Influence of Different Thicknesses of Monolithic Crowns Made from Different Resin-Bonded Glass Ceramic on Their Load-bearing Capacity (An *in vitro* Comparative Study)

Azad R. Abdalla¹, Abdulsalam R. Al-Zahawi*²

Abstract

**Objective**: To investigate the load-bearing capacity of the full-coverage crowns made from lithium disilicate glass-ceramic LDGC (IPS e.max®, Ivoclar Vivadent) and 10% zirconia reinforced lithium silicate glass ceramic ZLS (Dentsply DeTrey) with different thicknesses.

**Methods**: Forty resin dies with supporting bases were duplicated from two prepared typodont teeth for all-ceramic crowns as a maxillary first molar. Forty crowns corresponding to each die were prepared and then they were divided into four groups: Group I (n 10) made from ZLS with a restoration thickness of (1.0 mm occlusally and 1.0 mm radially) and Group II (n 10) made from LDGC with a restoration thickness of (1.0 mm occlusally and 1.0 mm radially), and Group III (n 10) made from ZLS (1.5 mm occlusally and 1.5 mm radially) and Group IV (n 10) made from LDGC (1.5 mm occlusally and 1.5 radially). All crowns were fabricated by chair side CEREC CAD/CAM and crystallized with Speed fire Dentsply Furness. The virolink resin cement (VariolinkII, Ivoclar Vivadent) was used to bond the crowns to the corresponding dies. All samples were thermo-cycled (10000 cycles between 5c and 55c) and tested for fracture resistance using a Universal testing machine at 0.5 mm/minute speed until failure. ANOVA and Tukey HSD test were used to compare the fracture resistance between groups.

**Results**: The result demonstrates that the fracture resistance means and SD of ZLS with different thicknesses ranged from 572 N ±122.002 to 1171±217.432 N, and those of LDGC with different thicknesses ranged from 625 N ±151.676 N to 845 N ±388.222 N.

**Conclusions**: The fracture resistance increased with increasing crown thickness using different glass-ceramic materials.

**Keywords**: Celtra Duo, Fracture resistance, Lithium Disilicate E.max, Thermocycling.

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Introduction

For more than a century, ceramics have been a mainstay of aesthetic dentistry. In 1889, Charles H. Land, the first dentist to use ceramics, obtained a patent for the jacket (an all-porcelain crown), a jacket-shaped covering placed around a tooth to repair it. Up to the 1950s, the material underwent improvements and saw extensive application. Since then, dental ceramics have changed in terms of their chemical components, aesthetic qualities, production methods, packaging, and indications. Early versions of dental ceramics produced outcomes that were both very aesthetic and biocompatible. Dental all-ceramic materials have been used increasingly in clinical applications over the past 30 years, progressing from single-unit anterior restorations to multi-unit posterior restorations, dental abutments, and, more recently, dental implants.

Dental ceramics can be classified into three types based on their composition: (1) polycrystalline ceramics, (2) glass matrix ceramics, and (3) resin-matrix ceramics. The phases present in their chemical composition serve as the basis for the criteria used to differentiate ceramic materials. To categorize all-ceramic materials, it is necessary to determine if a glass matrix phase (glass-matrix ceramics) is present or missing (polycrystalline ceramics), or if the material has an organic matrix that is usually filled with ceramic particles (resin-matrix ceramics).

LDGC (IPS e.max®, Ivoclar Vivadent), introduced in 2007 and used for all-ceramic restorations, is now the most widely used material. It contains glass or glass ceramics with moderate-to-high (i.e., > 50%) crystalline content. The microstructure of the substance is composed of a glass matrix enclosing the second phase of individual crystals. It starts as homogenous glass, but a secondary treatment causes crystals to nucleate and develop. This process improves the material’s mechanical and physical qualities by increasing the number of crystals present and creating compression stress around them. The material’s flexural strength (350 MPa) allows the design of fixed partial prostheses of up to three units.

ZLS ceramics (Celtra Duo, Dentsply DeTrey, Konstanz, Germany; Suprinity, Vita Zahnfabrik, Bad Säckingen, Germany) are a new group of machinable ceramics for CAD/CAM procedures. The mechanical characteristics of these materials, based on the manufacturer, have a strength of 210 MPa and this can be increased up to 370 MPa by fitting for 10 minutes. The material has a uniform texture after crystallization (mean grit size: roughly 0.5-0.7 nm). In comparison to lithium disilicate crystallites, the crystal sizes are 4 to 8 times smaller. ZLS can be finished by both glaze-firing and surface polishing. It is possible to etch zirconia-reinforced lithium silicate ceramics and then bond them with resin cement. Despite the high glass content, ZLS has a pleasing aesthetic quality. Due to its optical and physical characteristics, which are comparable to those of lithium disilicate E.max, the Celtra Duo is applicable for use to create several fixed dental prostheses for anterior and posterior teeth.

To determine the probability of failure and obtain insight into the durability of the brittle material used in dental ceramic restorations, the fracture behavior of the material should be assessed. Traditional in vitro tests involved static loading on the typical disk- or bar-shaped specimen until the sample appeared to have failed. However, in clinical practice, several factors, including adhesive technique, bonding surface treatment, composition, and ceramic thickness, influenced the fracture strength of ceramic crowns. Thickness was particularly important in determining the fracture strength of the ceramic crowns. In this study, the author investigates the load-bearing capacity of crowns made from LDGC and ZLS with different thicknesses. The study's hypothesis is that the crown’s thickness and material type do not affect the fracture resistance.

Materials and methods

The present study was approved by the Ethics committee of the Dentistry College at the University of Sulaimani (no. 21/75 on 9/11/2021). Based on the data from a previous study the result of power calculation indicated that the sample size of each group should be a minimum of 8 samples. Accordingly 10 teeth were selected for each group in this study. Group I stands for ZLS (1mm occlusal and 1mm radially), Group II stands for LDGC (1mm occlusal and 1mm radially), Group III stands for ZLS (1.5mm occlusal and 1.5mm radially), Group IV stands for LDGC (1.5mm occlusal and 1.5mm radially).

Preparation of the typodont teeth

Two typodont teeth (maxillary first molar) (Nissin Dental Products Inc., Kyoto, Japan) mounted on an arch model were prepared for all-ceramic crowns using a dental surveyor. The first one measured 1mm radially and 1mm occlusally, and the second one 1.5mm radially and 1.5mm occlusally, as shown in Figure 1.

Duplication of specimens:

Both prepared teeth were scanned by an Omincam scanner using the CEREC chairside CAD/CAM system (Dentsply Sirona- Bensheim-Germany) to produce a
digitally prepared model. The scanned prepared teeth were exported as a Standard Tessellation Language (STL) file and sent to the 3D printer (Jewelry resin model machine-iFun D89) to be duplicated as 20 resins (3D Printing UV Sensitive Resin – Eryone company). All specimens were checked for any change in the dimensions by digital Vernia (stainless hardened workzone -Globaltronics GmbH&Co.KGDomstn) and excluding any defective samples.

**All-ceramic crown fabrication:**

The prepared specimens were scanned by Omunicam CEREC CAD/CAM camera and then 40 crowns were designed and fabricated following the system instruction steps in sequence according to manufacturer’s protocol. The occlusal surface had normal anatomy, and the standardization of thickness was done by using the thickness measurement on the scanner system. After the CADiCAM restorations were fabricated, the crowns were sent to speed-fire DENTSPLY furnaces for full crystallization: 10 minutes for the ZLS and 24 minutes for the LDGC. All 40 fabricated crowns were placed in an ultra-sonic device (EASY HOME/CHINA) for 60 seconds with distilled water to remove any remnants of powder, then the fitting surfaces of both types of crowns were treated with 5% hydrofluoric acid gel (Ceramic etching gel; Ivoclar Vivadent) for 20 seconds as shown in Figure (2A), washed with distilled water, followed by alcohol 96% to remove the residual acid, and dried with oil-free air pressure for 60 seconds. Finally all the crowns were coated with silane (Monobond N; Ivoclar Vivadent) as shown in Figure (2B) and air dried for 60 seconds, and were cemented on the corresponding abutment using dual luting cement (VariolinkII, Ivoclar Vivadent) as shown in Figure (2C). At the margins, the excess luting cement was carefully removed and 1 kg applied to the crowns for 10 minutes using the dental surveyor as shown in Figure (2D)\(^6\), then all samples were light cured for 40 seconds on each side as shown in Figure (2E). Finally, all samples were preserved in distilled water at 37c before being exposed to thermo-cycling (10000 cycles between 5 and 55c).

**Fracture test:**

A universal testing machine (TERCO company/Sweeden) was used to evaluate the fracture resistance. All samples were secured in the machine with a steel jig in a vertical position and loaded against the rounded steel blunt end with a diameter of 4mm, with contact between the embrasure and the cusps. The experimental load was applied at a crosshead speed of 0.5 mm/ minute in a direction parallel to the long axis of the tooth and the fracture load was recorded for each sample.

![Figure 1: Preparation of the samples.](image-url)
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Figure 2: A: Etching with hydrofluoric acid gel, B: Coating with silane monobond, C: Applying cement, D: Applying 1 kg load, E: Light curing.

Results

Data were analyzed using the Statistical Package for Social Sciences (SPSS, version 25 by IBM). The normality of data was checked using the Shapiro-Wilk test. Accordingly, parametric tests were used, namely One-way analysis of variance (ANOVA) followed by Tukey’s HSD Post-Hoc test. The mean fracture load value of ZLS 1mm thickness was 572 N ± 122.002, while for 1.5mm thickness it was 1171±217.432 N and for LDGC 1mm thickness it was 625 N ±151.676 and for 1.5mm thickness was 845 N ±388.222, as shown in Table 1. ANOVA test was used to assess the influence of the thickness of the crowns on the fracture resistance and the result reveals the effect of the thickness of the fracture resistance was statistically significant (p<0.05).

Meanwhile, changing the ceramic material had no significant effect on the fracture resistance of the crowns (p>0.05). When the fracture resistances of the ZLS and LDGC with the same thickness were compared, no significant difference was found (p>0.05). However, one-way ANOVA testing showed a significant difference in fracture resistance with variation in thickness, in both ZLS and LDGC (p<0.05). The ZLS of 1mm thickness recorded the lowest value for fracture resistance (572 N), while the ZLS of 1.5mm thickness recorded the highest fracture resistance value (1171N). Comparisons between groups are shown in Table 2 and Figure 3.

Table 1: The Mean ± SD values of fracture resistance (N) and ANOVA test among groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Mean ±SD(NEWTON)</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI</td>
<td>572.00 ± 122.002</td>
<td>F= 14.589</td>
</tr>
<tr>
<td>GII</td>
<td>625.00 ± 151.676</td>
<td>DF= 3</td>
</tr>
<tr>
<td>GIII</td>
<td>1171.00 ± 217.432</td>
<td>P= 0.000</td>
</tr>
<tr>
<td>GIV</td>
<td>845.75 ± 388.222</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Tukey HSD post hoc test for multiple comparisons between groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI - GII</td>
<td>0.961</td>
</tr>
<tr>
<td>GIII - GIV</td>
<td>0.486</td>
</tr>
<tr>
<td>GI - GIII</td>
<td>0.000</td>
</tr>
<tr>
<td>GII - GIV</td>
<td>0.005</td>
</tr>
<tr>
<td>GI - GIV</td>
<td>0.001</td>
</tr>
<tr>
<td>GIII - GIV</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Discussion

This study investigated the fracture resistance of monolithic full-coverage crowns of different thicknesses made from ZLS and LDGC. ZLS and LDGC are two glass-ceramics with the advantage that they can be bonded to the tooth structure by resin luting agent after etching with hydrofluoric acid, although they differ in their composition, mechanical properties, and time needed for complete crystallization of the restoration. Reduced removal of natural tooth structure may be beneficial to the health of the teeth, especially in young patients who would wish to avoid the removal of a lot of sound and healthy tooth structure. Additionally, the fabrication of the crowns in the shape of a monolithic layer provides for easy manufacture, fewer steps of fabrication, and decreases the possibility of chipping later. The selection of these two material types to test the effect of the crown thickness on its load-bearing capacity was based on these above points that have a direct relation with the amount of tooth structure cutting. Therefore, the connection between monolithic crown thickness and fracture resistance was an essential factor to consider in conservative dentistry. It has been shown that maintaining accuracy in thickness and homogeneity of the crowns can provide uniform stress distribution. Consequently, in the current research, CAD/CAM technology was used to create all of the crown patterns, and resin material was used for duplicating the prepared teeth to control the accuracy of the thicknesses of the prepared teeth, taking into account the possibility that differences in the size, form, and quality of human teeth might enhance the variability of the fracture resistance. In the present study the mean and SD of fracture resistance for ZLS 1.5mm was 1171.00 ± 217.432 N which was the highest fracture resistance, while ZLS 1mm had the lowest fracture resistance (572.00 ± 122.002 N), and for LDGC 1.5mm fracture resistance was 845.75 ± 388.222 N and for LDGC 1mm was 625.00 ± 151.676 N. According to other research, males had an average occlusal bite force of 633 N, whereas females had an average bite force of 527 N in the posterior area. In a further study, the average high biting force in the posterior region was 847 N for men and 597 N for women. According to the result obtained in this study, ZLS 1.5mm and LDGC 1.5 mm would achieve a higher fracture resistance value than a human biting force in the posterior region, making them suitable for posterior restorations.
There was no statistical difference in fracture resistance values between ZLS and LDGC of the same thickness, but the resistance value for both materials increased with an increase in thickness. The fracture resistance of the crowns made from the same material but of different thicknesses showed statistically significant differences. There are studies that agree with our result in this study.\textsuperscript{14} A previous study showed that the fracture resistance of these materials can sustain physiological occlusal stresses, with durability being promising at 1.0 mm thickness for ZLS.\textsuperscript{21}

Furthermore, some studies have shown that thermocycling or mechanical aging of the crowns will decrease the fracture resistance of the crowns and could accelerate the damage of ceramic materials.\textsuperscript{22,23} In this study, all specimens were thermo-cycled for 1000 cycles between 5 and 55°C before testing, a clinical condition that has been adopted by many studies.\textsuperscript{14,24}

Around 70% of the crystalline phase in LDGC is incorporated into the glassy matrix. In addition, the flexural strength of LDGC is 360 ± 60 MPa, despite it having a high silica content of 55–65 weight percent. Meanwhile, ZLS ceramics gain improved flexural strength of 370–420 MPa after glazing as a result of the presence of lithia (15–21 wt%) and zirconia (8–12 wt%) (which contains roughly ten times more zirconium dioxide than traditional CAD/CAM glass-ceramic).\textsuperscript{25} This is one of the reasons that in our test the fracture resistance of ZLS was greater than the fracture resistance of LDGC with the same thickness. A previous study found that values for the fracture toughness (2.31 ± 0.17 MPa m\textsuperscript{0.5}), flexural strength (443.63 ± 38.90 MPa), elastic modulus (70.44 ± 1.97 GPa), and hardness (6.53 ± 0.49 GPa) of Vita Suprinity (zirconia reinforced lithium silicate glass-ceramic) were significantly higher than the values of ZLS with the same thickness.\textsuperscript{26}

Within the limitations of the study, it can be concluded that the crown's thickness will have a significant effect on the fracture resistance of both ZLS and LDGC crowns since both types of crowns with the same thicknesses showed the same fracture resistance, but the fracture strength will increase with the increase of the thickness.

**References**

6. Traini T, Sinjari B, Pasceatta R, Serafini N, Perfetti G, compared to those for lithium disilicate ceramic.\textsuperscript{26}

Another study agreed with our study’s finding that mean fracture loads were highest for zirconia-reinforced lithium silicate (766N, SD 98N) and significantly lower for both lithium disilicate (485N, SD 64N) and feldspar (372N, SD 116N).\textsuperscript{27}

Many studies have used 1.5mm thickness of the preparation and also it is helpful to increase the depth of the preparation to >1mm to minimize the primary initiation of radial cracks.\textsuperscript{28} Furthermore, another study found that lithium disilicate crowns of 1.5mm thickness showed high survival rates.\textsuperscript{29} Crown material and crown thickness were shown to be the most important parameters influencing fracture resistance.\textsuperscript{30}

According to the result of this study, using a 1.5mm thickness of the crown will increase fracture strength in clinical work.

**Conclusion**

Within the limitations of the study, it can be concluded that the crown's thickness will have a significant effect on the fracture resistance of both ZLS and LDGC crowns since both types of crowns with the same thicknesses showed the same fracture resistance, but the fracture strength will increase with the increase of the thickness.