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EVALUATION OF TRANSLUCENCY AND BIAXIAL FLEXURAL STRENGTH OF DIFFERENT CERAMIC MATERIALS (IN VITRO STUDY)

Taha Mohamed Kamel Alsharawi[1*], Hoda Mohamed Abdel Sadek [2], Tarek Salah ElDin Morsy [3]

ABSTRACT

Objective: To evaluate Translucency and Flexural strength of four ceramic materials Lithium disilicate (Emax), translucent zirconia (Bruxizir), Ultra translucent zirconia (Katana ST) and Zirconia reinforced lithium silicate (Suprinity), using two thickness, 0.5 mm and 1mm. **Materials and Methods:** Blocks of four CAD/CAM esthetic restorative materials (emax, suprinity, bruxzir and katana) were used to prepare 80 samples (disks) with the following dimensions: 10mm x 0.5mm and 10mm x 1mm for suprinity and emax ceramic material & 12mm x 0.6mm and 12mm x 1.2mm for Bruxzir and katana ceramic material. Using IsoMet 4000 micro saw by a diamond disk 0.6 mm thickness with cutting speed 2500 rpm. Then all the disks were crystallized and sintered. One Ceramic disc of each material were examined under a Reflective spectrophotometer (Model RM200QC, X-Rite, Neu-Isenburg, Germany) to determine the translucency for each disk. After that each disk was subjected to a biaxial flexural strength test. **Results:** For translucency test, at 0.5mm the highest value was found with Vita Suprinity (21.71±1.59), followed by Emax (17.89±3.47), then Bruxzir (13.27±1.86) while the lowest value was found with Katana ST (11.57±2.45). while at 1mm the highest value was found with Emax (14.78±1.63), followed by Vita Suprinity (14.65±1.58), then Katana ST (10.59±2.16) while the lowest value was found with Bruxzir (10.42±1.56). Otherwise for biaxial flexural strength, at 0.5 mm the highest value was found with bruxzir (194.04±59.50), followed by Katana ST (191.66±63.71), then suprinity (163.96±28.86), while the lowest value was found with Emax (113.70±26.76). while at 1mm the highest value was found with Katana ST (605.47±115.98), followed by Bruxzir (588.40±111.39), then Emax (474.62±68.36) while the lowest value was found with Vita Suprinity (419.50±76.96). **Conclusion:** Increasing thickness affect the flexural strength of ceramic material positively, while it affects the translucency negatively except for katana. Different ceramic material exhibited variable translucency and flexural strength values depending on their composition. Lithium disilicate materials show more translucency and lower flexural strength than zirconia materials.

KEYWORDS: Zirconia- reinforced lithium silicate, zirconium, CAD/CAM

INTRODUCTION

In the last two decades, there was a breakthrough in ceramic improvement through numerous developments in knowledge, techniques, and technology. Although to achieve esthetic and strength together is still challenge [(1)]. In the past several decades, the metal–ceramic crown has been the dominating approach for dental color replication. However, the metallic substructure, which is a total barrier to the transmission of light, gives the metal–ceramic crown an unfavorable chromatic aspect [(2)].

1. Master Candidate in Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University
2. Lecturer of Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University.
3. Professor of Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University.

• ***Corresponding author*:** dr.taha.alsharawi@gmail.com

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A variety of all-ceramic systems are commercially available and can offer a new esthetic dimension, particularly in anterior teeth. Ceramics are biocompatible and resistant to dissolution in the mouth and in contrast to certain metals, they are not susceptible to corrosion phenomena. There are no reports of allergy connected with dental ceramic whereas metals used in metal–ceramic restorations may cause allergic or toxic reactions within adjacent soft or hard tissues (3,4).

The lithium disilicate is glass reinforced ceramic which exhibits a high mechanical strength that may reach up to 400 MPa (5,6). Other chemical components may be added to a certain extent in order to improve the chemical solubility such as Al_2O_3 or ZnO. The resultant lithium disilicate in the system Li_2O–Al_2O3–SiO_2 is generally superior to the simple lithium oxide–silicon dioxide system in terms of chemical solubility (6,7,8).

The zirconia- reinforced lithium silicate (ZLS) is ceramic material based on a lithium-metasilicate (Li_2SiO_3) glass ceramic and reinforced with about 10% of zirconium dioxide (ZrO_2) that, after final crystallization process, leads to the formation of fine-grained microstructure (Li_2O-ZrO_2-SiO_2). ZLS belongs to a newly generation of materials intended for CAD/CAM use that combines the positive mechanical characteristics of the zirconia with the glass-ceramic aesthetic appearance (9).

Zirconia is the white crystalline oxide of zirconium (Zr). It's most naturally occurring form, with a monoclinic crystalline structure (10). Zirconia may exist in several crystal types (phases) depending on the addition of minor components. Typically for dental applications, about 3 wt% of yttria is added to pure zirconia (11,12). Zirconia exists in three phases: monoclinic, tetragonal, and cubic. The tetragonal phase is the most interesting because, when a crack initiates on the surface, the stress concentration at the top of the crack causes the tetragonal crystals to transform into monoclinic crystals with associated volumetric expansion. In the end, this is what shields the crack tip from the applied stress and enhances the fracture toughness (13).

Translucency is important factor which is the property of a substance that permits the passage of light, so it provides "lifelike" vitality and a natural appearance to the completed restoration(1). It is the characteristic of allowing the passage of light while scattering it in such a way that the complete image can't be clearly seen. Translucency stands somewhere between complete opacity and transparency (1). It can be adjusted by controlling the absorption, reflection, scattering and transmission of light through the material. Low reflectance and high scattering and transmission of light result in increasing translucency (1).

Flexural strength also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. (14,15). Therefore, studying the translucency and flexural strength at different thickness of ceramic material could be value. The current study the null hyposthesis, was that ceramic materials nor thickness will affect the translucency or biaxial flexural strength.

Samples grouping

Eighty disks of ceramic material were used. They were be divided into 4 groups according to ceramic material, each one has 20 samples. Each group was divided into two subgroups according to thickness of sample (0.5mm, 1mm).

Preparation of the specimens

Blocks of two CAD/CAM esthetic ceramic materials (suprinity and Emax) were used first to prepare the blocks by circulation and roundation to reshape the blocks into diameter of 10mm by isomet 4000 micro saw. (Buehler company, Lake Bluff, USA). (fig.1a,1b), cut into circular disk with the following dimensions: 10mm x 0.5mm and 10mm x 1mm for both suprinity and Emax material. (fig.1c).

MATERIALS AND METHODS

	Brand name	Material description	Manufacturer	Lot #	Chemical composition (in percentage)
1	Emax	Lithium disilicate glass ceramics	Ivoclar Vivadent AG Schaan, Liechtenstein	X31779	SiO_2 57.0 – 80.0 Li_2O 11.0 – 19.0 K_2O 0.0 – 13.0 P_2O_5 0.0 – 11.0 ZrO_2 0.0 – 8.0 ZnO 0.0 – 8.0 Other 0.0 – 12.0
2	suprinity	zirconia-reinforced lithium silicate (ZLS) ceramics	VITA Zahnfabrik H Germany	66613	SiO_2 56 - 64 Li_2O 15 - 21 K_2O 1 - 4 P_2O_5 3 - 8 Al_2O_3 1 - 4 ZrO_2 8 - 12 CeO_2 0 - 4 La_2O_3 0.1 Pigments 0 - 6
3	Bruxzir anterior	Cubic High-translucency (HT) zirconia	Glidewell Laboratories California,USA	Z0764736	ZrO_2 + HfO_2 87 - 92 Yttrium oxide 8 - 11 Other oxides 0 - 2
4	Katana UT	Cubic ultra-translucent (UT) zirconia	Kuraray Noritake Dental Inc. OKAYAMA JAPAN	DTCMD	Zirconium oxide (ZrO_2) + Y_2O_3 + HfO_3 + Al_2O_3 >99.9 Yttrium oxide (Y_2O_3) <5.15 Hafnium oxide (HfO_3) <3 Aluminum oxide (Al_2O_3) <0.5 Silicon oxide (SiO_2) <0.02 Iron oxide (Fe_2O_3) <0.01 Sodium oxide (Na_2O) <0.04

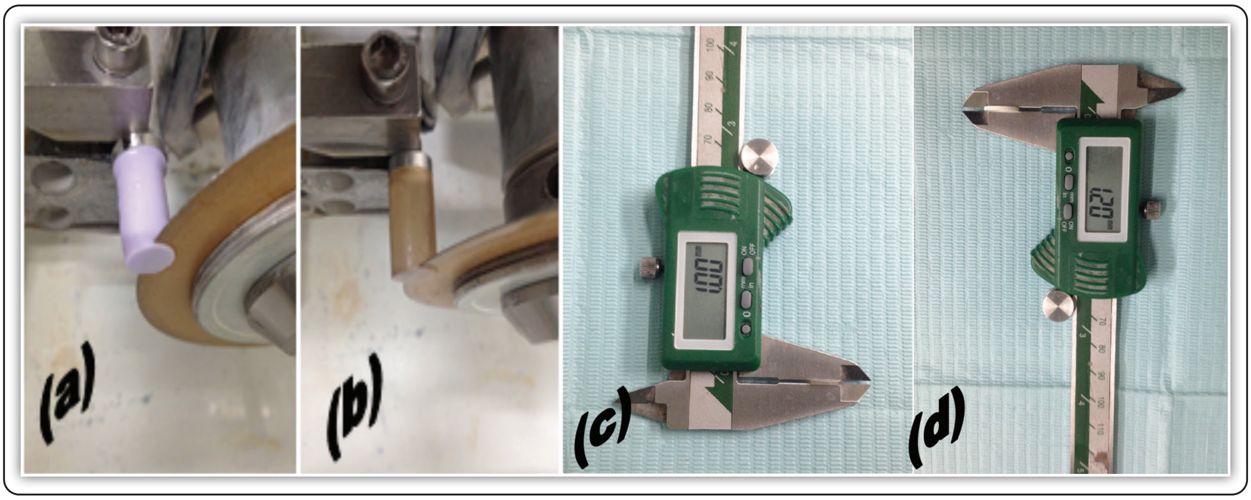

FIG (1) **(a):** Cutting emax block into disks. **(b):** Cutting suprinity block into disks **(c):** Thickness of suprinity and emax 1 mm by checking it in digital caliper. **(d):** Thickness of zirconia 1.2 mm by checking it in digital caliper.

Blanks of two CAD/CAM zirconia materials (katana and bruxzir) were used first to cut the disks into cylindrical shape with 12mm diameter. Blocks of zirconia are cut more than the actual dimension by 20% to overcome the dimensional change after sintering.

Followed by circulation and roundation with the dimension 12mm by isomet 4000 micro saw with cooling water system, by a diamond disk 0.6 mm thickness with cutting speed 2500 rpm. (Buehler company, Lake Bluff, USA). Cylinders were cemented to the metal base of other blocks.

Finally, the blocks cut into circular disk with the following dimensions: 12mm x 0.6mm and 12mm x 1.2mm for both Bruxzir and katana. (fig.1d). Using isomet 4000 micro saw.

Crystallization of Emax and Suprinity:

After cutting the disks, they were placed in a furnace for crystallization.

Emax: using Programat furnace the samples were first pre-dried at 403ºC for 6 minutes and the heating temperature was then increased at a rate of 90ºC/min until reached 820ºC and held for 10 minutes, then the temperature was then increased at a rate of 30ºC/min until reached 840ºC and held for 7 minutes.

Suprinity: using VITA VACUMAT furnace the samples were first pre-dried at 400ºC for 4 minutes and the heating temperature was then increased at a rate of 55ºC/min until reached 840ºC and held for 8 minutes.

Sintering of zirconia:

Bruxzir: using infire HTC speed, Sirona Dental Systems.

Long cycle: sample were located over the sintering beads in the sintering tray which was loaded into the furnace at room temperature, the temperature was gradually increased till reaching the sintering temperature (1510°C) which was held for 120 minutes, after that the crowns were cooled down to room temperature. The total cycle time was 8 hours.

Katana: using MIHM-Vogt furnace. Using general sitting: 7 hours sample were located over the sintering beads in the sintering tray, which was loaded into the furnace at room temperature, then the temperature was gradually increased by 10°C every minute, till reaching the sintering temperature (1550°C) which was held for 2 hours, after that the crowns were cooled down gradually -10°C every minute to room temperature.

Glazing: All the eighty samples were be glazed according to manufacturer's instructions.

Spectrophotometer Test:

Translucency of the specimens were measured using a Reflective spectrophotometer for all eighty samples (Model RM200QC, X-Rite, Neu-Isenburg, Germany), (fig.2). The measurements were performed at the center of each specimen over a white (CIE L*, a*and b*) and black backing (CIE L*, a* and b*) relative to the CIE standard illuminant D65.

FIG (2) Laboratory spectrophotometer X-rite

The specimens were placed in the center of the measuring port and kept in the same position. Three ready spots were taken from each background.

The translucency parameters (TP) values were obtained by calculating the color difference of the specimens over black and white backgrounds by using the following equation:

$$TP= ((L_b^* - L_w^*)^2 + (a_b^* - a_w^*)^2 + (b_b^* - b_w^*)^2)^{1/2}$$

Where letters "b" and "w" refer to color coordinates over the black and white backgrounds, respectively. The L* values is from 0 to 100 which is a measure of lightness-darkness of the material. The greater the L* is, the lighter the specimen. The a* and b* values represent the redness-greenness and yellowness–blueness. Positive a* relates to the amount of redness and negative values relate to greenness of the specimen. b* coordinate is a measure of the Chroma along the yellow-blue axis. Positive b* values relate to the amount of yellowness, while negative values relate to blueness of the specimen. [101]

Biaxial flexural strength Test:

Samples were subjected to a biaxial flexural strength test. Strength was measured using the biaxial flexural strength test, as described in (ISO standard 6872) for dental ceramics. To support the test specimen, three hardened steel balls, with a diameter of 1.8 mm, were positioned 120° apart on a support circle with a diameter of 8 mm. (fig.3a) The disc shaped specimens were positioned concentrically on these supports and the piston on three-ball test (15; Standard F-394-78), was used to fracture the discs. The load was applied at their center with a flat end punch tip steel piston that was 2 mm in diameter. The cylinder applied the load perpendicularly (90˚) to the plane containing the tops of the support balls. Load applied at a cross head speed of 0.5mm/min until failure occurred. Using a computer controlled universal testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a loadcell of 5kN and data were recorded using computer software (Bluehill computer software). The load P is generally assumed to be distributed uniformly on the contact area between the piston and the loading surface in analytical modeling.

The disk was mounted with a thin polyethylene sheet between the flat-ended loading cylinder and the glazed disc surface. To achieve homogenous stress distribution and minimization of the transmission of local force peaks. The first surface of the disk was the tension side while the opposite surface was the loaded one. The load to failure (N) of each sample was recorded and the biaxial flexural strength (MPa) was calculated. (Fig. 3b)

Biaxial flexural strength was calculated based on the recorded load at fracture using the standard equation:

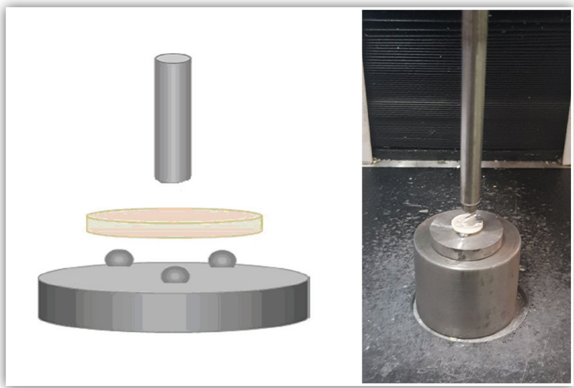

FIG (3) (a): Schematic drawing of biaxial flexture strength test.
(b): Ring with 3-ball bearing support used for test.

$$S = -0.2387P\,(X - Y)/d2$$

Where S is the biaxial flexural strength at fracture (in MPa), P is the load at fracture (in N), and d is the specimen thickness at fracture origin (in mm).

The X $\{X = (1 + v)\ \ln(B/C)2 + ((1 - v)/2)\ (B/C)2\}$ and

Y $\{Y = (1 + v)\ (1 + \ln(A/C)2) + (1 - v)\ (A/C)2\}$,

A is the support sphere radius (mm), B is the radius of the tip of the piston (mm), and C is the specimen radius (mm). V is the Poisson's ratio was used 0.25 on it is considered the standard recommendation.

RESULTS

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Two-way ANOVA was used to study the effect of different tested variables and their interaction. Comparison of main and simple effects were done utilizing pairwise t-tests with bonferroni correction. Spearman rank order correlation coefficient was used to study the correlation between biaxial flexural strength and translucency parameter. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with IBM, SPSS (IBM Corporation, NY, USA, SPSS, Inc., an IBM Company). Statistics Version 26 for Windows.

TABLE (1) Effect of different variables and their interactions on biaxial flexural strength (MPa)

Source	Sum of squares	df	Mean square	f-value	p-value
Ceramic material	208470.51	3	69490.17	12.19	<0.001*
Thickness	2536977.95	1	2536977.95	445.03	<0.001*
Material * Thickness	74649.66	3	24883.22	4.36	0.007*

df=degree of freedom; significant (p ≤ 0.05) ns; non-significant (p>0.05)*

TABLE (2) Mean ± standard deviation (SD) of biaxial flexural strength (MPa) for different ceramic materials and thicknesses

Thickness	Biaxial flexural strength (MPa) (mean±SD)				p-value
	Emax	Bruxizir	Katana ST	Vita Suprinity	
0.5 mm	113.70 ± 26.76^{A}	194.04 ± 59.50^{A}	191.66 ± 63.71^{A}	163.96 ± 28.86^{A}	**0.071ns**
1.0 mm	474.62 ± 68.36^{B}	588.40 ± 111.39^{A}	605.47 ± 115.98^{A}	419.50 ± 76.96^{B}	**<0.001***
p-value	**<0.001***	**<0.001***	**<0.001***	**<0.001***	

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

TABLE (3) Effect of different variables and their interactions on translucency parameter (TP)

Source	Sum of squares	df	Mean square	f-value	p-value
Ceramic material	2134.11	3	711.37	156.77	**<0.001***
Thickness	734.02	1	734.02	161.76	**<0.001***
Material * Thickness	293.29	3	97.76	21.54	**<0.001***

df=degree of freedom; significant (p ≤ 0.05) ns; non-significant (p>0.05)*

TABLE (4) Mean ± standard deviation (SD) of translucency parameter (TP) for different ceramic materials and thicknesses

Thickness	Translucency parameter (TP) (mean±SD)				p-value
	Emax	Bruxizir	Katana ST	Vita Suprinity	
0.5 mm	17.89 ± 3.47^{B}	13.27 ± 1.86^{C}	11.57 ± 2.45^{D}	21.71 ± 1.59^{A}	**<0.001***
1.0 mm	14.78 ± 1.63^{A}	10.42 ± 1.56^{B}	10.59 ± 2.16^{B}	14.65 ± 1.58^{A}	**<0.001***
p-value	**<0.001***	**<0.001***	**0.077ns**	**<0.001***	

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

DISCUSSION

This study was conducted to compare the translucency and flexural strength of four ceramic materials with different structure was selected which include Emax lithium disilicate glass ceramic material, and suprinity which is zirconia reinforced lithium silicate and bruxzir and katana as poly crystalline solids ceramics. Our study was applied to compare the translucency and biaxial flexural strength of material with different thicknesses [17].

In the present study, the null hypostheis were rejected except at 0.5mm thickness. At 0.5 mm, biaxial flexural strength (MPa) highest value was found with Bruxzir (194.04±59.50), followed by Katana ST (191.66±63.71), then Vita Suprinity (163.96±28.86) while the lowest value was found with Emax (113.70±26.76). There was no significant difference between samples of different materials. In accordance with our results, Reale et al, compared the relationship between biaxial flexural strength of recently developed high-translucency zirconia, high-strength zirconia, and lithium disilicate ceramics. No significant differences were found between BruxZir anterior and Katana STML, Katana UTML and IPS e.max LT, or IPS e.max LT and IPS e.max HT (P>.05). [18]

At 1.0 mm, the highest value was found with Katana ST (605.47±115.98), followed by Bruxzir (588.40±111.39), then Emax (474.62±68.36) while the lowest value was found with Vita Suprinity (419.50±76.96). In the present study, increasing the thickness increased the flexural strength. The result of this study corresponds with that of some other studies which reported an increase in flexural strength as the thickness of the ceramic increased[19-21].

The results obtained in the present study were consistent with Kim et al., who determined the effects of the total thickness and core/veneer thickness ratio of bilayered ceramics on the flexural strength. Two groups of specimens were prepared with two different total thicknesses, 1.0 mm and 0.6 mm. The flexural strength increased with the increasing thickness of zirconia [22].

As increase in thickness of samples from 0.5 to 1mm lead to increase in flexural strength of all ceramics material due to increase thickness of material which lead to increase transformation toughness due to the more cubic phase found in 1mm than 0.5mm, also the increase of the thickness will lead to decrease crack propagation with zirconia material, so the increase of the strength was significant. Also, greater the thickness will decrease the bending force in ceramic material which explain increasing in flexural strength with higher thicknesses [23-26].

In accordance with our results, Kwon et al., compared the flexural strength of 5Y-ZP (Katana UTML) with 3Y-TZP (Katana HT) and lithium disilicate (e.max CAD). A statistically significant difference was seen between the flexural strength of the materials. The flexural strength values (MPa) were 1194 ±111 (Katana HT), 688 ±159 (Katana UTML), and 450 ±53 (e.max LT). because Katana UTML has a flexural strength greater than 500 MPa but less than 800 MPa, it is graded as a class 5 material; therefore, it should be suitable as a “substructure ceramic for three-unit prostheses involving molar restorations.” This clinical recommendation, however, should be regarded with caution, as 5Y-ZP does not have the same potential to undergo transformation toughening [27].

Although there was an agreement with a study made by Elsaka and Elnaghy. [29] who found that Zirconia-reinforced glass-ceramic had a significantly higher flexural strength value than lithium disilicate ceramic, which they attributed to the zirconia fillers used to reinforce the glassy matrix of the material.

At 0.5 mm, the highest value was found with Vita Suprinity (21.71±1.59), followed by Emax (17.89±3.47), then Bruxzir (13.27±1.86) while the lowest value was found with Katana ST (11.57±2.45). At 1mm, the highest value was found with Emax (14.78±1.63), followed by Vita Suprinity (14.65±1.58), then Katana ST (10.59±2.16) while the lowest value was found with Bruxzir (10.42±1.56). In the present study, increasing the thickness decreased the translucency and the decrease was significant except with katana. This was attributed to the increase by the light scattering of the crystals and the ceramic thickness. [33] Zirconia is composed of large particles which result in intense light scattering. [34-36]

The results obtained in the present study were consistent with Kim et al., [27] who found that the translucency decreased with the increasing thickness of zirconia. The results obtained in the present study were consistent with Sen et al., who assessed and compared the translucency of 5 monolithic CAD-CAM restorative materials. Significant differences were found among the materials concerning translucency ($P<.05$). The highest mean transparency value was obtained in the VS group. Based on the results of the present study, zirconia-reinforced glass-ceramic revealed higher mean translucency than lithium disilicate ceramic, and dual-network ceramic [37].

In a recent study, Awad et al [38] compared the TP values of various CAD-CAM materials and reported a significant difference between lithium disilicate ceramic and zirconia-reinforced glass ceramic. Zirconia-reinforced glass-ceramic was reported to have a higher mean TP value than lithium disilicate ceramic. This may be due to the difference in translucency between the materials by grain size and crystalline structure differences. After crystallization, the crystals in zirconia-reinforced glass-ceramic have a mean grain size of 500 to 700 nm, which has been reported to be 4 to 8 times smaller than lithium disilicate crystallites in lithium disilicate ceramic [39, 40].

Lithium disilicate glass ceramic specimens showed higher translucency compared to monolithic KATANA zirconia of the corresponding shade. This is due to the optical compatibility between the glassy matrix and the crystalline phase, which minimizes internal scattering of the light as it passes through the material [41].

Although there was significant in translucency between suprinity and emax at thickness 0.5mm while there was no statistically significant in 1mm thickness as increase the thickness associated with decrease the translucency so the difference in translucency was insignificant with high thickness. [41]

Concerning translucency, thicker ceramic specimens exhibited lower TP values, a finding in line with those of previous studies [42,43]. Regarding, Katana ST translucency parameter (TP), there was no significant difference between samples of different thicknesses with the lowest transparency. The translucency of zirconia specimens (both thicknesses) tended to increase with the increase in yttria content. It prefers to use bruxzir in low thickness for biaxial flexural strength and suprinity in low thickness for higher translucency.

CONCLUSION

Increasing thickness affect the flexural strength of ceramic material positively, while it affects the translucency negatively except for katana. Different ceramic material exhibited variable translucency and flexural strength values depending on their composition. Lithium disilicate materials show more translucency and lower flexural strength than zirconia materials.

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