar Vivadent) (LD group), leucite reinforced glass ceramic (IPS Empress CAD, Ivoclar Vivadent) (L group) were tested for their translucency and flexural strength after receiving different surface treatments. (Table 1).

TABLE (1) Materials' Composition

Group	Material	Composition	Manufacturer
LD	Lithium disilicate re-inforced glass ceramic	SiO_2 (57–80%wt), Li_2O (11–19%wt), K_2O (0–13%wt), P_2O_5 (0–11%wt), ZrO_2 (0–8%wt), ZnO (0–8%wt), Al_2O_3 (0–5%wt) MgO Lot. (0–5%wt), colouring oxides (0–8%wt)	Ivoclar Vivadent-Schaan, Lichtenstein)
L	Leucite reinforced glass ceramic	Leucite crystal: $KAlSi_2O_6$ (35–45%vol) Standard composition: SiO_2 (60–65%wt), Al_2O_3 (16–20%wt), K_2O (10–14%wt), Na_2O (3.5–6.5%wt), other oxides (0.5–7%wt), pigments (0.2–1%wt)	Ivoclar Vivadent-Schaan, Lichtenstein)

Both; the partially crystallized IPS e.max CAD blocks and the fully crystallized IPS Empress CAD blocks were used for the construction of disc-shaped specimens 10mm (diameter) x 0.3 mm (thickness). IPS e.max CAD specimens were then crystallized in a ceramic furnace (Programat P300/G2, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer recommendations. The bottom surfaces of all specimens were finished and wet polished with a grinder-polisher machine (Buehler® EcoMet® 250 Grinder-Polisher and AutoMet® 250 Power Head) to make sure the surface is perfectly smooth and flat. A digital caliper (GA182, Grobet Vigor) was used to measure each specimen thickness to ensure the precise final thickness of the specimens (Table 2).

TABLE (2) Sample Grouping

Ceramic Material		**IPS. e.max CAD (LD) n=30**			**IPS Empress CAD (L) n=30**		**Grand Total**
Surface Treatment	Untreated Control Group (UN) n=10	Hydrofluoric Acid Etching (HF) n=10	Sandblasting (SB) n=10	Untreated Control Group (UN) n=5	Hydrofluoric Acid Etching (HF) n=10	Sandblasting (SB) n=10	60

Thirty specimens of each ceramic material were then divided into three sub-groups according to the surface treatment method applied (n=10) being either hydrofluoric acid etching (HF), sandblasting (SB), or an untreated control group (UN) (Table 2). For the (HF) group, the unpolished surfaces of the specimens were treated by 9% hydrofluoric acid (Ultradent Porcelain Etch) (Ultradent Products, Inc. 505 West Ultradent Drive, South Jordan.) for 20 seconds for the IPS e.max CAD specimens and for 1 minute for the IPS Empress CAD specimens, washed under running water and air-dried. For the (SB) group, the unpolished surfaces of all specimens were coated with 30 µm Al_2O_3 particles at a pressure of 2.5 bars for 20 seconds using a sandblasting unit (Renfert, Germany). The specially designed mold was used to fix the specimens at a distance of 10 mm from the sandblasting unit and prevent their movement during the coating process. After treatment, all specimens were cleaned in digital ultra-sonic cleaner (MSC., China) for 180 seconds and left to dry.

The translucency parameter representing the color difference between a material of a uniform thickness over a white and a black background was measured using the dental spectrophotometer VITA Easyshade Compact (Vita, Zahnfabrik H. Rauter GmbH&Co. KG.). Each specimen was measured three times against both white and black backgrounds. The TP_{00} values were calculated using the CIEDE2000 equation as the color difference between readings against the black and white backgrounds for the same specimen.

$$TP_{00}=\sqrt{\left(\frac{L'b-L'w}{KL\,SL}\right)^2}+\left(\frac{C'b-C'w}{KC\,SC}\right)^2+\left(\frac{H'b-H'w}{KH\,SH}\right)^2+RT\left(\frac{C'b-C'w}{KC\,SC}\right)\left(\frac{H'b-H'w}{KH\,SH}\right)$$

The subscript "b" refers to the color coordinates over the black background, while "w" refers to those coordinates over the white background. "RT" describes the interaction between hue and chroma in the blue region. "SL", "SC", and "SH" are weighting factors for lightness chroma and hue. Finally, "kL", "kC", and "kH" are the parametric weighting factors for variations in experimental conditions. In the present study, the parametric factors of the

CIEDE2000 color-difference formula were set to 1. The TP_{00} values were calculated by measuring the color difference (ΔE_{00}) between the L*,a*,b* values against both white and black backgrounds.

All specimens were tested for bi-axial flexural strength using a ball on a ring fixture. Discs were placed on an 8 mm diameter circular metal support. The load was applied with a universal testing machine (Lloyd Instruments) through a spherical punch 3.8 mm in diameter at the center of the specimen at cross-head speed 1 mm/minute. The unpolished surface was placed in tension for all specimens, while the polished side was loaded. A thin sheet of tin-foil was placed between each sample and the load applicator tip to ensure uniform load distribution.

The fracture's load was recorded, and biaxial flexural strength was calculated with the following equation;

$$\sigma = P/h^2\{(1+v)\ [0.485x\ In\ (a/h)+0.52]+48\}$$

Where (**σ**) is the biaxial flexural strength in (MPa), **(P)** is the measured load at fracture in (N), **(a)** is the radius of the circular knife-edge support in (mm), **(h)** is the specimen thickness and **(v)** is Poisson's ratio for the material. For IPS E.max CAD v=0.23 and for IPS Empress CAD v=0.25.

RESULTS

Translucency Parameter

One-way ANOVA followed by pairwise Turkey's post hoc tests showed a statistically significant difference ($P < 0.05$) between all surface treatments used for both the (LD) and (L) groups. For the (LD) groups, the (UN) sub-group showed the highest TP_{00} (TP_{00}=18.4) while (SB) sub-group showed the lowest TP_{00} value (TP_{00}=12.9). For the (L) groups, the (UN) sub-group showed the highest TP_{00} (TP_{00}=17.3) while the (HF) sub-group showed the lowest value (TP_{00}=10.6). Regardless of the surface treatment used, two-way ANOVA followed by Turkey's post hoc tests showed a statistically significant ($P < 0.05$) higher TP_{00} values for (LD) group than (L) group except in the (UN) sub-group where there was no significant difference. (Table 3).

Biaxial Flexural Strength

One-way ANOVA followed by the pairwise Turkey's post hoc tests showed no statistically significant difference between different types of surface treatments used for (LD) group. Nevertheless, the (UN) group showed the highest value (481.4679 MPa), and the (HF) group showed the lowest value of (371.5836 MPa). On the other hand, the (L) group showed a statistically significant difference ($P < 0.05$) only between the (UN) and the (HF) groups. Irrespective of the surface treatment used, Two-way ANOVA followed by pairwise Turkey's test showed a statistically significant ($P < 0.05$) higher flexural strength values for (LD) group compared to (L) group.(Table 4)

TABLE (3) Mean (SD) TP_{00} values for different materials under different surface treatments

Surface Treatment	Mean TP_{00} (SD)	
	IPS e.max CAD	**Empress CAD**
UN	18.4 (0.3)^{a}	17.3 (1.6)^{a}
HF	16.5 (0.7)^{*b}	10.6(1.5)^{*c}
SB	12.9 (0.3)^{*c}	15.2 (0.3)^{*b}

(*) indicate significance between different materials.

Different small superscripts indicate significance between different surface treatments

TABLE (4) Mean (SD) Biaxial flexural strength values for different materials under different surface treatments

Surface Treatment	Mean Biaxial flexural strength (SD)	
	IPS e.max CAD	**Empress CAD**
UN	481(60)^{*a}	146 (26)^{*a}
HF	371 (93)^{*a}	96 (24)^{*b}
SB	436 (112)^{*a}	123 (26)^{*ab}

(*) indicate significance between different materials.

Different small superscripts indicate significance between different surface treatments

DISCUSSION

The optical and mechanical properties seem to be affected by the chemical composition, micro-structure, and structural differences of the materials [18, 23]. The present study aimed at evaluating both the biaxial flexural strength as well as translucency for two different glass-ceramics after different surface treatments were applied.

Both null hypotheses were partially refused, where it was shown that both the material as well as the type of surface treatment affected both translucency parameter and biaxial flexural strength.

In the present study, the (UN) group showed the highest (TP_{00}) value compared to different surface treatments for both (L) and (LD) groups. These higher (TP_{00}) values could be explained by the very dense union between glassy and crystalline phases in both lithium disilicate and leucite reinforced ceramics leaving no voids or gaps between them [20].

It was clear in our study that both HF acid treatment and sandblasting had a negative result on (TP_{00}) in both (L) and (LD) groups compared to the (UN) group, which agrees with what was reported by **Turgut et al.** [13,19] in two previous studies. It is known that HF acid etching causes the glassy matrix of lithium disilicate to be selectively removed, exposing the crystalline structure. The etched ceramic turns into a three- dimensional porous structure with various porosities that act as black holes, altering light scattering. This explains well the negative effect of HF acid etching [21,22,24]. The greater impact HF acid etching has over (L) group compared to (LD) group may be explained by the by the fact that leucite crystals are retained on materials' surface by pure glassy phase. This structure when exposed to strong HF etching, will suffer greater dissolution and the peripheral glassy phase surrounding leucite crystals would be totally removed, causing complete crystal dislodgements. Consequently, wider and deeper irregularities were formed [20].

On the other hand, the SB group recorded the lowest TP_{00} values for IPS E.max, where changes in surface topography have been reported to occur after SB procedures. **Kara et al.** [17] had reported that air abrasion highly increased the surface roughness of lithium disilicate ceramics. Also, **Yavuz et al.** [16], using an atomic force microscope to analyze lithium disilicate pressed ceramics' surface, showed that both SB and HF acid etching caused the most distinct sharp peaks. It has been also reported that alumina particles might be embedded into the surface of ceramics, thus decreasing the TP values[25].

It was previously stated that the threshold for translucency difference using CIEDE2000 for 50:50% acceptance was defined as 2.62, while that for perceptibility was defined as 0.62 [6]. In our study, the differences between the TP00 values of (LD) specimens that were left untreated (UN) or those of the (HF) sub-group were found to be within the 50:50% acceptance range. In the (L) groups, the differences between the TP00 values for (UN) specimens or (SB) ones were also within the 50:50% acceptance range.

Flexural strength test, on the other hand, showed a significant difference in values between the two types of ceramics used in the study with IPS e.max CAD showing higher values, which agrees well with results obtained from past studies [8,9]**.** This higher flexural strength value for IPS e.max CAD is due to the inherent microstructure of lithium disilicate. It is characterized by having a densely packed crystalline structure that hinders crack propagation where a formed crack gets trapped within the crystal in a convoluted manner.

Evaluating the effect of different surface treatments used on flexural strength, it is clear it was not the same for both types of ceramics. For IPS e.max CAD, there was no significant difference between the three sub-groups, but with the (UN) group showing the highest value. Such results agree well with what was proved when authors in earlier studies concluded that both HF acid etching and sandblasting have negatively affect the flexural strength of machined lithium disilicate though this effect was non-significant [26]. However, (SB) group still showed lower flexural strength values which is consistent with results obtained by **Rigolin F et al.**[27] who showed that sandblasting led to decrease of flexural strength of lithium disilicate specimens when compared to hydrofluoric acid etching. They reverted this to the effect of alumina particles causing defects and fissures in the ceramic surface and leading to fracture under load.

For IPS Empress CAD, though the (HF) sub-group showed lower flexural strength values than the (SB) one, yet a significant difference was found only between the (UN) and (HF) sub-groups. This coincides with what was concluded by **Bagheri H** [26], who stated that HF acid had a destructive effect on leucite re-inforced ceramics with sandblasting coming next to it in its destructive effect also reducing the biaxial flexural strength values. Also, **Chen et al.** [24] reported that HF acid etching and sandblasting may lead to surface damage of leucite based ceramics.

The present study shows that different surface treatment methods may negatively affect the translucency and strength of different types of ceramics, even if that effect is clinically unnoticeable. Further investigations regarding the effect of the preparation stump, cement color, and polymerization mode are recommended. It is also advisable to carry on more in vivo studies to see the effect of the oral environment on color and translucency of the restoration, as well as its strength and bond strength with the tooth structure.

CONCLUSIONS

Within the limitation of this study, it was concluded that IPS E.max CAD had higher (TP) as well as biaxial flexural strength at the thickness used. Different surface treatments used, whether hydrofluoric acid etching or sandblasting, both affect the flexural strength and (TP) negatively in both materials used.

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