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Translucency & Flexural strength of three lithium disilicate ceramic materials for CAD/CAM restorations (In Vitro Study)

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Abstract:
Background: *In recent years, trends for aesthetic dentistry surprisingly increased. The demands of patients for tooth-colored restorations and the availability of new types of dental ceramics with good mechanical properties have driven increased use of ceramic materials in a variety of restorative restorations.*
Materials and Methods: *Three lithium disilicate glass ceramic materials were used in this study: IPS E.max CAD (Ivoclar Vivadent Liechtenstein), Rosetta SM (HASS corporation korea) and Upcera (Shenzhen upcera co.,Ltd china). A total of 42 discs were prepared with diameter (10 mm) and thickness 0.5mm and 1mm. Discs were divided into three groups according to the material; Group (1)Emax, Group(2)Rosetta sm and Group(3)upcera. Each group was further subdivided into two subgroups according to thickness; Group (A) 0.5mm and Group (B) 1mm. Specimens were placed into a ceramic furnace for glazing and crystallization according to manufacturer's instructions. Then, the specimens were thermocycled in a water bath for 5,000 cycles between 5ºc and 55ºc with a dwell time of 30 s. Each disc was tested for translucency using spectrophotometer to calculate the color differences of the specimens over black and white backgrounds. Then, the biaxial flexural strength test was conducted according to ISO 6872:2015 using a Universal Testing Machine.*
Results: *Finally, the results were analyzed via Two-way ANOVA ($p\leq0.05$) and Bonferroni's multiple comparison tests. For Translucency, the highest translucency parameter (TP) value was found in Rosetta, followed by Emax, while the lowest value was found in Upcera samples. And value of Upcera samples was found to be significantly lower than values of other materials. Translucency increases with the decrease in ceramic thickness for the three ceramic materials. While, for Biaxial Flexural Strength, the highest value was found in E.max, followed by Rosetta, while the lowest value was found in Upcera samples. And value of Upcera samples was found to be significantly lower than values of other materials. And 1 mm thick samples had significantly higher value than 0.5 mm thick samples.*
Conclusion: *E.max and Rosetta showed no significant difference in translucency and flexural strength and both were better than Upcera in translucency and flexural strength. By increasing the thickness, the translucency decreased and the flexural strength increased regardless the material.*
Key Word: *lithium disilicate ceramics, Thermocycling, Translucsency, Biaxial flexural strength.*

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I. Introduction

Recent years have witnessed a growing demand for dental aesthetics accompanied by rising concerns regarding metal allergies, resulting in the increasing use of metal-free all ceramic restorations, which are now expected to reproduce not only the shade and luster of natural teeth but also their natural translucency [(1).] Different processing methods such as: conventional porcelain build up, press technique, and CAD/CAM technology are adopted to process various ceramic materials. Lithium disilicate glass ceramic materials, which can be processed either by lost wax pressing or by milling via CAD/CAM, are widely employed for crowns, inlays, onlays, laminates and occlusal veneers in both anterior and posterior regions [(2).]

Aesthetics has become a primary criterion for successful fixed prosthodontics treatment, especially regarding restoration of the front teeth. The aim of aesthetic dentistry is to create a restoration which does not differ in color from natural teeth. Therefore, optical properties of restorative materials are of exceptional importance. In dental prosthodontics, ceramic materials are considered superior materials to composites from the aesthetical point of view because of their excellent optical properties [3].

The color and appearance of teeth is a complex phenomenon which includes a number of factors [4]. Natural teeth are not of a uniform structure and are characterized by different color and grades of translucency from the cervical to the incisal part. Translucency is the relative amount of passage of light through an object [5]. Translucency of the restorative material gives natural appearance and vitality to the restoration. Therefore, in order to achieve optimum aesthetic results, in addition to mimicking the color of natural teeth, it is equally important to mimic their translucency [6].

Glass-ceramic is a material that mimics dental tissue to a great extent, and has the best optical properties among all prosthetic materials. The advantage of glass-ceramic over other restorative materials is its translucency, which allows the passage of light in the same way as in natural teeth. It was created by developing silicate ceramics by procedures of controlled glass crystallization. It is characterized by great mechanical resistance, hardness and stability to temperature changes. The quality of a ceramic material depends on its components; type and amount of glass matrix and the type, amount, size and distribution of grains, techniques of fabrication and treatment of the restoration, and cycles and temperature of firing and cooling [3].

Ceramics are inherently brittle materials that prone to breaking under involuntary bending forces. In intraoral circumstances, the restoration should attain a strength sufficient to withstand the repeated masticatory forces [7]. Flexural strength commonly represents the capacity to tolerate chewing force. Structure of monolithic lithium disilicate can resist the masticatory stresses and dissipating stresses throughout the entire restoration [8].

CAD/CAM ceramics are popular dental restorative systems because of their high marginal integrity, translucency, less porosity and high mechanical properties (2). IPS e.max CAD has been widely used in the dental market for many years. Then, more manufacturers have entered the lithium disilicate market with other formulations.

For ceramic materials, the type of material and thickness are considered important parameters for optical and mechanical properties and changes in color and translucency may be expected when the thickness of porcelain layer changes. In prosthetic dentistry, depending on the restoration type, different thicknesses of monolithic restorations can be used because of esthetic considerations. To improve the esthetic and strength outcome of restorations, it is important to evaluate the effect of thickness on the optical and mechanical properties of monolithic ceramic restorations [9]. Therefore, this in vitro study was done to evaluate the effect of three different lithium disilicate ceramics (IPS e.max CAD, Rosetta SM, Upcera CAD) with two different thicknesses on translucency and biaxial flexural strength.

II. Material And Methods

In this in vitro study, three lithium disilicate ceramics of the same shade **(HTA1)** with two different thicknesses were used to compare their translucency and flexural strength after thermocycling.

Study Design: In-vitro study

Study Location: Study done in Department of Fixed prosthodontics, Ain-shams University, Egypt.

Study Duration: May 2018 to January 2022.

Sample size: 42 specimens.

Sample size calculation: A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups. By adopting an alpha (α) level of (0.05), a beta (β) of (0.2) (i.e. power=80%), and an effect size (f) of (0.596) calculated based on the results of a previous study (10); the predicted sample size (n) was a total of (42) samples (i.e. 21 samples per group and 7 samples per subgroup). Sample size calculation was performed using G*Power version 3.1.9.7 [11].

Procedure methodology

1- **Cylinder Formation:**

Blocks of each material were first ground into cylinders using Universal tool grinder machine C40 SungKwang[*] with a sufficient coolant for heat control preventing the formation of any cracks or flaws in the block (fig. 1). The cylinders were of diameter 10 mm. Insize Digital Caliper[**] was used for dimensions' standardization in every step (fig 2).

(*)Universal Tool Grinder machine C40, Sung Kwang Machinery-Siheung, Korea

(**) Digital Caliper Code: 1112-150, INSIZE®-India

Figure (1): Universal tool grinder machine grinding the blocks of each material into cylinders.

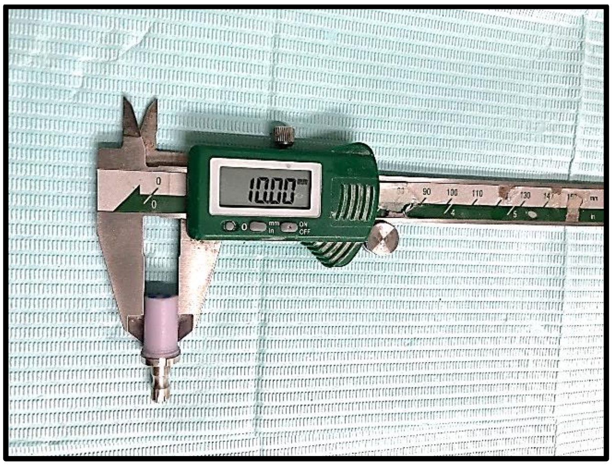


Figure (2): Insize digital caliper checking the diameter of cylinder of each block after grinding.

2- Sample preparation:

The cylinders were sliced into 14 discs for each material 7 discs with thickness 0.5 mm and 7 discs with thickness 1 mm. The slicing was done using a water cooled IsoMet™ 4000 Linear Precision Saw* with diamond disc** (IsoMet™ Buehler, thickness 0.3mm, diameter 127mm) with blade speed of 2500 rpm and a feed rate of 13.7 mm/min (Fig 3 and 4).

Ceramic slice thickness was checked using a digital caliper of accuracy 0.01 mm (Fig. 5).

(*) IsoMet™ 4000 Linear Precision Saw, BUEHLER-USA

(**) Diamond Disc, BUEHLER-Lake Bluff, IL, USA

Figure (3): IsoMet™ 4000 Linear Precision Saw.

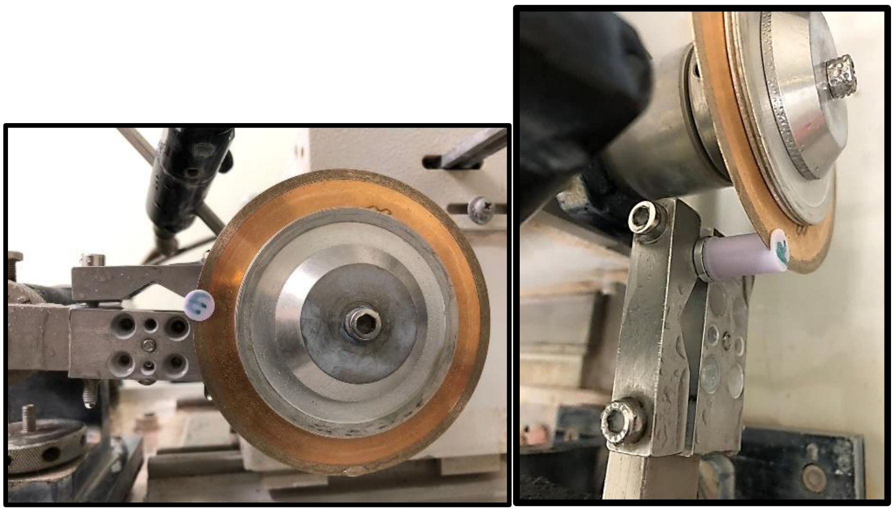
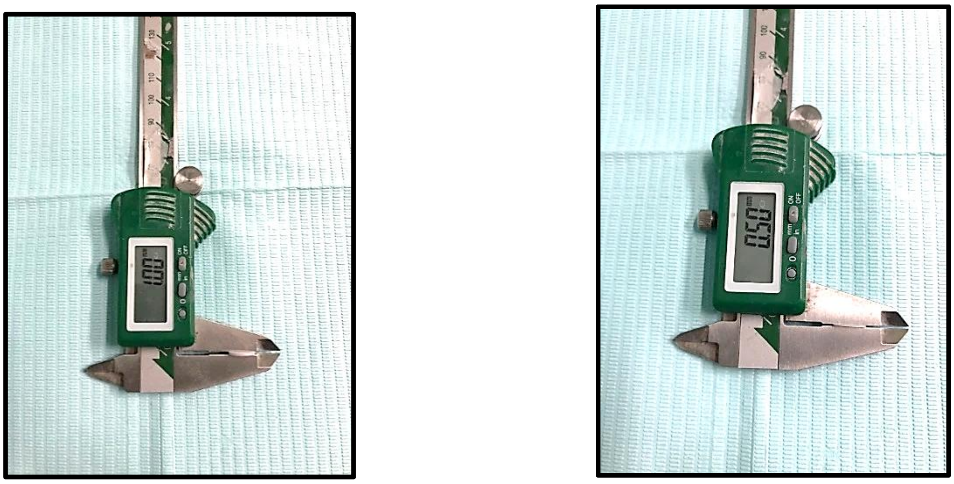


Figure (4): The diamond disc slicing the cylinder into discs.



(a) **(b)**

Figure (5): Checking the thickness of each disc using Insize digital caliper

(a) 1 mm (b) 0.5 mm

3- Glazing and Crystallization of specimens:

Before glazing, discs were cleaned to be free of grease. According to manufacturer's instructions the surfaces were cleaned thoroughly with soap and water and stored to avoid any contamination after cleaning. To assure standardization, all the following steps were done by the principal operator.

A thin layer of **IPS e.max** CAD Crystall Glaze Paste* (fig.6) was applied using Profi Renfert Glazing Brush** (fig. 7) in one direction to ensure even layer of glaze, covering the whole disc surface.

Figure (6): IPS **e**.max CAD Crystall Glaze Paste

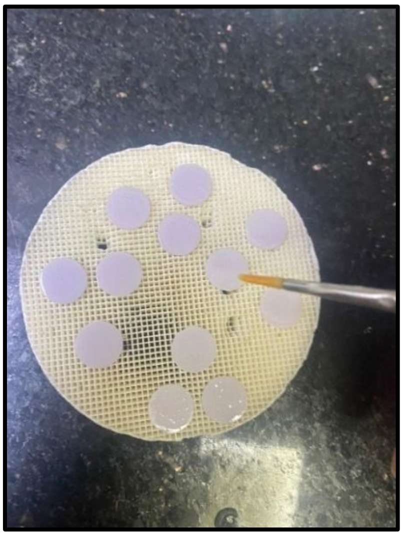


Figure (7): Glazing applied using Profi Renfert Glazing Brush

Discs were placed on a honeycomb tray (fig. 8) and fired using Ivoclar Vivadent Programat P310 Furnace***(fig. 9) according to the manufacturer's firing recommendation table for each material (table 1, 2 and 3) (fig.10,11 and 12).

Figure (8): Discs placed on honeycomb tray for firing

(*) IPS **e**.max CAD Crystall Glaze Paste by Ivoclar Vivadent- Liechtenstein.
(**) Profi ™ Glazing Brush, Renfert-Germany
(***) Programat P310 Furnace, Ivoclar Vivadent-Germany

Figure (9): Glazing and crystallization of the specimens using Ivoclar Vivadent Programat P310 Furnace

Table (1): Crystallization parameters for **E.max CAD:**

Furnace	Stand-by temp B [°C/°F]	Closing time S [min]	Heating rate t1 [°C/°F/min]	Firing temperature T1 [°C/°F]	Holding time H1 [min]	Heating rate t2 [°C/°F/min]	Firing temperature T2 [°C/°F]	Holding time H2 [min]	Vacuum 1 11 [°C/°F] 12 [°C/°F	Vacuum 2 21 [°C/°F] 22 [°C/°F]	Long-term cooling L [°C/°F]	Cooling rate tl [°C/°F/min]
Programat CS/CS2 Program	403/757	6:00	90/162	820/1508	0:10	30/54	840/1544	7:00	550/820 1022/1508	820/840 1508/1544	700/1292	0

Figure (10): Firing cycle of E.max CAD

Table (2): Crystallization parameters for **Rosetta:**

Entry temperature	Heating rate	Final Temperature	Holding Time	Lowering Table	Vacuum On	Vacuum Off
400 °C	60 °C / min	840 °C	10:00 min	700 °C	550 °C	840 °C

Figure (11): Firing cycle of Rosetta SM

Table (3): Crystallization parameters for **Upcera CAD:**

	Stand by temperature °C	Drying time min	Heating rate °C/mm	Holding temperature °C	Retention time mm	Vacuum begin °C	Vacuum close °C	Firing temperature °C
Second stage heat up	403	6:00	60/30	770/850	0:10/10:00	550/770	770/850	550
First stage heat up	403	6:00	40	850	15:00	550	850	550

Figure (12): Firing cycle of Upcera CAD

4- Thermocycling of specimens:

All the specimens were subjected to thermocycling through THE- 1100 SD Mechatronic Thermocycler machine[*]. Specimens were subjected to 5,000 cycles representing 6 months intraoral function [(12)]. Each cycle was exposed to hot water bath with temperature of 55°C, and cold water bath with temperature of 5°C (Fig. 13).

Figure (13): Thermocycler

5- Assessment of translucency:

Each disc were tested for translucency using spectrophotometer to calculate the color differences of the specimens over black and white backgrounds.

Translucency parameter (TP):

A spectrophotometer[**] in tooth Single mode (fig. 18) was used to record the CIELAB coordinates (L^*, a^* and b^*) of the ceramic samples. Translucency parameter (TP) values were determined by calculating the color difference between readings against black and white backgrounds for the same specimen, according to the following equation:

$$TP=\sqrt{}\,(L*B-L*W)2+(a*B-a*W)2+(b*B-b*W)2$$

where the subscripts *B* and *W* refer to color coordinates over black and white backgrounds, respectively [(13)]. The greater the TP value, the higher the translucency of the ceramic specimen.

Figure (1): Backing the discs with white and black backgrounds using 'Agilent Cary 5000 spectrophotometer'

(*)THE-1100 , SD MECHATRONIK GMBH

(**) Agilent Cary 5000 spectrophotometer, USA

6- **Biaxial Flexural Strength Test:**

All discs of each material were tested for biaxial flexural strength (BFS) according to the guidelines of ISO standard 6872 for testing dental ceramics materials. The test was done using piston-on-three ball technique in a universal Testing Machine Instron-3345* (Fig. 14) together with Instron BlueHill universal software [14].

Figure (14): Universal testing machine Instron-3345

3 standard steel balls with a diameter of 3.4 mm forming an equilateral triangle 60, resting on a support circle with a diameter of 14mm, were used for supporting the tested disc (Fig. 15).

Figure (15): Disc supporting platform with the three symmetrically spaced steel balls

(*)Universal Testing machine Instron-3345, Instron-UK

Each disc was placed centrally on the steel balls with the glazed surface upwards (Fig. 16). The load was applied from above at the center of the disc by a piston of 1.4±0.1mm diameter and 1mm/min crosshead speed at room temperature until fracture occurred (Fig. 17 and 18).

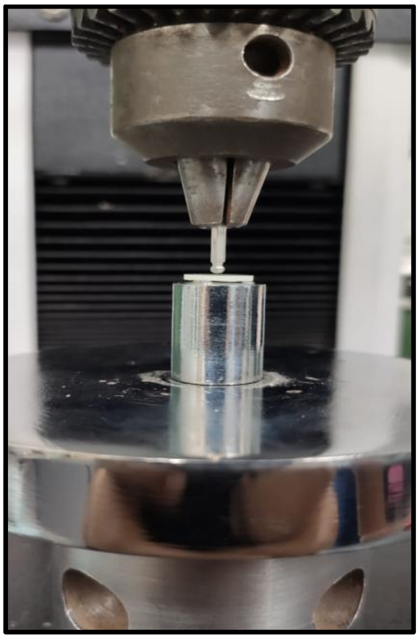


Figure (16): Load applied at the center of the specimen

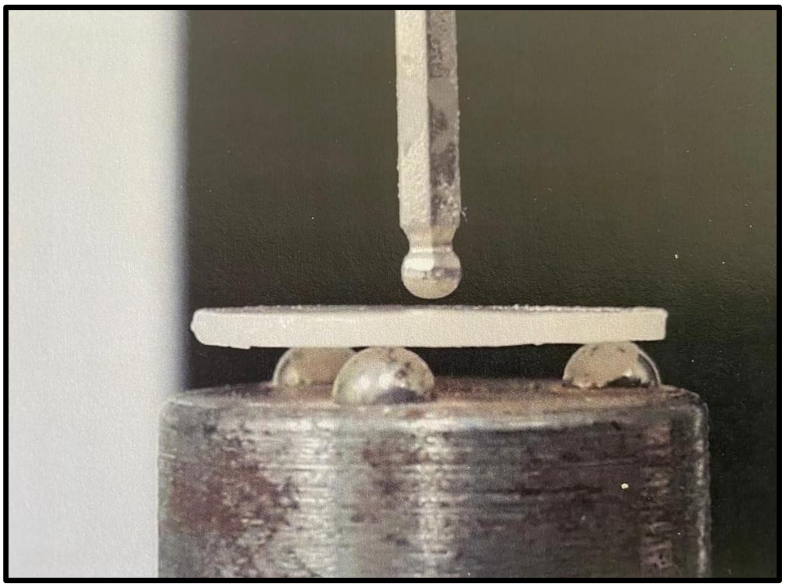


Figure (17): Close-up view of metallic platform, steel balls, ceramic disc and piston

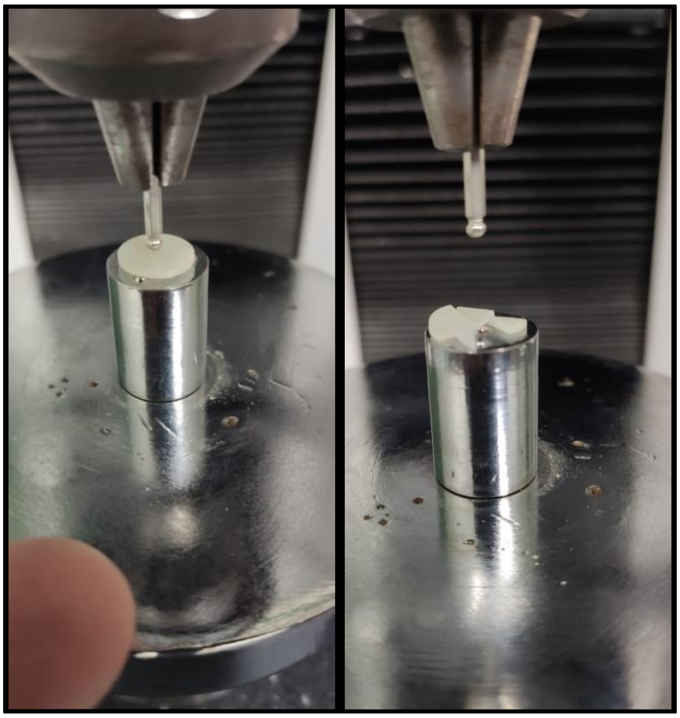


Figure (18): Load applied on the specimen till fracture occurred

Definitive fracture load for each sample was recorded (in N) and biaxial flexural strength was calculated from the following equation:
The biaxial flexural strength (in Megapascals) was calculated using the following equation:

$$\boldsymbol{\sigma = -0.2387\ P\ (X - Y)/b^2}$$

where,
σ is the maximum center tensile stress (in MPa)
P is the total load at fracture (in N)
b is the specimen thickness at the fracture origin (0.5mm/1mm)

$$\mathbf{X = (1 + v)\ ln\ (r_2/r_3)^2 + [(1 - v)/2]\ (r_2/r_3)^2}$$
$$\mathbf{Y = (1 + v)\ [1 + ln\ (r_1/r_3)^2] + (1 - v)\ (r_1/r_3)^2}$$

In which,
v is Poisson's ratio (0.25) the standard value for conventional ceramics
$\mathbf{r_1}$ is the radius of the support circle (6mm)
$\mathbf{r_2}$ is the radius of the loaded area (0.75mm)
$\mathbf{r_3}$ is the radius of the specimen (5mm)
The results for the specimens in MPa were tabulated.

Statistical analysis

Numerical data were explored for normality by checking the data distribution using Shapiro-Wilk test. Data showed parametric distribution so; they were 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 multiple t-tests with bonferroni correction. The significance level was set at p ≤0.05 within all tests. Statistical analysis was performed with IBM® SPSS® Statistics Version 26 for Windows.

® IBM Corporation, NY, USA.
®SPSS, Inc., an IBM Company.

III. Result

I-Translucency parameter (TP)

1. Descriptive statistics:

Table (4): Descriptive statistics for translucency parameter (TP) for different groups

Material	Thickness	Mean	Std. Deviation	Median	Range
Emax	**0.5 mm**	23.48	1.73	24.03	4.28
	1 mm	20.31	1.49	20.11	4.01
Rosetta	**0.5 mm**	24.62	0.23	24.54	0.56
	1 mm	21.31	0.23	21.26	0.63
Upcera	**0.5 mm**	19.46	0.19	19.47	0.46
	1 mm	15.78	0.21	15.75	0.55

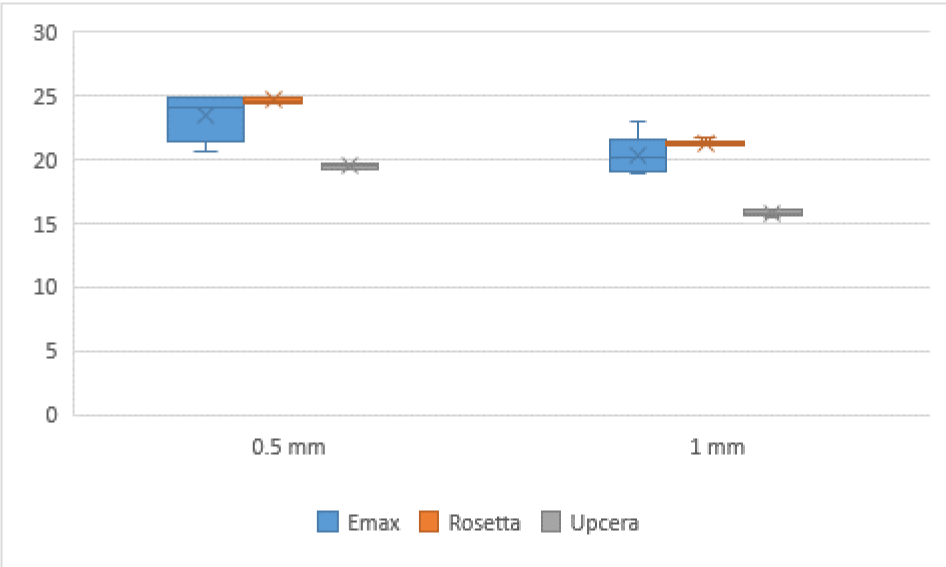


Figure (19): Box plot showing translucency parameter (TP) value for different groups

2. Effect of different variables and their interaction:

Effect of different variables and their interaction on translucency parameter (TP) were presented in table (5).

Material type and sample thickness had a significant effect on translucency ($p<0.001$), while the effect of their combined interaction was not statistically significant ($p=0.760$).

The mean values with their statistical significance are shown in table (6) and figures (20 and 21).

Table (5): Effect of different variables and their interactions on translucency parameter (TP)

Source	Sum of Squares	df	Mean Square	f-value	p-value
Material	223.59	2	111.79	124.34	**<0.001***
Thickness	120.19	1	120.19	133.68	**<0.001***
Material * Thickness	0.50	2	0.25	0.28	**0.760ns**

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

Table (6): Mean ± standard deviation (SD) of translucency parameter (TP) for different materials and thicknesses

Thickness	Translucency parameter (TP) (mean±SD)			p-value
	Emax	Rosetta	Upcera	
0.5 mm	$23.48{\pm}1.73^{A}$	$24.62{\pm}0.23^{A}$	$19.46{\pm}0.19^{B}$	**<0.001***
1 mm	$20.31{\pm}1.49^{A}$	$21.31{\pm}0.23^{A}$	$15.78{\pm}0.21^{B}$	**<0.001***
p-value	**<0.001***	**<0.001***	**<0.001***	

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

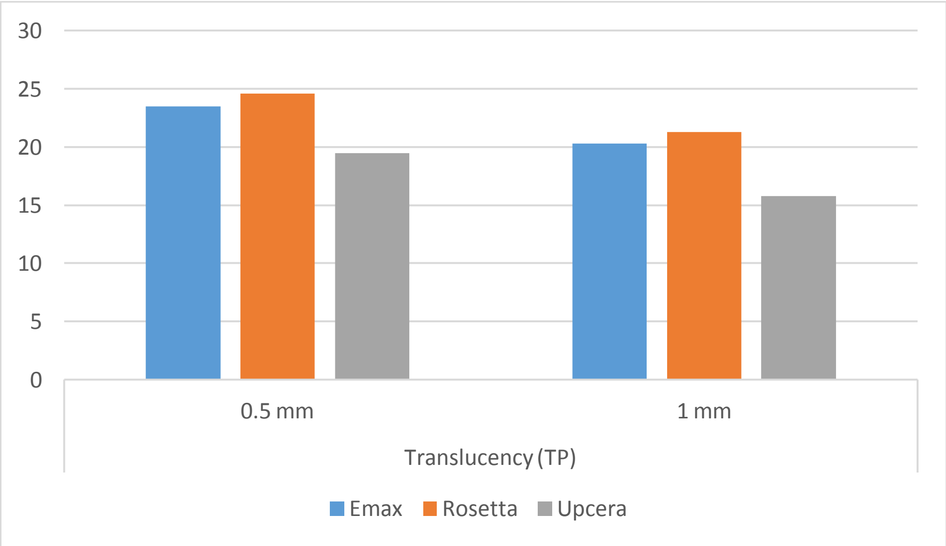


Figure (20): Bar chart showing average translucency parameter (TP) for different materials and thicknesses (A)

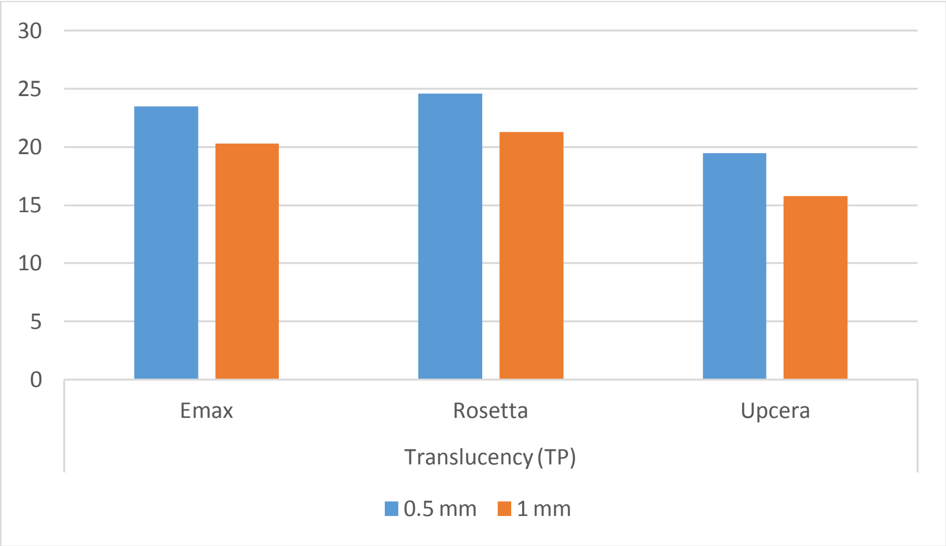


Figure (21): Bar chart showing average translucency parameter (TP) for different materials and thicknesses (B)

3. Main effects:

A-Effect of material:

Mean and standard deviation (SD) values of translucency parameter (TP) for different materials were presented in table (7) and figures (22).

There was a significant difference between values of different materials ($p<0.001$). The highest translucency parameter (TP) value was found in Rosetta (22.96±1.73), followed by Emax (21.90±2.26), while the lowest value was found in Upcera samples (17.62±1.92). Post hoc pairwise comparisons showed value of Upcera samples to be significantly lower than values of other materials ($p<0.001$).

Table (7): Mean ± standard deviation (SD) of translucency parameter (TP) for different materials

Translucency parameter (TP) (mean±SD)			p-value
Emax	**Rosetta**	**Upcera**	
21.90±2.26[A]	22.96±1.73[A]	17.62±1.92[B]	**<0.001***

Means with different superscript letters are statistically significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

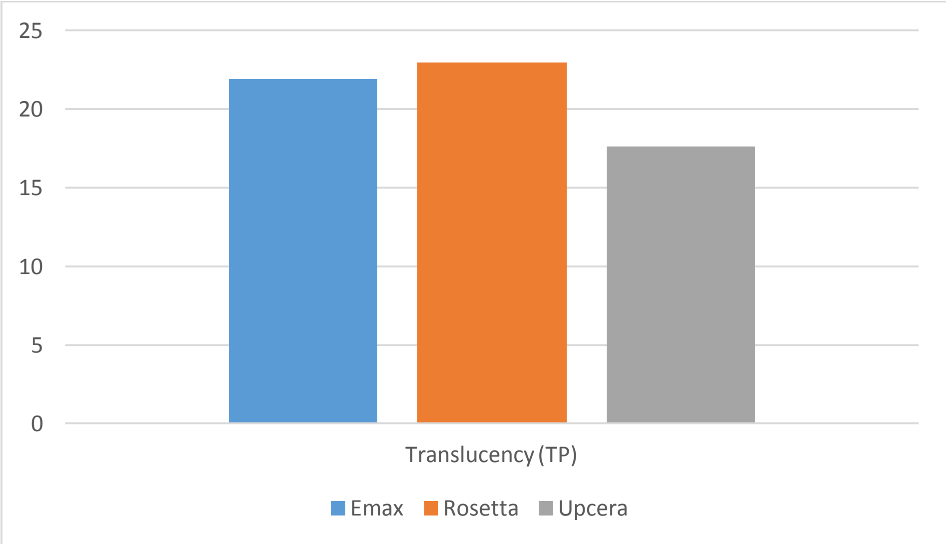


Figure (22): Bar chart showing average translucency parameter (TP) for different materials

B- Effect of thickness:

Mean and standard deviation (SD) values of translucency parameter (TP) for different thicknesses were presented in table (8) and figures (23).

0.5 mm thick samples (22.52±2.46) had significantly higher value than 1 mm thick samples (19.13±2.60) (p<0.001).

Table (8): Mean ± standard deviation (SD) of translucency parameter (TP) for different thicknesses

Translucency parameter (TP) (mean±SD)		p-value
0.5 mm	**1 mm**	
22.52±2.46	19.13±2.60	**<0.001***

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

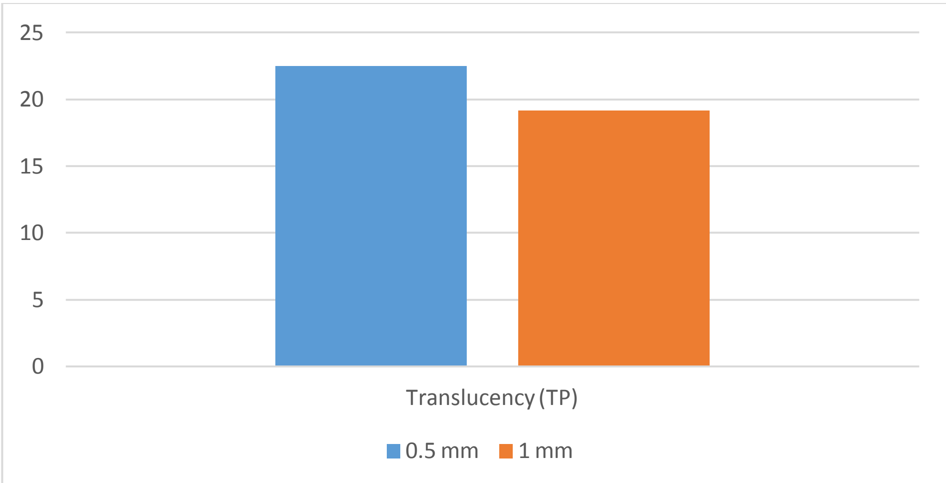


Figure (23): Bar chart showing average translucency parameter (TP) for different thicknesses

II- Biaxial flexural strength (MPa)

1. Descriptive statistics:

Table (9): Descriptive statistics for biaxial flexural strength (MPa) for different groups

Material	Thickness	Mean	Std. Deviation	Median	Range
Emax	0.5 mm	209.06	8.97	211.57	27.95
	1 mm	480.91	55.30	470.68	137.47
Rosetta	0.5 mm	198.30	10.92	198.21	31.02
	1 mm	461.95	21.59	466.11	62.95
Upcera	0.5 mm	99.62	9.47	94.17	26.28
	1 mm	349.82	27.21	340.27	67.58

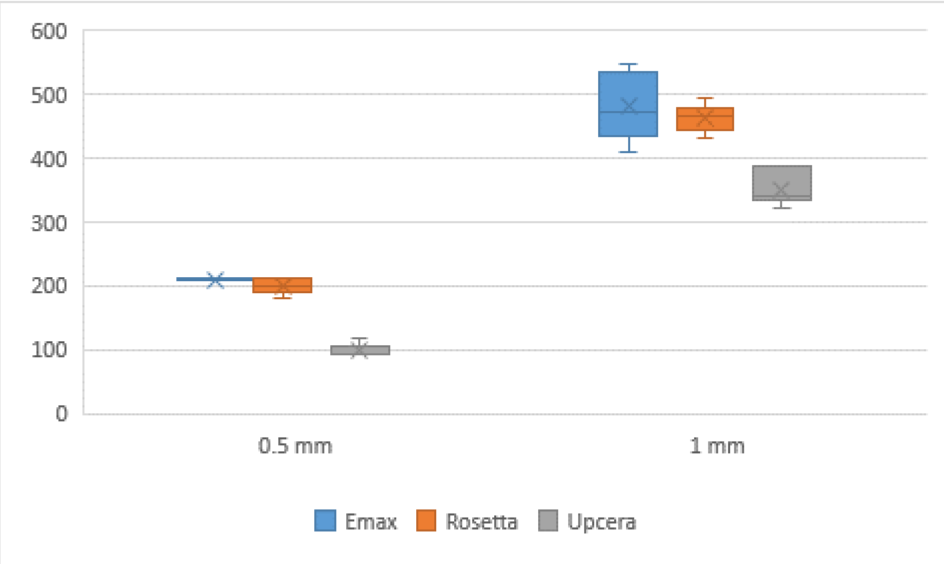


Figure (24): Box plot showing biaxial flexural strength (MPa) value for different groups

2. Effect of different variables and their interaction:

Effect of different variables and their interaction on biaxial flexural strength (MPa) were presented in table (10).

Material type and sample thickness had a significant effect on biaxial flexural strength ($p<0.001$), while the effect of their combined interaction was not statistically significant ($p=0.581$).

Table (10): Effect of different variables and their interactions on biaxial flexural strength (MPa)

Source	Sum of Squares	df	Mean Square	f-value	p-value
Material	120375.65	2	60187.82	79.29	<0.001*
Thickness	720230.24	1	720230.24	948.80	<0.001*
Material * Thickness	835.96	2	417.98	0.55	0.581ns

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

The mean values with their statistical significance are shown in table (11) and figures (25 and 26).

Table (11): Mean ± standard deviation (SD) of biaxial flexural strength (MPa) for different materials and thicknesses

Thickness	Biaxial flexural strength (MPa) (mean±SD)			p-value
	Emax	Rosetta	Upcera	
0.5 mm	209.06±8.97^{A}	198.30±10.92^{A}	99.62±9.47^{B}	<0.001*

1 mm	480.91±55.30[A]	461.95±21.59[A]	349.82±27.21[B]	**<0.001***
p-value	**<0.001***	**<0.001***	**<0.001***	

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

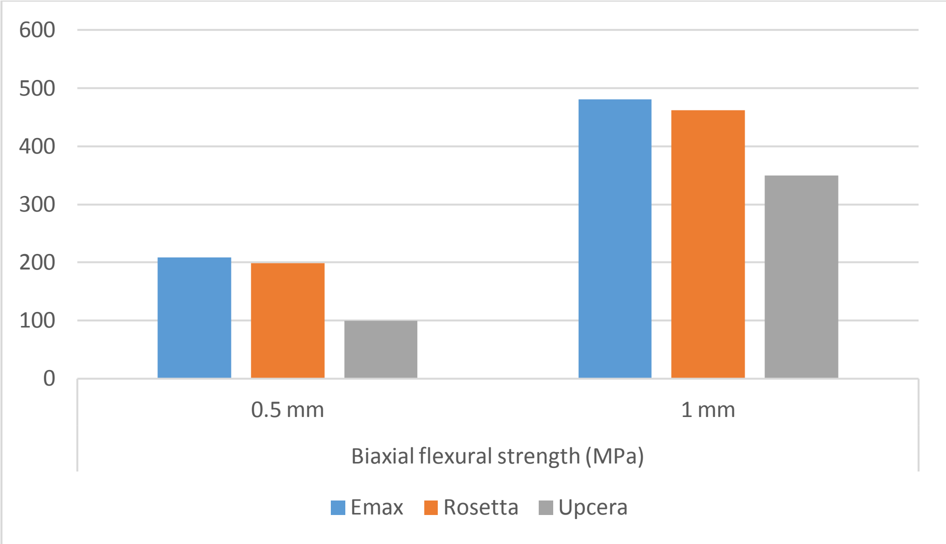


Figure (25): Bar chart showing average biaxial flexural strength (MPa) for different materials and thicknesses (A)

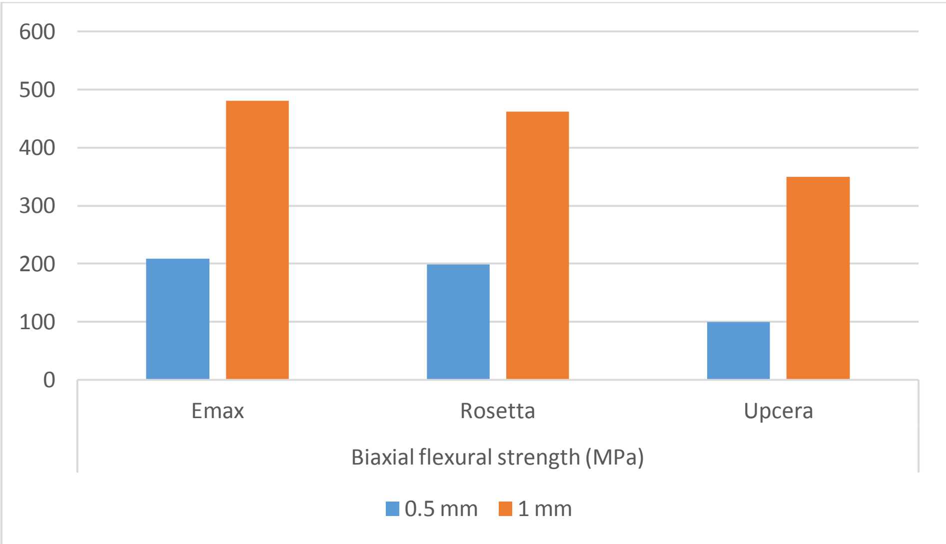


Figure (26): Bar chart showing average biaxial flexural strength (MPa) for different materials and thicknesses (B)

3. Main effects:

A-Effect of material:

Mean and standard deviation (SD) values of biaxial flexural strength (MPa) for different materials were presented in table (12) and figure (27)

There was a significant difference between values of different materials ($p<0.001$). The highest biaxial flexural strength (MPa) value was found in Emax (344.99±66.10), followed by Rosetta (330.13±77.79), while the lowest value was found in Upcera samples (224.72±61.29). Post hoc pairwise comparisons showed value of Upcera samples to be significantly lower than values of other materials ($p<0.001$).

Table (12): Mean ± standard deviation (SD) of biaxial flexural strength (MPa) for different materials

Biaxial flexural strength (MPa) (mean±SD)			p-value
Emax	Rosetta	Upcera	
344.99 ± 66.10^{A}	330.13 ± 77.79^{A}	224.72 ± 61.29^{B}	**<0.001***

Means with different superscript letters are statistically significantly different *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

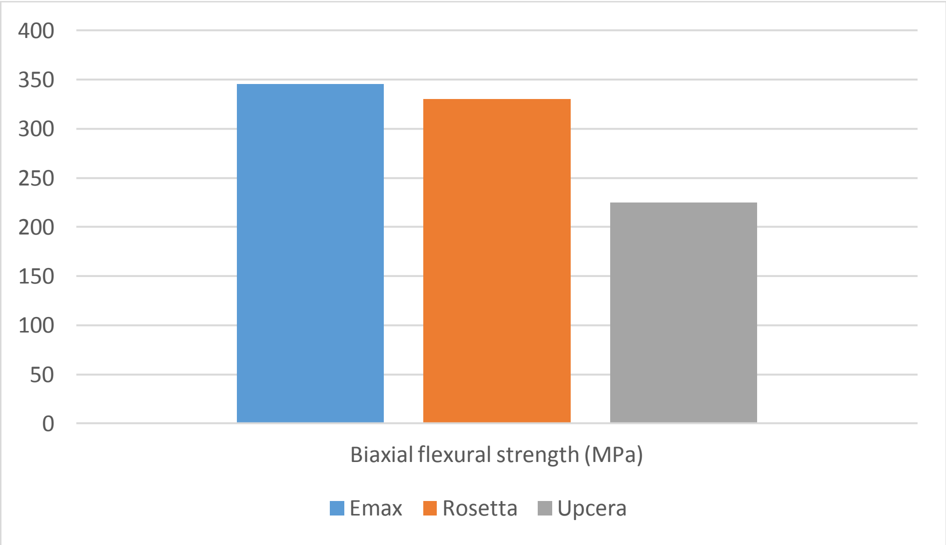


Figure (27): Bar chart showing average biaxial flexural strength (MPa) for different materials

B-Effect of thickness:

Mean and standard deviation (SD) values of biaxial flexural strength (MPa) for different thicknesses were presented in table (13) and figure (28)

1 mm thick samples (430.90±69.23) had significantly higher value than 0.5 mm thick samples (168.99±51.32) ($p<0.001$).

Table (13): Mean ± standard deviation (SD) of biaxial flexural strength (MPa) for different thicknesses

Biaxial flexural strength (MPa) (mean±SD)		p-value
0.5 mm	1 mm	
168.99±51.32	430.90±69.23	**<0.001***

*; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

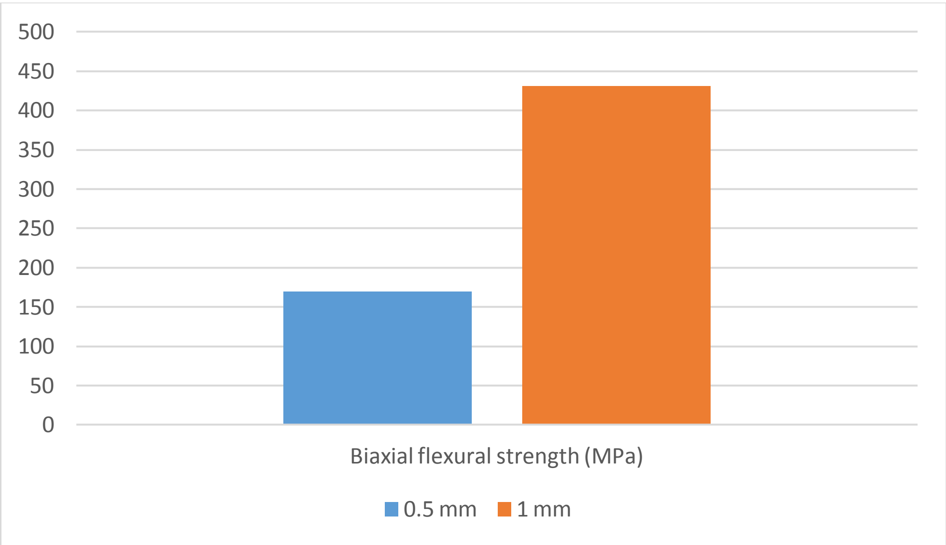


Figure (28): Bar chart showing average biaxial flexural strength (MPa) for different thicknesses

IV. Discussion

Currently, several types of ceramic materials such as leucite-reinforced glass ceramic, lithium disilicate glass ceramic, and zirconia-based core ceramic have been utilized for chair-side fabrication of all-ceramic restorations using CAD/CAM.

Ceramic materials used for esthetic restorations are brittle, therefore they are subjected to the risk of fracture under cyclic forces such as occlusal forces [(15)].

The IPS e.max Cad ceramic material used in our present study is the most commonly used all ceramic material for CAD/CAM restorations in dentistry. Then, several manufacturers have marked novel lithium disilicate glass ceramic systems, thus promoting their clinical application.

The purpose of this study was to compare the translucency and flexural strength of three lithium disilicate ceramics for CAD/CAM restorations using two different thicknesses.

Three types of lithium disilicate ceramic materials were selected in this study: IPS E.max CAD, Rosetta SM and Upcera CAD.

The two thicknesses were 0.5 mm and 1 mm. These two thicknesses were selected as they represented the thickness of all-ceramic restorations where the 0.5 mm specimens were for veneers and the 1 mm specimens were for full coverage restorations.

In the present study the steps were done in the same fashion and by the same operator for the three lithium disilicate materials.

All materials were in the form of blocks. Blocks of all materials were of shade HTA1 as we were going to measure the translucency parameter so the shade and the translucency level were standardized for the three materials.

Blocks of each material were first ground into cylinders with 10 mm diameter using universal tool grinder machine C40 Sungkwang. Cylinders were further sliced into discs with 0.5 and 1 mm thickness using Isomet 4000 linear precession together with diamond disc. Cutting was done under sufficient coolant to control heat and avoid formation of any cracks in the specimens which in turn would affect the biaxial flexural strength test.

Insize digital caliper was used for checking dimensions' standardization in every step.

An appropriate surface finish was done for all the discs using polishing procedures to create parallel faces.

Before glazing, discs were cleaned to be free of grease. According to manufacturer’s instructions the surfaces were cleaned thoroughly with soap and water and stored to avoid any contamination after cleaning.

Crystallization of the discs was performed to reach the shade and the maximum flexural strength of the material according to manufacturer’s recommendations. And glazing cycles were done to simulate the surface finish used for clinical indications as specified by the manufacturers.

Crystallization and glazing cycles were done using Ivoclar Vivadent Programat P310 Furnace according to the manufacturer’s firing recommendation table for each material.

These ceramic specimens had been subjected to:

Thermocycling, the specimens were thermocycled in a water bath for 5,000 cycles between 5ºc and 55ºc as it represents 6 months intraoral function. As the oral cavity is in a constant dynamic change. The pH changes, temperature changes, abrasive action of food, titratable acidity of solution, role of saliva etc., are all subjecting the ceramic to a fluctuating environment. So, thermodynamic aging is a commonly used procedure for artificial aging of ceramics mimicking the oral environment, simulating its effect on longevity of restorations giving the chance to examine the behavior of ceramic material intraorally. **Vasiliu et al in 2020** [(16)], studied the effect of thermocycling on the optical properties of CAD/CAM and pressable glass ceramics. They found that aging process influenced milled glass ceramics more than heat pressed ones, additionally they concluded that milled groups showed more significant change than heat pressed regarding optical properties. A study was performed to compare the effect of heat treatment on flexural strength and crystalline structure of IPS e.max CAD and Rosetta SM, the researchers reported that both materials had similar flexural strength and crystalline patterns.

After then, the discs of each group were subjected to Translucency Test and Biaxial Flexural strength Test to evaluate the translucency and mechanical strength according to ISO 6872:2015. Dentistry-ceramic materials; 2015.

Translucency is the relative amount of light transmission or diffuse reflectance from a substrate surface. For translucent materials most of the incident light is transmitted and some is absorbed, whereas less translucent materials tend to reflect and absorb light falling on it. Ceramic translucency can be affected by many factors including thickness, micro structure, number of firing cycles, type and thickness of underlying cement [(17)].

The Translucency Parameter is considered as one of the most reliable methods to compare translucency between ceramic materials, calculated by calculating color difference between the same specimen under black and white backgrounds. The greater the TP value, the higher the translucency of the ceramic specimen.

Spectrophotometer has been a reliable method in evaluating translucency of lithium disilicate ceramics [17].

Mechanical strength is an important property that determines the performance of brittle materials [18]. Hence, clinically relevant in vitro test methods are suggested to study the mechanical durability of the ceramic materials [19]. The optimum strength of any ceramic is dependent on the fabrication procedure and minimization of flaws [20]. Furthermore, several factors can also influence the definitive strength of ceramic materials, including dimension of specimens, test environment, polishing procedures, rate of stressing area of specimen subjected to the stresses, and testing methods [21]. To closely mimic in vivo conditions and monitor material stability, the biaxial flexural strength test was used to investigate the mechanical properties of the three ceramic materials (IPS Emax cad, Rosetta SM and Upcera cad).

The measurement of the strength of brittle materials under biaxial flexure conditions rather than uniaxial flexure (3 or 4 point flexure tests) is often considered more reliable, because the maximum tensile stresses occur within the central loading area, and edge failures have no effect on specimen fracture [22]. It has been noticed that when dental ceramic bars are tested for uniaxial strength measurements, defects are commonly formed by bend processing. These defects are not found in clinical dental crowns, and they are also absent in disc specimens that are used for biaxial strength measurement [23].

The three-point flexural strength testing method was performed in this study as it was approved by ISO 6872 standard (2008) for dental ceramics [14]. Three-point test is often used due to its simplicity. Difference in samples shapes and surface flaws may result in only 10% variation of results. Rounding edges and good polishing reduce the effect of surface flaws and improve test reproducibility for 20–30% [24].

In this study, the piston-on-three ball test was used, because excellent results by this method have been previously reported [22]. A small piston tip diameter will result in a higher biaxial flexural strength because a smaller area of the specimen is subjected to the maximum tensile stresses [25]. It has been shown that a piston tip between 0.5mm and 3mm in diameter will match wear facets that are seen on fractured surfaces in clinical failure restoration. Therefore, a 1.4mm tip diameter piston tip was used which gave reliable results.

I- Translucency parameter (TP):

In this study the null hypothesis was rejected and the results showed that there was a significant interaction between the translucency and the type and thickness of the ceramic.

i) Regarding the effect of ceramic material:

Results of the present study confirmed presence of difference in translucency between the three ceramic materials. Generally, E.max and rosetta showed no significant difference and both were significantly higher in translucency than upcera. The highest translucency parameter (TP) value was found in Rosetta (22.96±1.73), followed by E.max (21.90±2.26), while the lowest value was found in Upcera samples (17.62±1.92).

These findings of E.max and Rosetta can be regarded for similar composition and similar crystalline arrangement in both ceramics. These results were in agreement with **Kang et al in 2013** [26] who showed that the FE-SEM (field-emission scanning microscopy) images presented similar patterns of crystalline structure in the two ceramics. The IPS e.max CAD showed typical lithium metasilicate crystals embedded in a glass matrix. The typical platelet-shaped grains had a length of approximately 0.5 µm. The Rosetta SM had crystals resembling the shapes and sizes of those of IPS e.max CAD. And XRD analysis (X-ray diffraction) showed that the IPS e.max CAD and Rosetta SM also had similar patterns, presenting high peak positions corresponding to the standard ones for lithium metasilicate and lithium disilicate at each stage of heat treatment, as well as the background intensities of Rosetta SM and IPS e.max CAD to be similar to each other in spite of the difference in crystals size after crystallization. However, they recorded larger crystals in IPS e.max CAD compared to Rosetta SM. They reported that variation in crystals size might be seen in the same product according to opacity or shade. Heat treatment, base glass composition, and nucleating agents greatly affects crystals' size among different factors [27].

So, Microstructure plays a major role in determining the translucency of ceramics as mentioned by **Jung SK in 2021** [28] who said that the translucency can be modified by varying the volume, size, and density of crystals. A fine-grained microstructure is desirable in order to improve the translucency in glass ceramics. Ceramics with crystallites of a dimension smaller than the wavelength of light especially show improved translucency. A microstructure with a high crystal density makes the ceramic less translucent as the light scattering is decreased. Although the translucency of a ceramic can also be modified by adding pigments into the glass frit, the final results are more dependent on the phase composition and microstructure of the glass than on influences from a specific compound.

While, for Upcera the result is most probably attributed to a different microstructure. As mentioned by **Wang et al in 2021** [29] who said that the current trend correlations showed that when translucency increased, grain size also increased to more than 1000 nm due to the decreased grain boundaries. Therefore, scattering, refraction, and reflection of light were reduced. On the contrary, limiting the grain size under 100 nm could increase the crystals' density and decrease the grain boundaries to increase translucency, although there were no enough studies supporting this result.

ii) Regarding the effect of ceramic material thickness:

The results of the present study showed that ceramic material thickness has a significant effect on TP, translucency increases with decrease in ceramic thickness for the three ceramic materials. The higher value was found with 0.5 mm samples while the lower value was found with 1 mm samples for all materials. These results can be explained by increased light scattering, absorption within the ceramic material and decreased light transmission on increasing ceramic thickness.

These results were in agreement with **Wang et al in 2013** [30] who used a spectrophotometer to measure the translucency parameters (TP) of the glass ceramics, which ranged from 2.0 to 0.6 mm, and of the zirconia ceramics, which ranged from 1.0 to 0.4 mm. The relationship between the thickness and TP of each material was evaluated using a regression analysis (α=.05). The TP values of the glass ceramics ranged from 2.2 to 25.3 and the zirconia ceramics from 5.5 to 15.1. There was an increase in the TP with a decrease in thickness, but the amount of change was material dependent. An exponential relationship with statistical significance (P<.05) between the TP and thickness was found for both glass ceramics and zirconia ceramics. He concluded that the translucency of dental ceramics was significantly influenced by both material and thickness. The translucency of all materials increased exponentially as the thickness decreased. All of the zirconia ceramics evaluated in this study showed some degree of translucency, which was less sensitive to thickness compared to that of the glass ceramics. So, the thinner the lithium disilicate layer, the greater the translucency and the higher the ΔE values as concluded by **Basso et al in 2017** [31] who evaluated the masking ability and translucency of monolithic and bilayer CAD-CAM ceramic structures.

II-Biaxial flexural strength test:

In this study the null hypothesis was rejected and the results showed that there was a significant interaction between the biaxial flexural strength and the type and thickness of the ceramic.

i) Regarding the effect of ceramic material:

There was a significant difference between values of different materials (p<0.001). The highest biaxial flexural strength (MPa) value was found in Emax (344.99±66.10), followed by Rosetta (330.13±77.79), while the lowest value was found in Upcera samples (224.72±61.29). Post hoc pairwise comparisons showed value of Upcera samples to be significantly lower than values of other materials (p<0.001).

The highest value of biaxial flexural strength in IPS e.max CAD is mainly regarded to its microstructure which contains small interlocking randomly oriented platelet-like crystals. These crystals result in deflecting, blunting or branching cracks, thus, arresting their propagation within the material causing high flexural strength. It consists of approximately 70% by volume fine grained (Li2 Si2 O5) crystals in glass matrix as mentioned by **Salem and Asaad in 2020** [32].

No significant difference between E.max and Rosetta can be regarded for similar composition and similar crystalline arrangement. This result was supported by **Kang et al in 2013** [26] who concluded that IPS E.max CAD and Rosetta SM showed no significant differences in flexural strength. They had a similar crystalline pattern and molecular composition.

Also, **Travares et al in 2020** [33] analyzed the structural, morphological and mechanical properties of two different lithium disilicate glass-reinforced ceramics for CAD/CAM systems (IPS e.max CAD and Rosetta SM). Five methodologies were used for both ceramics: microstructure was analyzed using x-ray diffraction (XRD); morphological properties were analyzed by scanning electron microscopy (SEM), with and without hydrofluoric etching; porosity was assessed using 3D micro-computed tomography (micro-CT); flexural strength was measured using the three-point bending test; and bond strength was determined with self-adhesive resin cement, using a microshear bond test. High peak positions corresponding to standard lithium metasilicate and lithium disilicate with similar intensities were observed for both ceramics in the XRD analysis.

Morphological analysis showed that the crystalline structure of the two ceramics studied showed no statistical difference after acid etching. Additionally, no significant differences were recorded in the number or size of the pores for the ceramics evaluated. Moreover, no differences in flexural strength were found for the ceramic materials tested, or in the bond strength to ceramic substrates for the resin cements. Based on the study results, no significant differences were found between the two CAD-CAM lithium disilicate glass-reinforced ceramics tested, since they presented similar crystalline structures with comparable intensities, and similar total porosity, flexural strength and bond strength.

While, Upcera is significantly lower than other materials in flexural strength which is also most probably due to difference in crystal size and arrangement. In general, the mechanical properties of ceramic are affected by the crystal size, crystalline contents, and the irregularity of particles. The ceramic composed of smaller particles shows better mechanical properties because the critical flaw size is proportional to the crystal size. An increase in the crystalline content leads to improved mechanical properties of ceramics. The ceramic composed of particles with various size shows lower mechanical properties because irregular particle size induces stress, raising flaws, and breaking the interfacial interaction between the matrix and particles. Still there are few available data regarding the matter.

Mechanical and optical properties of ceramics are greatly influenced by microstructural parameters as grain size and porosity**. Li et al in 2016** [34], investigated the influence of crystal size on mechanical properties of lithium disilicate ceramics. They reported that flexural strength recorded a prominent change with increasing crystal size. They proved the presence of micro-residual compressive stresses in the crystals due to variation in thermal expansion between the crystalline phase and glassy matrix. Residual stresses increased as crystal size increased creating balancing tensile stresses in the glass matrix. So crystal size performed interlocking as well as micro-residual stress effects. Thus, it had a dual effect on flexural strength of the glass ceramic. However, these stresses within the glassy matrix would counteract the crystals “interlocking effect” that might cause strength degradation.

ii) Regarding the thickness in each material:

1 mm thick samples (430.90±69.23) had significantly higher value than 0.5 mm thick samples (168.99±51.32) ($p<0.001$).

These findings were in accordance with **Sasse et al in 2015** [35] who evaluate the influence of ceramic thickness and type of dental bonding surface on the fracture resistance of non-retentive full-coverage adhesively retained occlusal veneers made from lithium disilicate ceramic. Occlusal all-ceramic restorations were fabricated from lithium disilicate ceramic blocks (IPS e.max CAD) in three subgroups with different thicknesses ranging from 0.3 to 0.7mm in the fissures and from 0.6 to 1.0mm at the cusps. Specimens were subjected to dynamic loading in a chewing simulator with 600,000 loading cycles at 10kg combined with thermal cycling. Only specimens in the group with the thickest dimension (0.7mm in fissure, 1.0mm at cusp) survived cyclic loading without any damage. Survival rates in the remaining subgroups ranged from 50 to 100% for surviving with some damage and from 12.5 to 75% for surviving without any damage. Medians of final fracture resistance ranged from 610 to 3390N. In groups with smaller ceramic thickness, luting to dentin or composite provided statistically significant ($p\leq0.05$) higher fracture resistance than luting to enamel only. The thickness of the occlual ceramic veneers had a statistically significant ($p\leq0.05$) influence on fracture resistance. The results suggest to use a thickness of 0.7-1mm for non-retentive full-coverage adhesively retained occlusal lithium disilicate ceramic restorations.

However, controversial ceramics’ flexural strength results might be attributed to the influence of multiple factors on its measurements, as samples dimensions, polishing technique and tools, stress rate, environmental conditions and testing method as well [36].

In our present study, the mean biaxial flexural strength for IPS e.max cad was 344.99±66.10 and Rosetta was 330.13±77.79, but this difference was not statistically significant probably this difference would not be clinically detectable. And both were above 300 MPa and below 500 MPa. Therefore, it should be categorized in class 3 where it is recommended for anterior or posterior single-unit prostheses and three-unit prostheses not including molar restoration based on ISO 6872 specifications (ISO6872, 2015). While, the mean value for Upcera was 224.72±61.29, thereby it fulfills the ISO requirements for Class 1 and 2. Accordingly, it is recommended for anterior or posterior single-unit prostheses.

Dentists should carefully choose dental ceramics for use in clinical practice. It is important to analyze the flexural strength, translucency parameters, color, fracture toughness, elasticity module, and biocompatibility, among other factors. The optimization of these factors in ceramics will properly promote their use, making it possible to provide satisfactory patient treatment.

V. Conclusion

Within the limitations of this current in vitro study, the following conclusions were drawn:

- E.max and Rosetta showed no significant difference in translucency and flexural strength and both were better than Upcera in translucency and flexural strength.
- By increasing the thickness, the translucency decreased and the flexural strength increased regardless the material.

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