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The Effect of two margin designs on fracture resistance of Zirconia re-enforced lithium silicate crowns

Iman Jaber[1], Marwa mohamed Wahsh[2], Maged Zohdy[3]

Aim: The continuous search for better qualities and properties will never stop. As advancements in dentistry continue, new materials and techniques are being introduced to the market to meet the increasing demand for superior esthetics and best physical and mechanical properties. This study was conducted to evaluate the fracture strength of full-contour crowns of Zirconia re-enforced lithium silicate (Celtra Duo) with two different marginal designs. Deep chamfer finish line (1mm) and Featheredge finish line (0.2mm).

Materials and methods: 14 full contours monolithic Celtra Duo crowns were divided into two groups (n=7) according to each preparation design. Group (C): samples with deep chamfer finish line design (7 samples) Group (F): samples with feather edge finish line design (7 samples)

Results: Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Independent-samples t-test of significance was used when comparing between two means. The significance level was set at $p \leq 0.05$ within all tests.

Conclusion: The highest value of the fracture strength was detected in Celtra duo crowns with feather edge design.

Keywords: Zirconia-PEEK, acrylic-metal, fixed detachable implant prosthesis, clinical, radiographic, prosthetic outcomes.

1-B.D.S. Future University in Egypt,2012
2-Professor of Fixed Prosthodontics Department, Faculty of Dentistry, Ain Shams University
3-Associate professor of Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University
Corresponding author: Iman Jaber, email: amy14@gmail.com

Introduction

Advancements in computer system technologies have revolutionized the field of dentistry through the introduction of CAD/CAM systems. The popularity of these systems over the past 25 years is attributed to their efficiency, precision of designing and manufacturing.

This technology was developed to overcome 3 challenges: First, is to ensure adequate strength for the restoration. Second, is to provide a restoration with a natural appearance and the third, to produce a much more accurate restoration faster and easier.[(2)(1)]

The CAD/CAM non-metal restorative materials are either ceramics or composite or hybrid ceramics.

The ceramic materials include feldspathic glass ceramics, leucite re-enforced glass ceramics, Lithium disilicate glass ceramics, zirconia oxide, lithium silicate re-enforced glass ceramics *(ZLS)*, translucent zirconia and high translucent zirconia. [(2)] whereas Resin materials such as PMMA and Resin composite blocks. Then hybrid ceramics *(resilient ceramics)* includes, polymer infiltrated ceramic network *(PICN)* in addition to Nano ceramics *(LAVA ultimate)* and *(Cerasmart)*.

The comparison between the characteristics of all 3 groups of CAD/CAM materials for indirect use *(ceramics, composite and hybrid ceramics)* regarding their mechanical, physical and esthetic properties shows that ceramics are considered the hardest and the most resistant to wear among them all. They are biocompatible and provide superior esthetic qualities [(3)]. Yet, they are very brittle and highly susceptible to fracture except for zirconium oxide. They don't accept add on adjustments and cause excessive wear to the opposing natural dentition. [(4)]

On the other hand, composite shows different behavioral features. They are resilient less resistant to wear. They have easy finishing and polishing properties and can easily be repaired and altered. Besides, they are less abrasive to the opposing natural teeth.[(4)]

An attempt to merge both materials together *(ceramics and composite)* in order to get both of their qualities combined and avoid their drawbacks, resulted in the production of hybrid ceramic materials. Their mechanical properties are similar to enamel and dentine. They have inferior brittleness, hardness and rigidity comparing to ceramics. But, in terms of machine handling properties and fracture toughness they are superior to ceramics therefore, they can provide more precise results at areas of thin margins, therefore, post milling procedures such as firing or finishing and polishing are not necessary [(4)]

There are different marginal designs applied for the various types of fixed restorations, they can be classified into: horizontal finish line *(shoulder or chamfer)* and vertical finish line *(feather edge)* or (without finish line) [(6, 7)]. The last two types are considered as biologically oriented preparation technique *(BOPT)* [(8) (5)].

The widely used preparation design for ceramic crowns is the chamfer finish line, the favorable reasons behind this are the precise marginal fitting of the crown over the abutment, the increased crown resistance for fracture and the esthetics qualities provided by this design for the restoration to attain long-term durability. [(6, 7, 8)]

While the feather edge design, in which an acute angle is formed with the restoration is commonly indicated in periodontally compromised cases with severe erosion. This approach is the least invasive when it comes to the conservative goals of reduction and comparing to the common horizontal margin designs [(9)]. It permits for high preservation of the pulp tissues since the cervical zone is the most sensitive area for the pulp integrity [(10)].

Aim of the study

This study was conducted to evaluate the fracture strength of full-contour crowns of Zirconia re-enforced lithium silicate with two different marginal designs.

The marginal designs:

- Deep chamfer finish line (1mm)
- Featheredge finish line(0.2mm)

Materials and Methods

Epoxy Resin:

It is a polymer which cures or sets into hard shape using curing method such as heat or radiation. The setting process is irreversible and it is compatible with most substrates. It is used to form the dies in this study.

Celtra duo comes in the form of blocks as shown in fig. ***(1)***. It contains 10% zirconium dioxide ***(ZrO_2)*** in highly dispersed form in the glass phase of ceramic. This prevent crystallization of the zirconium oxide; this material has high translucency and opalescence and is less opaque than zirconium oxide ceramics. The highly dispersed ZrO_2, forms new nuclei of crystallization, resulting in formation of high number of small crystallites rather than a few numbers of large ones. The structural characteristics in ZLS lead to special mechanical properties (table 1)

Fig (1): Celtra Duo blocks

Table (1): physical and mechanical properties of Celtra Duo

Physical and mechanical properties	Celtra Duo directly from the cerec^R MC XL and polished	Celtra duo with glaze firing
Flexural strength ***(MPA)***	210	370
E-modulus	Approx. 70	
Hardness ***(HV)***	Approx. 700	
Intrinsic strength	420 MPa	

Total-cem:

Total-cem is self-etch, self-adhesive, dual-cured resin cement. Its significant advantage that it is considered all-in one cement ***(Etch + Bond + Cement)***. Its curing time is 3-4 sec. It is also in-soluble and radio-opaque. Fig. ***(2)***

Fig (2): Totalcem resin cement

Methods

In this vitro study, 2 extracted maxillary premolars were prepared and duplicated into fourteen epoxy resin dies on which 14 full-contour Celtra Due crowns were constructed using the CAD/CAM system. The crowns were constructed with 2 margin designs and were cemented over the epoxy dies using self-adhesive resin cement.

Load to fracture was then applied to the specimens and the load at which each specimen fractured was recorded and analyzed.

Samples Grouping

14 full contour monolithic Celtra Duo crowns were divided into two groups **(n=7)** according to each preparation design.

Group (C): samples with deep chamfer finish line design **(7 samples)**

Group (F): samples with feather edge finish line design **(7 samples)**

1- Natural teeth preparation:

Two extracted maxillary first premolars were fixed on acrylic base for easier manipulation. The CNC machine was used for performing an accurate and standardized preparation design simulating all ceramic full cover crown preparation of a maxillary premolar as shown in fig. **(3)**. Two designs were produced according to the following parameters:

The chamfer design: occlusal reduction **(1.5 mm)**, axial reduction **(1mm)**, taper **(6^0-10^0)**, finish line thickness **(1mm)**.

The feather edge design: occlusal reduction **(1.5 mm)**, axial reduction **(1mm)**, taper **(6^0-10^0)**, finish line thickness **(0.2 mm)**.

Fig (3): Two prepared maxillary first premolars

2- Fabrication of Epoxy resin dies:

Additional silicon impression material was used to take an impression for the extracted first premolars after being prepared into two preparation designs to create an index for molding the poured epoxy resin and produce the resin dies.

Scanning and designing of epoxy dies

Each epoxy sample was sprayed with a thin uniform coat of scanning spray **(Tele scan)** as in fig. (4) and scanned separately using the digital scanner1 **(shining 3D DS-EX)** fig. **(5),** then every scanned sample had a separate file which is going to be transferred to the ExoCad software **(ExoCAD Matera 2.3)** for designing of the ceramic crowns.

Fig (4): using scanning powder Fig (5): scanning machine

Crown Designing:

Starting with the ExoCad software, selection of the tooth to be restored **(maxillary first premolar)** was made from the dental arch on the screen menu, then selection of the restoration type **(crown framework)** was done and confirmed. A window for a new restoration was opened and a dialog box appeared where data regarding the new restoration were entered.

14 crowns were designed on the scanned dies (7) for each margin design. several important parameters were set including margin placement, insertion axis, occlusal thickness and cement spacer.

Milling of Celtra Due crowns

The ceramic material used was Celtra Duo. The material was milled into 14 ceramic crowns, 7 of them had chamfer finish line and the other 7 crowns had the feather edge design.

For the material selection, the dialog box appears, by which the chosen material for the fabrication of the crowns was selected.

The blocks of the ceramic material were then placed inside the **(Redon Hybrid machine)** for milling and as shown in fig. **(6,7**). Then, the marginal thickness of every crown was measured again after milling using a caliper. As shown in fig. **(8)**

Fig (6): Milled crowns fixated in milling machine

Fig (7): milling machine (Redon Hybrid machine)

Fig (8): checking marginal thickness using manual caliper

Adhesive bonding of Celtra Duo crowns

The internal surface of the crowns received chemical surface treatment using Donto-bond etch and silane-coupling agent. First, (9%) hydrofluoric acid etch was applied using micro-brush for 30 seconds on the entire internal surface of the crown. Fig. (9) Then, the crown was rinsed with water and dried with air using air/water syringe until the whole fitting surface showed a chalky white appearance. Fig. (10, 11)

Later on, a silane-coupling agent was applied and allowed to soak for 60 seconds as shown in fig.(12) .Then the crown is ready for cementation as in fig. (13)

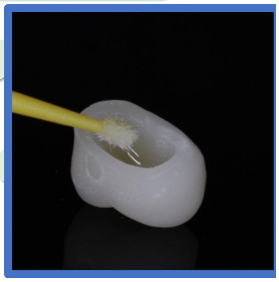

Fig (9): etching

Fig (10):rinse and dry

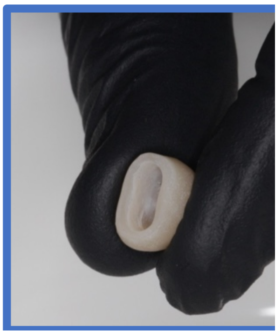

Fig (11):chalky white apearance

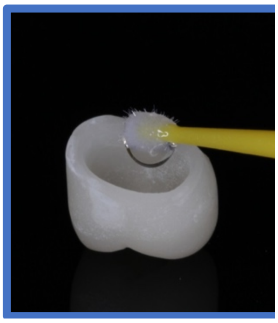

Fig (12): silanation

Fig (13): crown is ready for cementation

For cementation, self-etch, self-adhesive, dual cure resin cement was used. Each crown was filled with resin cement; the cement was applied to the internal surface of the crowns and covers the axial walls completely as shown in fig. (14). The applied cement was then lightly thinned with air to avoid its coagulation and air voids. The crown was held and seated over their relevant epoxy resin dies by static finger pressure. Initial curing with (blue phase light cure) was done for 1 second (spot curing) per surface (buccal, distal, lingual and mesial) to remove the excess cement manually using metal probe. The cementation procedure was done using a modified dental surveyor under a constant load of 5 Kg. The load was applied vertically on the occlusal surface of the crown for 5 minutes. During this period, a light curing unit was done according to the manufacturer's instructions fig. (15) until complete setting of the cement. Every sample is polished using the nylon polishing discs to remove any cement residues at the margin fig. (16)

Fig (14):applying resin cement

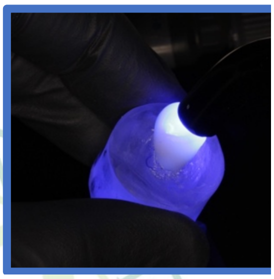

Fig (15): curing

Fig (16): finishing and polishing

The specimens were subjected to 5000 cycles of thermal cycle using a thermocycler (SD Mechatronic, Germany) at temperatures between (50C) and (550C) for 20 seconds at an interval of 10 seconds. fig. (17)

Fig (17): Emerged samples

Fracture Load Test

Each sample was attached into the Universal Testing Machine (Instron Universal Testing Machine model 3345, England) fig. (18) until fracture take place, the samples were screwed and fixed to the attachment which was screwed to the lower head of the machine, and the samples were then loaded vertically on the central fossa of their occlusal surface. The loading piston was centered along the long axis of the samples. The loading piston was a semi-spherical vertically movable rod, 3mm in diameter. fig. (19). Thrust speed of the machine was 0.5 mm/min. The universal testing machine was controlled via computer software system, which also completed the stress- strain diagram and recorded the breaking load. Fracture was determined as load suddenly dropped by acoustic events.

Compression mode of force applied at cross head speed (1 mm/minute) at fixed rate up to specimen failure. The soft-ware of the universal testing machine (blue hill free) adjusted the amount of applied force and register the fracture values of the samples as soon as the fracture occurs. fig. (20)

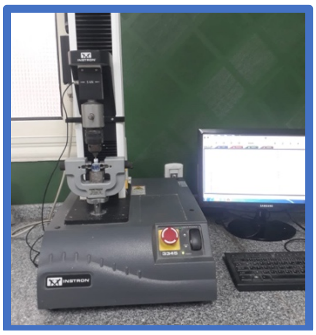

Fig (18): universal testing machine

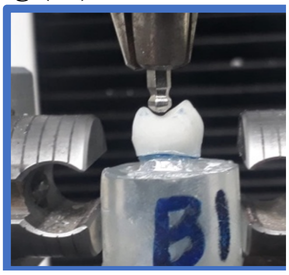

Fig (19): applying load

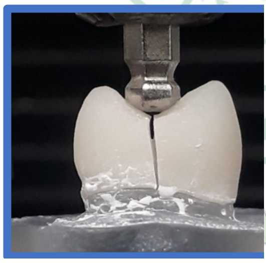

Fig (20): point of fracture

Statistical analysis:

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Independent-samples t-test of significance was used when comparing between two means. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with IBM SPSS Statistics Version 26 for Windows.

Results

Descriptive statistics:

Descriptive statistics for fracture resistance (N) of different preparation design at Celtra Duo were presented in table (2).

Table (2): Descriptive statistics for fracture resistance (N) of different groups

Material	Preparation Design	Mean	SD	Median	Min.	Max.
Celtra Duo	Deep chamfer	1206.78	80.79	1223.32	1091.03	1307.03
	Feather edge	1339.74	110.23	1363.86	1169.40	1474.71

Effect of preparation design within Celtra Duo in table (3).

Samples prepared with feather edge finish line (1339.74±110.25) had a significantly higher value than deep chamfer samples (1206.78±80.79) (p=0.024).

Table (3): Mean ± standard deviation (SD) of fracture resistance (N) for different preparation designs.

Preparation design	Celtra Duo
Deep chamfer	1206.78±80.79B
Feather edge	1339.74 ±110.23B
p-value	**0.024***

Using: Independent Sample t-test; *; significant ($p \leq 0.05$)

Discussion

The purpose of this in vitro study was to evaluate the influence of different margin designs on the fracture resistance of Celtra Duo (zirconia re-enforced lithium silicate).

Two extracted maxillary first premolars were machine prepared using CNC machine into two standardized preparation designs to eliminate any possible human errors that may be introduced in the reduction process. The epoxy resin material was then chosen to duplicate the extracted first premolars and create resin dies. The epoxy material simulates the natural tooth in the matter of hardness and it doesn't need any surface treatment as the natural tooth does.

The modulus of elasticity of the support (the epoxy resin dies) influences the susceptibility to fracture of a cemented ceramic crown, thus the epoxy resin was chosen for the fabrication of the abutments as they have a modulus of elasticity of 12.9 GPa which is close to the reported modulus of elasticity of human dentin 14.7 GPa. *(11, 12, 13)*

The epoxy dies mimic the reduced maxillary premolars with 5.5 mm height, 7.5 mm diameter and 12° total occlusal convergence angle as recommended by Goodcare et al *(23)*. They were divided into two groups according to the preparation design/ finish line thickness into (deep chamfer with 1mm thickness) and (feather edge finish line with (0.2 mm thickness).

The crowns were designed with standard parameters using ExoCad software and then milled.

Celtra Crowns were first milled then glazed by firing at 840 ºC for 22 minutes. *(15)*

Celtra Duo (zirconia reinforced lithium silicate), the internal surface of the crowns was surface treated chemically to provide mechanical roughness and chemically activated surface

The hydroflouric acid dissolve the glassy component in the silica based restoration producing a porous surface. Silane was then applied to form a chemical bond with the silica in the ceramic restoration and the resin cement for adhesive cementation. *(16)*. Self-Adhesive dual cured resin cement containing MDP was chosen in this study as it eliminates the need of pretreatment of abutments.

Thermo-cycling was done by exposing the specimens to a range of temperature similar to temperature of the oral cavity which can produce adverse consequences as a result of different co-efficient of thermal expansion between the epoxy abutments and restorative material *(17)*.

All specimens were tested using vertical compressive load by computer-controlled universal testing machine, even though lateral forces are the most damaging, so clinical implications of the current study must be limited to that application. All samples were loaded until fracture occurs and the maximum breaking load of each sample was recorded. A 3mm diameter semi-spherical stainless steel vertical rod was used. The use of a small ball increased the contact pressure in the crown system compared to the clinical contact pressure. In this study, all ceramic materials were subjected to the same load frequency and contact pressure *(18)*

Regarding the effect of each design on the fracture strength of the Celtra Duo crowns

In Celtra Duo the fracture strength mean value in this study was significantly higher with feather edge design more than chamfer design.

Samples prepared with feather edge finish line *(1339.74±110.25)* had a significantly higher value than deep chamfer samples *(1206.78±80.79) (p=0.024)*.

another study showed that the fracture resistance values of celtra Duo crowns with vertical preparation are slightly higher than the fracture resistance value of celtra due crowns with horizontal preparation. The results of this study showed that the values were non-significant. It was promising for vertical preparation design to achieve such results by *Kasem, A. T., et al.* *(19)*

Reich et al *(20)* studied the effect of finish line preparation and layer thickness on the failure load and fractography of zirconia copings. The results showed that a higher mean failure load was measured for vertical preparation (0.5 mm, 1110 ± 175 N; 0.3 mm, 730 ± 160 N) vs chamfer preparation (0.5

mm, 697 ± 126 N; 0.3 mm, 455 ± 79 N). They stated that the fracture load required for vertical preparation was greater than that required for chamfer preparations by 38%.

Conclusion

With the limitations of this study, the following conclusions could be drawn:

The higher value of the fracture strength detected in Celtra Due crown was with the feather edge margin design. The feather edge margin design is a promising alternative to other margin designs, as it is more conservative approach and as long as resin cement is being used as adhesive cement to increase the fracture strength and durability.

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