

## The effect of two glass ceramic materials bonded with light and dual cure resin cement on the fracture resistance of anterior sectional veneers following cyclic loading: In-vitro study

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### ARTICLE INFO.

#### Article History:

Received 1 July 2025

Revised 9 August 2025

Accepted 11 October 2025

Available online 28 October 2025

#### Keywords:

Lithium disilicate,  
thermocycling, fracture  
resistance, adhesive cement,  
dual cure and light cure.

### Abstract

**Background:** . This study aimed to evaluate the fracture resistance following aging of anterior sectional veneers fabricated from two different glass ceramic materials, bonded with resin cement under different curing modes.

**Methods:** . Forty extracted human central incisors were collected. Samples were randomly divided into two groups according to ceramic material used lithium disilicate glass ceramic (IPS e.max press) and zirconia reinforce lithium silicate glass ceramic (Celtra press). Then the two main groups were subdivided into 4 subgroups according to resin cement used; light cure resin cement or dual cure resin cement (n=10). Teeth were held into epoxy resin blocks milled by CAD/CAM technology. Samples were prepared, cemented then subjected to 10000 cycles of artificial accelerated aging, in addition to 120,000 cycles of dynamic loading. All samples were subjected to universal testing machine to determine fracture resistance values.

**Results:** All data collected were statistically analyzed by One-way ANOVA followed by Tukey's post hoc test. Significant difference ( $p<0.001$ ) between the two materials, where Celtra Press glass ceramics showed higher fracture resistance value ( $674.81\pm78.29$ ) compared with Ips Emax Press glass ceramic ( $396.76\pm84.32$ ). Dual cure resin cements showed significantly ( $p=0.001$ ) higher strength values ( $601.58\pm152.99$ ) compared to light cure resin adhesive ( $469.99\pm160.71$ ).

**Conclusion:** Celtra Press glass ceramic possessed enhanced fracture resistance value compared to IPs Emax Press glass ceramic for restoring teeth with sectional veneers. Dual curing mode of resin cement possessed greater fracture resistance compared to light curing mode.

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## 1 Introduction

Smile is the key of attraction due to its impact on the facial aesthetics beside its effect on the self-esteem, thus it alters the psychological status <sup>1,2</sup>. Alignment, color, size and shape of the anterior maxillary and mandibular teeth; have a strong significance on the smile <sup>3-5</sup>. Accordingly dental esthetics modalities are directed to fulfill patient's satisfaction conjunct with the most conservative approaches <sup>6,7</sup>. Following the concept of preservation of dental tissue, non-invasive treatments as dental laminate veneers was implemented, as a stipulation technique to restore the beauty and preserve the dental tissues, anterior <sup>8,9</sup>. In such cases dental glass ceramic veneers showed great progress at the level of

bonding and durability beside their wear resistance, and biocompatibility<sup>10</sup>.

On the other hand they are contraindicated in cases of exposure, extensive occlusal destructive forces, severe malposition, and presence of soft tissue diseases, highly fluoridated teeth and teeth with extensive existing restorations hindering bonding<sup>11</sup>. In certain situations, as diastemas, the escalating concept of conservatism required even less non-invasive approach as the anterior sectional veneers<sup>12</sup>. The material to be used must fulfill the prospect of restoring the natural appearance of the anterior teeth and their harmony with the soft tissue, nevertheless reduction in material thickness is also a necessity along with the important requirement of adhesion<sup>13</sup>. Lithium disilicate ceramics (LDC) satisfied these fundamentals, possessing flexural strength resembling tooth enamel, translucency, along with its high compatibility, smooth surface and optimum marginal fit<sup>14</sup>. LDCs can be fabricated into ultra-thin forms under 0.5 mm thick while preserving excellent marginal integrity and desirable optical and mechanical properties<sup>15</sup>. Celtra® is a family of materials comprising the pressable Celtra® Press and the CAD/CAM-compatible Celtra® CAD. Celtra® Press is a zirconia reinforced lithium silicate with the incorporation of 10% wt. zirconium oxide (ZrO<sub>2</sub>) as a nucleating agent. Throughout heat pressing, ZrO<sub>2</sub> encourages volume crystallization of glasses and obstructs crystal growth. Subsequently, minor crystalline phases are present which improve optical properties and decrease surface roughness. Based on the manufacturer, Celtra® Press exhibits mechanical properties values comparable with those of lithium silicate glass-ceramics<sup>15</sup>. While, Celtra Duo (Dentsply, Sirona) is a zirconia-reinforced lithium silicate (ZLS) CAD/CAM block material produced explicitly for application with Cerec<sup>16</sup>.

Anterior dental laminate veneers bonding has always been a challenge<sup>11</sup>. Resin-based cements have proved their success regarding the adhesion of dental laminate veneers<sup>17</sup>. Two types of resin-based cements are marketed; light and dual cure, where light cure is considered more favorable due to its higher bond strength and better color stability<sup>18</sup>.

The concern in dual cure resin cement was the content of tertiary amine group, and over time degradation of color occurs. However, the color change of the photo-initiator camphorquinone, which is widely used in only light-polymerized resin cements, is much more insignificant, innovations delivered a content free from tertiary amines which resulted in better color stability<sup>19</sup>.

Fracture resistance of dental ceramics is considered a key factor for its clinical success;

mechanical failure occurs when the functional stresses becomes higher than the inherent strength of the ceramic material. Fracture resistance is not only affected by the material type but also by the cement type and long term usage inside oral cavity<sup>20,21</sup>.

Thermal and mechanical fatigue loading have a great impact on ceramic restorations features. Ceramics weaken in the wet environment by gradually generating cracks, stresses resulting from thermal changes in the oral environment provoke these cracks. Thermocycling is implemented as an artificial aging technique since it mimics the oral cavity atmosphere<sup>22</sup>.

The null hypothesis of this study was that there was no difference regarding the fracture resistance of sectional laminate veneer made from two different glass ceramic materials and there was no difference regarding the fracture resistance of sectional veneers cemented by resin based cements with different curing modes. The aim of this study was to evaluate the fracture resistance following aging of anterior sectional veneers fabricated from two different glass ceramic materials, bonded with resin cement under different curing modes; light and dual cure.

## 2 Materials and Methods

### 2.1 Materials:

**Table 1.** Lists the main materials used in the study

| Commercial name of the material                             | Description                    |            | Manufacturer                            | Batch no. |
|-------------------------------------------------------------|--------------------------------|------------|-----------------------------------------|-----------|
| IPS e.max press (Lithium-disilicate pressed glass ceramic)  | Oxides                         | Weight (%) | Ivoclar Vivadent, Schaan, Liechtenstein | Z013CG    |
|                                                             | SiO <sub>2</sub>               | 57.0-80.0  |                                         |           |
|                                                             | Li <sub>2</sub> O              | 11.0-19.0  |                                         |           |
|                                                             | K <sub>2</sub> O               | 0.0-13.0   |                                         |           |
|                                                             | P <sub>2</sub> O <sub>5</sub>  | 0.0-11.0   |                                         |           |
|                                                             | ZrO <sub>2</sub>               | 0.0-8.0    |                                         |           |
|                                                             | ZnO                            | 0.0-8.0    |                                         |           |
|                                                             | Al <sub>2</sub> O <sub>3</sub> | 0.0-5.0    |                                         |           |
|                                                             | MgO                            | 0.0-5.0    |                                         |           |
|                                                             | Coloring Oxides                | 0.0-8.0    |                                         |           |
| Celtra press (Zirconia reinforced lithium silicate ceramic) | Oxides                         | Weight (%) | Sirona Dentsply, Milford, DE, USA.      | 16003308  |
|                                                             | SiO <sub>2</sub>               | 58.0       |                                         |           |
|                                                             | P <sub>2</sub> O <sub>5</sub>  | 5          |                                         |           |
|                                                             | Al <sub>2</sub> O <sub>3</sub> | 1.9        |                                         |           |
|                                                             | Li <sub>2</sub> O              | 18.5       |                                         |           |
|                                                             | ZrO <sub>2</sub>               | 10.1       |                                         |           |

|                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |     |                                                              |              |
|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|--------------------------------------------------------------|--------------|
|                                                                                        | Tb4<br>O7                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1.0 |                                                              |              |
|                                                                                        | CeO<br>2                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2.0 |                                                              |              |
| <b>Rely X Veneer.<br/>(Light cure resin<br/>cement)</b>                                | - Bisphenol-A-<br>diglycidylether<br>dimethacrylate<br>(BisGMA).<br>- Triethylene glycol<br>dimethacrylate<br>(TEGDMA)<br>polymer.<br>- Zirconia/silica<br>fumed silica fillers,<br>approximately 66%<br>by weight.                                                                                                                                                                                                                                                           |     | 3M ESPE,<br>USA                                              | 8714TR       |
| <b>RelyX™ Ultimate<br/>Adhesive Resin<br/>Cement.<br/>(Dual cure resin<br/>cement)</b> | - <b>Base<br/>Paste</b><br>. Methacrylate<br>monomers.<br>. Radiopaque.<br>. Silanated fillers.<br>. Initiator.<br>. Stabilizers.<br>. Rheological<br>additives.<br>- <b>Catalyst<br/>Paste</b><br>. Methacrylate<br>monomers<br>. Radiopaque<br>alkaline (basic)<br>. Fillers components<br>. Initiator<br>components<br>. Stabilizers<br>. Pigments<br>. Rheological<br>additives<br>. Fluorescence dye<br>. Dark cure<br>activator for<br>Scotchbond<br>Universal adhesive |     | 3M ESPE,<br>USA                                              | 7824424      |
| <b>Scotchbond™<br/>Universal Adhesive<br/>bonding agent.</b>                           | MDP, Phosphate<br>Monomer,<br>Dimethacrylate<br>resins, HEMA,<br>Vitrebond,<br>Copolymer, Filler,<br>Ethanol, Water,<br>Initiators, Silane                                                                                                                                                                                                                                                                                                                                    |     | 3M ESPE,<br>USA                                              | 90521B       |
| <b>Acid Etch</b>                                                                       | 37 % phosphoric<br>acid in water<br>thickened with<br>unique polymer.                                                                                                                                                                                                                                                                                                                                                                                                         |     | Ivoclar,<br>Vivadent                                         | X46215       |
| <b>Porcelain etch</b>                                                                  | Hydrofluoric acid<br>9.5 %                                                                                                                                                                                                                                                                                                                                                                                                                                                    |     | Cerkamed,<br>Poland                                          | 2801211      |
| <b>Silane</b>                                                                          | Methacrylic silane,<br>organic solvent.                                                                                                                                                                                                                                                                                                                                                                                                                                       |     | Cerkamed,<br>Poland                                          | 2901211      |
| <b>Zermack Elite<br/>HD+</b>                                                           | Additional silicone<br>putty soft normal<br>set                                                                                                                                                                                                                                                                                                                                                                                                                               |     | Zhermack<br>dental ,Poland                                   |              |
| <b>CMB Kemapoxy<br/>150-3D Clear<br/>Epoxy Resin</b>                                   | Clear epoxy resin                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     | (Cmb, Egypt)                                                 | 784119       |
| <b>Universal glaze (5<br/>gm)</b>                                                      | Glaze powder                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     | Dentsply<br>Sirona,<br>Charlotte,<br>North<br>Carolina, U.S. | 1900428<br>3 |

## 2.2 Methods

### 2.2.1 Ethical approval

This study was approved by the Research Ethics Committee of the Faculty of Dentistry, October University for Modern Sciences and Arts. Approval number: ETH18

### 2.2.2 Sample size

A power analysis was calculated to have satisfactory power to apply a statistical test of the research hypothesis (null hypothesis) that there was no difference regarding the fractional resistance of sectional laminate veneer made of different materials and cemented with different resin cement systems following cyclic loading. By adopting an alpha ( $\alpha$ ) level of 0.05 (5%), a beta ( $\beta$ ) level of 0.20 (20%) i.e., power=80%, and an effect size (f) of (0.677) calculated based on the results of **Chan C and Weber H**<sup>23</sup>. The predicted sample size (n) was a total of 28 samples. i.e. 7 samples per group. Samples were increased to 40 samples. i.e. 20 samples per group then divided into 10 samples per subgroup to account for any losses that might occur during the study Sample size calculation was performed using G\*Power version 3.1.9.2.

### 2.2.3 Selection of teeth

Forty intact, sound, freshly extracted human central incisors were collected from the Oral Surgery Department Faculty of Dentistry, October University for Modern Sciences and Arts. Teeth were used after a signed consent from the patients once explaining the steps of the study. Following extraction, teeth were washed under running water then scaled with ultrasonic scaler (Acteon satelec suprasson P5 ultrasonic scaler, France). Teeth were then polished with prophylaxis paste (Alpha-pro prophylaxis paste, USA), soft rubber cups (elephant prophy cups, CIHINA) and brush at low speed (NSK FX25 LOW SPEED, JAPAN). Teeth shades were brought close using vita classic shade guide, then confirmed and chosen using old version of easy shade digital shade selection.

Using digital caliber, teeth sized were selected to be close to these dimensions; MD=8.5 mm and IG= 10 mm +or- 1mm. Teeth were then examined under 10x magnification clinic microscope to ensure the absence of any crack or caries by caries detecting dye (SABLE SEEK SYR, Ultradent, USA). The teeth used were selected to be as close as possible to shade (A2) and dimensions with an average crown length of 11 mm ( $\pm 0.5$  mm) and mesio-distal diameter of 9 mm ( $\pm 0.5$  mm) to obtain standardization which were confirmed by a digital caliber (Digital Caliper, Adoric, CHINA). Teeth were stored in a box with saline changed every 3 days.

### 2.2.4 Fabrication of epoxy resin blocks

Forty epoxy resin blocks were fabricated and customized for each tooth to act as a holder during testing, with dimensions of (2×2×2cm) for the outer surface. Regarding the inner surface, it was designed to accommodate each individual tooth after enlarging its root dimensions by 0.21mm to accommodate the periodontal ligament simulating material (3M ESPE Impegum soft monophase polyether), using pentamix mixing machine to release the impression material inside the elastomer syringe and then be injected inside the epoxy blocks then followed by tooth placement, excess was then completely removed. The margins of epoxy blocks were placed 2mm below cemento-enamel junction (CEJ).

### 2.2.5 Sectional laminate veneers tooth preparation design

An index was constructed for each tooth individually using additional silicon putty impression material (Elite H-D Putty, Zhermack, Badia Polesine, Rovigo, Italy) to assist in checking the amount of reduction produced. The preparation was performed by one operator using the 0.5mm depth cutter (Tiefenmarkierer depth marker 834 (552) Öko DENT Gruppe Germany) to produce uniform thickness for the entire targeted area of preparation by forming 4 grooves and outlining them using a graphite pencil. A round-ended tapered diamond cutting stone (Diamond instruments 856P, Drendel Zweiling Diamant GMBH, Germany) was used to connect and remove the depth cuts on cervical area at 0.5 depth. The reduction was increased to 0.6mm in the middle and 0.7 mm in the incisal third to accommodate veneer with thickness of 0.7mm.

Preparation was extended 1mm above cemento-enamel junction and from the middle of the tooth at the most concave point on the labial surface to the most convex point on the proximal surface. Preparation depth of each tooth was checked by silicon index proximally and incisally, then rechecked using digital scanner to design a virtual restoration of the tooth.

### 2.2.6 Randomization

The prepared teeth (n=40) were randomly assigned equally into two main groups according to the type of glass ceramic materials (n=20) and then further subdivided into four subgroups according to the resin cement used (n=10). (www.random.org).

### 2.2.7 Allocation concealment

Following randomization, each group was

placed in a sealed plastic bag with different number, allocation ratio was 1:1. Each embedded tooth was given a number from 1-40, then placed in labeled sterilization sealed plastic bag with different numbers for the concealment of allocation. The randomization sequence was further done according to the material used, each group was then subdivided into two subgroups according to the cement used. Then teeth were stored in a labeled container with separate labeled chambers and filled with saline.

### 2.2.8 Wax pattern fabrication

Spacer was applied in two layers up to 1 mm away from margins of the preparation margin (spacer application 9–11 µm). Virtual wax pattern was designed and extended 1mm proximally, the cement gap was placed at (0.04 mm, 1mm away from margins) by exocad software (dentalDB 3.0 Galway, exocad Dental CAD, exocad GmbH, Germany). The insertion of the sectional veneers was obtained. The sectional wax veneers received a semi-anatomic shaping in the software for getting a constant ceramic thickness and then the milling (Aidite, Qinhuangdao, Hebei, province) was started using a CAD/CAM machine (Ceramill motion 2, Amann Girrbach AG, Herrschaftswiesen 1, 6842 Koblach | Austria).

### 2.2.9 Lithium disilicate ceramics (IPS E-max) laboratory steps

#### 2.2.9.1 Spruing

The wax veneers were sprued using the IPS Multi wax, then attached to the IPS investment ring base 100 g with wax and special laboratory tool.

#### 2.2.9.2 Investing

After securing the position of the wax pattern to the investment ring base a little investment material (IPS Press VEST), was applied carefully. Then the IPS silicone ring 100 g was placed on the IPS investment ring Base 100 g. The investment material was then slowly poured into the investment ring and the ring gauge was pressed on the IPS silicone ring until it stopped. Then IPS ring gauge was removed in a turning movement.

#### 2.2.9.3 Preheating

After setting time (1 hour) the investment ring was pushed out of the IPS silicone ring. The investment ring was placed in the preheating furnace (Neytech Vulcan Benchtop Furnace Model D-550) reaching a final temperature of 850°C and a holding time of the investment ring at final temperature for 45 min.

#### 2.2.9.4 Pressing

The investment ring was removed from the

preheating furnace immediately after completion of the preheating cycle and placed into pressing furnace. This step took 30 seconds to prevent the investment ring from cooling down too much. A cold IPS e.max Press ingot was placed into the hot investment ring and the ingot was then inserted into the investment ring. A cold IPS alox plunger was placed into the hot investment ring which had been coated with separator. The loaded investment ring was placed in the center of the hot press furnace (Programat EP 3010 Ivoclar Vivadent, Schaan, Liechtenstein ) and the pressing program was started.

#### 2.2.9.5 Divesting

After cooling to room temperature (60 minutes), polishing beads (aluminum oxide 50  $\mu\text{m}$ ) were used to divest the pressed objects (rough and fine divestment) at 2 bar (29 psi) and 4 bar (58 psi) pressure.

#### 2.2.9.6 Removing of reaction layer

After fine divestment, the reaction layer formed during the press procedure was removed using IPS e.max Press Invex Liquid in an ultrasonic cleaner for 30 minutes, while the white reaction layer carefully removed with type 100  $\text{Al}_2\text{O}_3$  at max. 1 – 2 bar (15 – 29 psi) pressure.

#### 2.2.9.7 Finishing

All specimens were polished with ceramic diamond polishing kit (EVE, Diasynt plus Diapro, Germany) at low speed and pressure to avoid overheating.

#### 2.2.9.8 Glazing

Glazing material was applied evenly onto the restoration. The glaze firing was conducted on a honey-comb firing tray in pressing furnace for 6 min at 770° C. Restorations were then removed from the furnace allowed to cool down to room temperature.

#### 2.2.10 Zirconia reinforced lithium silicate ceramic (Celtra press)

The same strips for the fabrication of e.max were followed with Celtra press samples except for the investing step and preheating program as Celtra press has a special investing product (Celtra Vest) (phosphate-bonded investment).

#### 2.2.11 Sectional laminate veneer cementation

All specimens were ultrasonically cleaned for 10 min before cementation. A dual cured resin cement

(Relyx Ultimate 3M ESPE, USA) and a light cured resin cement (Relyx veneer 3M ESPE, USA) with translucent shade were used to bond the restorations according to their assigned groups.

#### 2.2.12 Ceramic preparation for cementation

The intaglio surface of the IPS e.max press groups and the Celtra press group's restorative sectional veneers were etched with a 9.5 % hydrofluoric acid gel for 20 sec, rinsed with water spray for 60 sec, and thoroughly dried with oil-free air. Sectional laminate veneers were subjected to post etching cleaning using phosphoric acid with a brushing motion for 1 minute followed by rinsing for 20 seconds. The silane coupling agent was then applied to the pretreated surfaces with a micro-brush and left for 60 seconds then the excess was blown using a stream of oil-free air spray.

#### 2.2.13 Tooth preparation for cementation

The prepared area was etched for 30 seconds with 37 % phosphoric acid, rinsed and dried. The bonding agent was applied according to the manufacturer instruction's; the prepared surface was coated with a layer of the bonding agent, which was left uncured until the application of the luting resin.

The dual cure luting resin cement (RelyX Ultimate) automix translucent shade was applied according to the manufacturer instructions to the surface of the prepared teeth. Then, each restoration was seated on its respective prepared tooth using gentle finger pressure. Excess resin was removed gently with a cotton pellet and then light curing was done for 20 sec at 5mm distance from the labial, proximal and palatal surfaces.

The light cure resin cement (RelyX Veneer) translucent shade was applied on the fitting surface of the restorations and the veneers were placed over the teeth in the same way. Excess cement was removed followed by light curing for 40 seconds labially and palatally. The restorations were then stored in distilled water at 37°C for 24 hours to ensure that auto-polymerization of the luting resin was completed.

#### 2.2.14 Artificial Accelerating Aging process

##### 2.2.14.1 Static Fatigue Testing

For resembling the oral conditions, specimens were subjected to dual-axis computerized chewing simulator for number of cycle's equivalent to one year of clinical service. All specimens were first thermo-cycled in a thermo-cycler machine (Thermocycler THE-1100, SD sd-mechatronik, Germany)

10000 times between 5 and 55°C in tap water with a 30 second dwell time at each temperature and transfer time 20 second.

### 2.2.14.2 Dynamic Fatigue Testing

Specimens were then subjected to a chewing simulation to resemble the functional chewing movements in the mouth. The use of SD Mechatronik chewing simulator CS-4 machine for 120,000 cycles with 100 (N) load which equalizes a one year of clinical service in the oral cavity. All samples survived the static and dynamic adding procedures were subjected to fracture loading.

### 2.2.15 Fracture Resistance Testing

The fracture test was operated by applying compressive loading. Specimens were loaded using a universal testing machine (Instron) at an angle of 135 degrees, resembling incisal forces using a ready-made solid base with securing screws to hold the specimen in position during testing. A metal rod indenter with round tip (5 mm diameter) was used to apply the load at a cross-head speed of 1 mm/min. until fracture. The results were provided by the universal testing machine's computer software, recorded and tabulated for statistical analysis<sup>24</sup>.

## 2.3 Statistical Analysis

Numerical data were presented as mean and standard deviation (SD) values. They were explored for normality by checking the data distribution using Shapiro-Wilk test. Data showing parametric distribution were subjected to two-way ANOVA followed by Tukey's post hoc test. Comparison of main and simple effects was done utilizing one-way ANOVA followed by Tukey's post hoc test. P-values were adjusted for multiple comparisons using Bonferroni correction. The significance level was set at  $p \leq 0.05$ . Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows (R Core Team (2022). R: A language and environment for statistical computing. R Foundation for statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>).

## 3 Results

### 3.1 Effect of materials and cement type on fracture resistance

Mean and Standard deviation (SD) values of fracture resistance (N) for different materials and cements were presented in table (2) and figure (1); Celtra Due had a significantly higher fracture resistance mean value than Emax ( $p < 0.001$ ). Dual cured cement had a significantly higher value than light cured cement

( $p = 0.001$ ).

**Table 2.** Mean and Standard deviation (SD) values of fracture resistance (N) for different materials

| Fracture resistance (N) (mean±SD) |               |         |
|-----------------------------------|---------------|---------|
| Celtra Press                      | Emax          | p-value |
| 674.81±78.29                      | 396.76±84.32  | <0.001* |
| Dual cured                        | Light cured   | p-value |
| 601.58±152.99                     | 469.99±160.71 | 0.001*  |

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

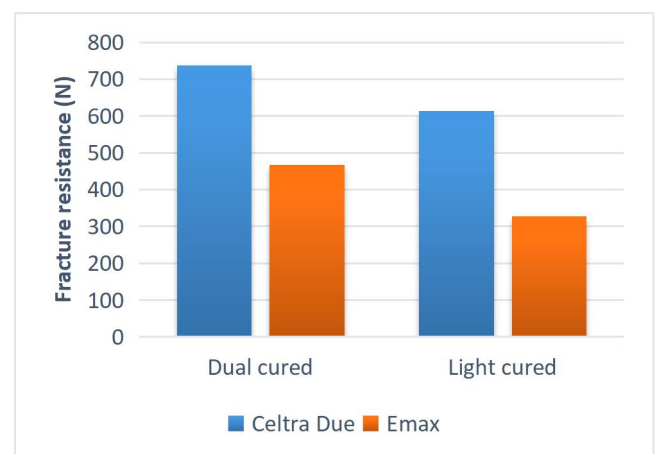
### 3.2 Effect of materials within each cement type on fracture resistance

Mean and Standard deviation (SD) values of fracture resistance (N) for different materials within each cement type were presented in table (3) and figure (1). **Dual cured:** Celtra Press had a significantly higher fracture resistance mean value than Emax ( $p = 0.002$ ). While, **Light cured:** Celtra Press had a significantly higher fracture resistance mean value than Emax ( $p < 0.001$ ).

**Table 3.** Mean, Standard deviation (SD) values of fracture resistance (N) for different materials within each cement type

| Cement type | Fracture resistance (N) (mean±SD) |              | p-value |
|-------------|-----------------------------------|--------------|---------|
|             | Celtra Press                      | Emax         |         |
| Dual cured  | 736.63±45.78                      | 466.53±41.29 | 0.002*  |
| Light cured | 612.98±41.97                      | 326.99±38.27 | <0.001* |

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



**Figure 1.** Bar chart showing average fracture resistance (N) for different materials within each cement type

### 3.3 Effect of different cement types within each material

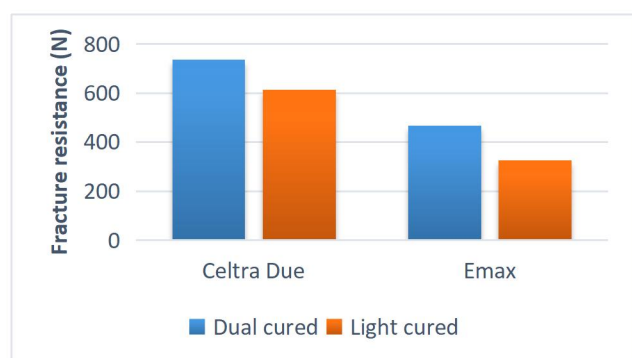
Mean and Standard deviation (SD) values of fracture resistance (N) for different cement types within

each material were presented in table (4) and figure (2). **Celtra Press:** dual cured cement had a significantly higher mean value than light cured cement ( $p=0.026$ ). While **Emax:** dual cured cement had a significantly higher mean value than light cured cement ( $p=0.013$ ).

**Table 4.** Mean, Standard deviation (SD) values of fracture resistance (N) for different cement types within each material

| Material            | Fracture resistance (N) (mean±SD) |              | p-value       |
|---------------------|-----------------------------------|--------------|---------------|
|                     | Dual cured                        | Light cured  |               |
| <b>Celtra Press</b> | 736.63±45.78                      | 612.98±41.97 | <b>0.026*</b> |
| <b>Emax</b>         | 466.53±41.29                      | 326.99±38.27 | <b>0.013*</b> |

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



**Figure 2.** Bar chart showing average fracture resistance (N) for different cement types within each material

### 3.4 Intergroup comparison

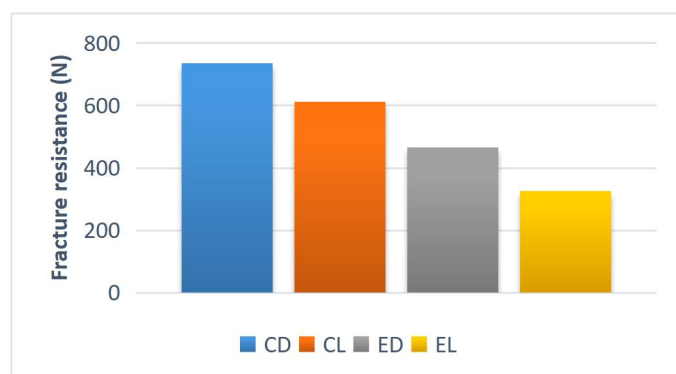
Mean and Standard deviation (SD) values of fracture resistance (N) for different groups were presented in table (5) and figure (3).

There was a significant difference between different groups ( $p < 0.001$ ). The highest mean value was found in CD, followed by CL, then ED, while the lowest mean value was found in EL. All post hoc pairwise comparisons were statistically significant ( $p < 0.001$ ).

**Table 5.** Mean, Standard deviation (SD) values of fracture resistance (N) for different groups

| Fracture resistance (N) (mean±SD) |               |               |               | p-value           |
|-----------------------------------|---------------|---------------|---------------|-------------------|
| CD                                | CL            | ED            | EL            |                   |
| 736.63±45.78A                     | 612.98±41.97B | 466.53±41.29C | 326.99±38.27D | <b>&lt;0.001*</b> |

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



**Figure 3.** Bar chart showing average fracture resistance (N) for different groups

## 4 Discussion

By means of the growing passion about dental esthetics and smile boosting, dentists are confronted by a number of challenges when restoring anterior teeth as regards; form and contour particularly within the light of recent conservative approach and minimal teeth invasion techniques<sup>1</sup>. Incisal fracture, diastema closure, chipping and class IV cavities of anterior teeth represent major challenges. Consequently, sectional veneers were adopted as a line of treatment for such situations<sup>2</sup>. This innovative treatment modality permitted reproduction of superior esthetical outcome through the ability of reforming and realigning of anterior teeth, either vertically or horizontally<sup>4</sup>.

In the current study, forty sound extracted human upper central incisor teeth were used. It is vital to meticulously simulate the clinical situation, as well as to benefit from elemental properties as, evaluation of bonding and elasticity between restoration and natural tooth<sup>25</sup>. Human teeth are surrounded by supporting tissues preserving them from harmful stresses that might lead to fracture or failure<sup>26</sup>. Accordingly, 3M ESPE Impregum Soft Monophase Polyether was utilized to resemble the periodontal ligament attachment. Rathi A. *et al.* in 2018<sup>27</sup>, their study demonstrated the significance of implementing polyether impression material for mimicking the periodontal ligaments wrapping the radicular portion, that might act as a shock absorbing cushion component. The coronal tooth portion preparation design directly impacts the bonding and success rate of the treatment modality, multiple preparation designs were presented for laminate veneers that were priority investigated: feather edge, window preparation, incisal overlap and butt joint<sup>28</sup>. Designs as butt joint and incisal overlap comprise the incisal edge in the preparation, on the contrary, feather edge and window preparation designs don't, thus allowing conservation of enamel and enhancing bonding and preservation of tooth structure<sup>8, 28</sup>. In the light of sparing more peripheral enamel, feather edge was chosen for this

study in order to promote adhesion<sup>9</sup>.

Thickness of the preparation is a critical factor that has a great effect on the strength and retention of the restoration<sup>29</sup>. A unified thickness was demarcated and applied to all extracted natural teeth receiving restorations; 0.5 mm cervically and 0.7mm incisally. These thickness values have documented significance in sufficient tooth structure preservation for higher bonding values, moreover attainment of sufficient restoration thickness, resulting in improved mechanical attachment and strength<sup>30-32</sup>.

Bone morphology is considered an influencing factor regarding force absorption and distribution for avoiding destructive forces, besides fixation and alignment of teeth<sup>33</sup>. Epoxy resin blocks were fabricated to aid in precise housing of the radicular portion of the tooth, these blocks were fabricated using CAD/CAM technology through scanning of each individual root<sup>34</sup>.

For optimum results, the restoring material should produce adequate esthetical and optical properties along with superior mechanical properties<sup>35</sup>. Lithium disilicate glass ceramics are categorized by their rod-shaped and platelet shaped crystals with equal lengths and high aspect ratio establishing interlocking microstructure, combined by their ability in providing superior bonding measures to tooth structure, besides displaying excellent esthetical results. Their 70 % crystal phase permitted natural refraction of light, with acceptable flexural strength ranging from 360 to 400 MPa (13)<sup>36</sup>.

Innovations brought out the revealance of hybrid glass ceramics, which enhanced the mechanical properties of glass ceramics to meet the desired criteria without hindering their optical properties. Their etchability is considered a beneficial criteria enabling enhanced bonding to tooth structure, accompanied with high strength values gained from infusing 10 % of zirconium oxide in the glass phase within the atomically dissolved form, beside their small sized crystals and the ultra-fine microstructure which advocate higher flexural strength, along with high glass content<sup>37</sup>.

Following the satisfactory characteristics of Lithium disilicate glass ceramics; high aesthetical properties and ability to restore the natural shades of the tooth besides their impressive mechanical properties<sup>38</sup>, they were chosen to be compared to the newly introduced zirconia reinforced lithium silicate glass ceramic.

Accelerated artificial ageing procedure helps in simulating oral factors, it was conveyed that one year of clinical conditions is equivalent to 10,000 cycles of thermal cycling at temperature ranges from 5°C - 55°C with dwell time of 30 seconds, additional cyclic or

dynamic loading procedure resemble directional loading masticatory forces<sup>39</sup>.

In the current study, specimens were subjected to 120,000 cycles with 100 N load to resemble one year of clinical service, according to Elsayed S. *et al.* in 2019<sup>40</sup>, who reported that 60,000 cycles with 100 N is equivalent to six months of clinical conditions.

Following ageing procedures, fracture test was conducted as a load to failure test, using a universal testing machine (Instron), samples were mounted at an angle of 135 degree to grip the samples in the desired position, resembling the incisal forces. Samples were all loaded until fracture and the results were recorded by the universal testing machine's computer software. This was in agreement with study Gresnigt M. *et al* in 2021<sup>41</sup>, they indicated that the significance of loading to failure at 135 angle degree simulates the incisal forces on anterior teeth.

The samples (n=40) were randomly assigned into 2 main groups according to glass ceramic material which were then subdivided into 4 subgroups according to resin cement ([www.random.org](http://www.random.org)). Following randomization, each subgroup was placed in a sealed plastic bag with different number with allocation 1:1. Each tooth were given no. from 1-40 then placed in labeled sterilization plastic bag with different no. for the concealment of allocation that was done by the supervisor to avoid disclosing. Blinding was stopped when the cementation procedure began, to avoid detection bias, the statistician also worked blindly with the data.

Results showed that zirconia reinforced lithium silicate had higher statistically significant fracture resistance mean value than lithium disilicate glass ceramics. Zirconia reinforced lithium silicate had mean fracture resistance value of 674 N compared to lithium disilicate glass ceramic which recorded 396 N (**Table 2**). Indicating the rejection of the first null hypothesis. This might be explained by the infusion of the zirconia fillers in the glass phase that promoted the mechanical properties of the ceramic material. This was correspondent with the findings of Hamza T. *et al.* in 2017<sup>42</sup>, whom their study revealed that fracture resistance of zirconia reinforced lithium silicate glass ceramics was superior over lithium disilicate. Moreover, Schwindling F. *et al* in 2017<sup>43</sup>, they compared the fracture resistance of zirconia reinforced lithium silicate and lithium disilicate materials. Their results showed that zirconia reinforced lithium silicate recorded mean value of 766N while lithium disilicate recorded 485 N.

These results might be attributed to the incorporation of zirconia grains within the glassy matrix, that act as a nuclei of crystallization which might produce more smaller crystallites (0.5 – 1  $\mu$ m) rather than few large crystallites (1.5  $\mu$ m) present in lithium disilicate, that might explain why glass phase of Celtra Press is in higher

ratio when compared to lithium disilicate ceramics, despite having higher percentage of crystal phase (about 70 %) compared to Celtra Press <sup>42</sup>. Also, the lower modulus of elasticity of Celtra Press (70 GPa) compared to E.max CAD (95 GPa), might suggests that stress accumulation in E.max CAD is higher than Celtra Press <sup>44</sup>. Moreover, the incorporation of zirconia might have increased the fracture toughness through stress induced toughening mechanism that prevent crack propagation <sup>45</sup>.

On the contrary, Hallman L. *et al.* in 2019 <sup>46</sup>, they stated that the lathe-like crystals with short length and low aspect ratio result in low fracture toughness of zirconia reinforced lithium silicate glass ceramics. Also, Corado *et al.* in 2020 <sup>47</sup>, they assumed that the incorporation of zirconia might decrease the crystallinity of the ceramic leading to increased microcracks on the surface, resulting in decreased fracture strength values. while, Mogahed *et al.* in 2021 <sup>22</sup>, they explained the lower fracture strength of zirconia reinforced glass ceramics might be due to severe incompatibility in coefficient of thermal expansion between phases (3 crystal phases and 1 glass phase containing dissolved ZrO<sub>2</sub>) leading to residual stresses during cooling which led to microcracks.

The statistically high fracture resistance means value of zirconia reinforced lithium silicate might be due to the manufacturing techniques, where the press technique is assumed to have higher mechanical strength due to the compaction of smaller sized particles, higher glass matrix and lowered crystal phase. Press technique might also have an enhanced re fracture resistance compared to CAD technique due to crystals orientation and flowability during pressing that aid in providing enhanced fit with no reaction layer formation, that requires no correction or alteration <sup>48</sup>.

This was in accordance with Rasha S. *et al.* in 2020 <sup>49</sup>, their results showed higher strength values exhibited by Celtra Press (500 MPa) compared to CAD technique (370 – 420 MPa).

However, Riad M. *et al.* in 2017 <sup>50</sup>, their results revealed higher strength values with CAD technique over press technique on lithium disilicate glass ceramics. This might be due to difference in the manufacturing companies of the materials used.

The discrepancies in the reported values for Celtra Press, with other published data claiming higher values and others lower, can be attributed to a number of factors, primarily related to the specific test methodologies and the material's unique composition and processing.

Results of the current study showed significant difference in fracture resistance and bonding regarding

dual and light curing modes of resin cement, dual cure resin cement had higher fracture resistance mean value compared to light cure resin cement. Indicating the rejection of the second null hypothesis.

This was in agreement with the findings of Ge C. *et al* in 2018 <sup>51</sup>, they concluded that the thickness has to be confined to the enamel portion to enhance the bonding strength. Also, Turp *et al.* in 2018 <sup>52</sup>, their results revealed the superiority of dual cure resin cement over light cure resin cement. These findings might be attributed to the higher depth of curing in dual curing mode <sup>53</sup>.

Dual-cured resin cement combines the benefits of both light and chemically polymerized resins; sufficient degree of polymerization is achieved besides offering a prolonged working time. Accordingly, a rapid initial set of the resin cement promotes to a stabilized restoration. In addition, it exhibits greater mechanical properties in contrast to other activation mechanisms <sup>54</sup>. This might justify the higher fracture resistance values of the dual cured resin cement compared to light cured.

On the other hand, Gresnigt M. *et al.* in 2017 <sup>41</sup>, their findings showed presence of chipping and wear of samples bonded with dual cure resin cement compared with light polymerizing luting agent which suffered wear only.

This study had some limitations, first midline definite margins are hard to conceal but were chosen in the current study to standardize the sample preparations. Second the study only tested preparation thickness of the preparation of 0.5 mm and 0.7 mm while other thicknesses may yield different results. Third although, the samples were exposed to accelerated artificial aging by thermal cycling process and dynamic loading. However, the anterior teeth are daily subjected to ultraviolet light that may stimulate the oxidation of amine accelerator in luting resin cements. Fourth, only one resin cement material from one manufacturer was used, whereas including materials from multiple manufacturers is recommended to ensure an applicable result. Lastly, In vitro study design may not replicate complex oral forces and environmental factors.

## 5 Conclusion

Within the limitations of the study the following conclusions may be drawn:

- Zirconia reinforced lithium silicate (Celtra press) demonstrated statistically higher fracture resistance than lithium disilicate (IPS e-max press) after undergoing thermodynamic loading, indicating superior performance under simulated clinical conditions.
- Dual cure resin cement possesses higher fracture

resistance values compared to light cure resin cement following thermodynamic loading, suggesting enhanced durability and performance under simulated clinical conditions.

- Both glass ceramic materials may be used as sectional veneers to restore maxillary incisors.

## Recommendations

1. It is recommended to use a dual cure resin cement free of aromatic tertiary amine especially with Celtra Press glass ceramic restorations.
2. It is recommended that other sectional veneer designs should be tested.
3. Further in vivo studies are required to evaluate the effect of new materials, cements and preparation designs.

## Authors' Contributions

**Mohamed Fouad:** manuscript writing and design.  
**Nadia Zakaria Fahmi:** manuscript writing and design.  
**Mai Hesham Abd ElRahman:** concepts, design.  
**Mohamed Mokhtar:** design and definition of intellectual context.

## Conflict of interest

The authors declare that they hold no competing interests.

## Funding

The research study was self-funded by the authors.

## Acknowledgement

We would like to thank all MSA staff for their support in bringing this work to fruition.

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