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FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH LITHIUM DISILICATE CROWNS RETAINED WITH FIBER POSTS COMPARED TO CERASMART AND CELTRA DUO ENDOCROWNS (IN VITRO STUDY)

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ABSTRACT

Aim: The purpose of this study wasto evaluate the fracture resistance of cerasmart and Celtra Duo endocrowns compared to endodontically treated teeth restored with glass fiber post and lithium disilicate crowns.

Methodology: Eighteen sound maxillary premolars were endodontically treated, then divided into three groups: Group (GE) received fiber post, resin core and lithium disilicate (IPS E.max CAD, Ivoclar-Vivadent) crown. Group (GC) received endocrown with butt joint finish line design fabricated from hybrid ceramic (CERASMART, GC Dental USA). Group (GD) received endocrown with butt joint finish line design fabricated from zirconia reinforced lithium disilicate (CELTRA DUO, Dentsply Sirona). All restorations were fabricated using (CEREC MC XL SW 4.0) milling machineand cemented with self-adhesive dual cureresincement. Thermo-mechanical fatigue was applied on all samples and fracture test was then done. Scanning electron microscope was used for examining the fractured samples.

Results: Fracture resistance test showed that there was statistically significant difference between the three groups (P-value = 0.001, Effect size = 0.603). GE showed statistically significant highest median fracture value (1866 +/- 399.9). Meanwhile, there was no statistical difference between mean fracture resistance values of GC of (1045.1 +/- 122.1) and GD (1377 +/-307) where both showed statistically significant lowest mean fracture resistance values.

Conclusion: Conventional post, core andcrown treatment option remains the gold standard for treating endodontically treated maxillary premolar, nevertheless endocrown restoration on premolars needs further research to become a viable restoration in this condition.

KEYWORD: Endodontically treated teeth, Endocrowns, Post and core

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INTRODUCTION

The restoration of endodontically treated teeth is considered one of the clinical challenges. Loss of the structural integrity is due to previous dental caries, pre-existing restorations and also the performance of endodontic procedures which make them more brittle and thus resulting in teeth weakening.

Despite the success achieved clinically using intraradicular posts, several drawbacks were reported including the need to remove sound tooth structure, tooth fracture, risk of root perforation, post decementation and the mismatch of modulus of elasticity between dentin and post material. These drawbacks created a necessary demand to have an alternative treatment options. Among these options is the use of endocrown restoration, which has the advantage of preservation of the remaining tooth structure.[1]

Technological development in the dental industry enabled the production of all-ceramic materials with many favorable characteristics such as excellent esthetic appearance due to excellent optical properties (translucency and transparency), natural tooth color and chromatic stability, biocompatibility, chemical inertness and low thermal conductivity. Also, optimal mechanical properties such as high flexural strength and fracture toughness, as well as wear resistance and low abrasive properties made it a preference to dental clinicians. Ceramic materials can be used for manufacturing of all kind of single-tooth restorations such as veneers, inlays, onlays, crowns and posts.

Moreover, flexible composite CAD/CAM milling blocks have been introduced for the fabrication of endocrown restorations instead of ceramic blocks that were originally described for the construction of the endocrown. From a biomimetic perspective, these less brittle composite CAD/CAM blocks have mechanical properties that are approximately close to those of human dentin. [2]

Zirconia reinforced lithium disilicate materials have also been launched recently. Their outstanding properties are owed to their unique microstructure. The presence of 10% zirconia in the glass phase in atomically dissolved form provides high strength and ensures safe and long-lasting restorations [3].

Endocrowns lately have gained increased popularity; however, there is little evidence in the literature about this treatment option. Thus the aim of this study was to evaluate the fracture resistance of cerasmart and Celtra Duo endocrowns compared to endodontically treated teeth restored with glass fiber post and lithium disilicate crowns.

MATERIALS AND METHODS

Eighteen caries free recently extracted human maxillary premolars were selected for this study. To standardize procedures and materials, all teeth used in this study had two root canals with a curvature of less than 5°, evaluated by Schneider's technique and teeth with a root length of 15±1 mm. Specimen ranged 10 ± 2 mm in size, measured at the widest buccolingual dimension. Regarding the mesiodistal dimension, specimen ranged 7 ± 2 mm. Teeth were measured using a caliper*.[4, 5].

The selected teeth were disinfected by immersion in 5% sodium hypochlorite solution for 15 minutes at room temperature followed by cleaning using an ultrasonic scaler** at low power and under copious amount of water coolant to avoid the formation of any micro-cracks.

All teeth were mounted in epoxy resin blocks by the aid of a custom-made round Teflon shape sample holder (2cm length & 2cm internal diameter) in a vertical direction using centralizing device up to

* MarCal 16 DN caliper Made in Germany
** Ultrasonic scaler, woodpecker Made in China

TABLE (1): Grouping of samples:

Sample grouping	Group (E)	Group (C)	Group (D)
Type of restoration	Conventional crowns with fiber post and composite core	Endocrowns	Endocrowns
Type of material	IPS E.max CAD	Cerasmart	Celtra Duo
Number (N)	6	6	6
Total	18		

2mm below the cement-enamel junction to simulate the bone level and were held in position till complete polymerization of the resin.

Teeth were divided randomly into 3 main groups 6 samples each according the type of restoration and material used.

Allocation concealment was done where sequence generation was performed by an external person as well as the data of the sorting of the randomized table. All steps of sample selection, randomization and preparation were assigned by the candidate under supervision. Blinding was done by the technician (assessor). Randomization was applied where all samples were numbered from 1 to 18 and were divided by website (www.random.org) into 3 equal divisions.

The crowns of the collected teeth were cut horizontally 2mm above the cement enamel junction from the proximal surfaces using a diamond disc* and sufficient coolant. Endodontic treatment was done using Protaper** rotary system, till size F2 with 1mm left before apical foramen this was followed by canal obturation using gutta purcha points coated with AD seal resin sealer (ADSEAL, root canal sealer, Metabiomed, Korea) using the lateral condensation technique.

Group E (GE) received glass fiber posts size no.2 and light cured resin composite core. After coronal sectioning, the gutta percha was removed from the palatal canal using a gates*** no.2 and 3 to a length of 10mm from the preparation margins. Post space was prepared using corresponding caliberating drill (size no.2) from decoronated surface included in the post system. The canals were irrigated then dried with paper points followed by etching with 37% phosphoric acid for 15 seconds. Canals were then thoroughly rinsed with water, dried with compressed air and paper points****[6]. Light cure adhesive bond was applied inside the root canal using micro-brush***** then rubbed to canal walls for 10 seconds using a micro-brush followed by removal of excess solvent by compressed air for 1-3 seconds. Curing was then done for 20 seconds according to manufacturer's instructions. The post was cemented with dual cure self adhesive resin cement (Totalcem) which was automixed and applied along the surface of the post and inside the post space. [7]

Posts were cemented using dual cure self-adhesive resin cement (Totalcem) and the desired amount of light-core material was injected around the fiber post and inside a transparent celluloid crown****** then adapted over the post to fabricate the core build up in a standardized manner.[6,8,9]

* FriosMicroSaw Diamond Discs, DENTSPLY Maillefer, Switzerland
** Protaper system, DENTSPLY Maillefer, Switzerland
*** Lexicon Gates Glidden Drills, DENTSPLY Maillefer, Switzerland
**** Paper point, DENTSPLY Maillefer, Switzerland
***** Micro Brush Etch/Seal Green 100 DENTSPLY Maillefer, Switzerland
****** Crown Form Refil, DENTSPLY Maillefer, Switzerland

Preparations of teeth were performed using a Computerized Numerical Control (CNC)[*] milling machine adjusted to prepare the teeth with 2mm circumferential ferrule axial wall heights and with 10^{o} convergence. All axial walls had circumferential shoulder finish line 1mm wide with rounded internal line angle. Occlusal surface was prepared flat for better load distribution during the test. The height of the prepared teeth was adjusted to be 6mm from the finished line to the occlusal surface (2mm ferrule & 4mm core).

As for group C and group D (GC & GD) a circular butt margin was created after decapitation where the flat margin of the butt joint was standardized with a milling machine[**]. The guttapercha was removed till the canal orifices, and a layer of flowable composite of 1 mm depth measured with periodontal probe was injected and cured[***] in the pulp chamber. Pulp chamber height was 3 mm in depth to improve the accuracy of the impression.[(9)].

The walls of the preparation were done with 6^{o} divergence adjusted with the angle of a blue coded stone[****] mounted on a high speed contra[*****]. All internal line angles were smooth and rounded.[(1)]

An impression was taken with duralay[#] for the pulp chamber of the first prepared tooth and casted in metal to further standardize the rest of the preparations in terms of width and height.

The pulp chamber walls were prepared to eliminate any undercuts with a 6^{o} coronal divergence standardized in the first preparation with blue coded stone. [(10)]

All samples were then scanned using Omnicam scanner to obtain a three dimensional image of each prepared tooth on the cerec CAD/CAM software system.

With the aid of cerec software, the prepared scanned teeth were correlated to a virtual full crown with 1.5mm restoration thickness and 1.5mm occlusal surface thickness. Endocrown restoration had 5.5mm buccal cusp and 5mm lingual cusp height for standardization of the tooth form [(11)]

A CAD/CAM system (CEREC MC XL SW 4.0) was used for the fabrication of all samples in this study

Samples were constructed using IPS E.max CAD, Cerasmart and Celtra duo blocks. After milling IPS E.max CAD ceramic crowns were in their pre-crystallized state[##] where they appear bluish grey in color. The programat P300 furnace was used for crystallization and glaze firing of the IPS E.max CAD. The crystallization process gives the glass ceramic its final strength and esthetic properties. As for Celtra duo endocrowns they were also placed in the furnace on a firing tray with a firing pad according to the manufacturer's instructions for the additional crystallization and glaze firing cycle.

As for cerasmart, it is a hybrid ceramic material, thus the restorations were finished and didn't need crystallization or glaze firing. Finishing was done using ultimate finishing and polishing kit[###] in addition to diapolisher[####] paste, which was applied with low hand speed. The luster appeared immediately as the restorations were being polished.

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* MAHO Milling Machine 700, Model: 1982, Type of control: CNC 432
** BV 20B-L Automatic Feed Bench Lathe
*** Elipar Deep Curing LED Curing Light ,3M ESPE , USA
**** Intensiv Dental Products , Switzerland
***** W&H Synea 500 air high-speed handpiece (TK-97L)
# Duralay, Reliance dental, USA
CEREC MC XL SW 4.0 in milling machine, Sirona, Germany
ULTIMATE finishing and polishing kit, GC America, Tokyo, Japan
###Diapolisher paste, GC America, Tokyo, Japan

For bonding of restorations, internal surfaces of each restoration were treated according to the manufacturer's instructions corresponding to the block material. As for the application of 5% hydrofluoric acid IPS E.max CAD was etched for 20 seconds while cerasmart was etched for 60 seconds. Celtra Duo was lastly etched for 30 seconds. Restorations were then rinsed for 60 seconds under running water followed by dryness for 30 seconds with moisture free air. A ceramic primer containing silane coupling agent was applied to the internal surfaces of all restorations and allowed to dry for 60 seconds.(12)(13).

As for the natural teeth surface treatment, 37.5% phosphoric acid etchant was applied on all teeth surfaces for 15 seconds, rinsed for 20 seconds, and dried with oil free air for 5 seconds. Two separate coats of all-bond were applied on the preparations without curing in between coats. Gentle air drying was applied to dry excess solvent for 3 seconds followed by 20 seconds light curing.

Totalcem dual cure resin cement was applied on the preparation surfaces using a micro-brush* followed by adapting the crowns and endocrowns each on its corresponding tooth with finger pressure. Tack curing was done for 1 seconds then removal of excess cement was done. The samples were then place in the cementation device under 2 kg load to ensure standardization of cementation. Complete curing of the cement was then done for 20 seconds.(14)

Thermal cycling was applied to all samples where they were subjected to 2000 cycle's which is nearly equivalent to 6 months. Dwell times were 25 s. in each water bath* with a lag time 10 s. The low-temperature point was 5 °C. The high temperature point was 55 °C. (15)

Mechanical aging was also applied in which the specimens were embedded in chemical cured acrylic mold which in turn fixed by tightening screw to Teflon holder in the lower part of simulator. A weight of 5 kg, comparable to 49 N of chewing force was exerted. The test was repeated 75,000 times to clinically simulate the 6 months chewing condition, according to previous studies(16)

Fracture test was performed using Bluehill Lite Software from Instron® (Model 3345;Instron Industrial products, Norwood, MA, USA). All samples were individually mounted on a computer controlled materials testing machine with a load cell of 5 kN. Compressive loading was applied to all samples using a universal testing machine using a load applicator in the form of a stainless steel round tip of a 3.4mm diameter centered in the occlusal surface between the buccal and lingual cusps while inserting a tin foil sheet in-between to achieve homogenous stress distribution at crosshead speed of 1mm/min and then data were recorded using computer software (Instron® Bluehill Lite Software). This was followed by examining the fractured surfaces under scanning electron microscope. Surface images of nano-particles were recorded using scanning Quanta FEG 250 electron microscope**. Samples were mounted onto SEM stubs. Applied SEM conditions were: a 10.1 mm working distance, with in-lens detector with an excitation voltage of 10 kV and 1000x magnification.

RESULTS

Statistical Analysis:

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). Fracture resistance data showed normal (parametric) distribution. Data were presented as mean and standard deviation (SD) values.

* Micro Brush Etch/Seal Green 100 DENTSPLY Maillefer, Switzerland
** Quanta FEG 250 , FEI Company, USA

One-way Analysis of Variance (ANOVA) was used to compare between the three groups. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. Failure mode (Qualitative) data were presented as frequencies and percentages. Fisher's Exact test was used to compare between the two groups. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

:Statistical results 3.2

TABLE(2): Descriptive statistics and results of one-way ANOVA test for comparison between fracture resistances (N) of the three groups

	IPS E.max CAD	Cerasmart	Celtra Duo
Mean	1866	1045.1	1377
Standard deviation	399.9	122.1	307
P-value	0.001*		
Effect size	0.603		

: Significant at P ≤ 0.05, Different superscripts are statistically significantly different

Fracture resistance test showed that there was statistically significant difference between the three groups (*P*-value = 0.001, Effect size = 0.603). Pair-wise comparisons between the groups revealed that GE showed statistically significant highest median fracture value (1866±399.9). Meanwhile, there was no statistical difference between mean fracture resistance values of GC which recorded fracture median value of (1045.1±122.1) and GD which showed median fracture value of (1377±307) where both showed statistically significant lowest mean fracture resistance values.

Failure mode

Visual analysis

After samples were visually assessed, GE showed fracture of all 6 crown restorations with no fractures related to the tooth structure. Only 1 sample presented fracture of the core with no affection of the ferrule part. All fractures were repairable fractures since tooth structure was not affected. As per the GC group, catastrophic failures were detected for all groups were fracture of the tooth occurred below the cemento-enamel junction making the tooth unrestorable. Similar results were obtained for the GD group where only 1 sample showed repairable fracture while the remaining 5 showed irreparable catastrophic failures. There was a statistically significant difference between fracture types in the three groups (*P*-value = 0.001, Effect size = 0.897). GE group showed the highest prevalence of repairable fracture while GC group showed the highest prevalence of irreparable fracture.

TABLE (3): Descriptive statistics and results of Fisher's Exact test for comparison between fracture types in the three groups.

Fracture type	**GE IPS E.max CAD**	**GC Cerasmart**	**GD Celtra Duo**	P-value	Effect size (v)
	n (%)	**n (%)**	**n (%)**		
Reparable	0 (0)	6 (100)	5 (83.3)	0.001*	0.897
Irreparable	6 (100)	0 (0)	1 (16.7)		

: Significant at P ≤ 0.05

Scanning electron microscope

Representative samples for each group were examined under scanning electron microscope (SEM) to reveal the type of failure whether adhesive cohesive or mixed in each type of material.

SEM images for IPS E.max CAD crowns (GE) showed that the samples failed cohesively within the cement with internal surface of the crown together with the tooth surface totally cover with cement. (Fig. 1)

As for the cerasmart endocrowns (GC), the scanned samples for this group showed very little amounts of cement on the restoration surface where the tooth surface was partially covered by cement. Also several parts of the cerasmart restoration showed no cement at all. The type of failure detected in this group was of the mixed type which was cohesive within the cement in areas and adhesive between cerasmart restoration and the cement in other areas. (Fig. 2)

Images of the scanned endocrowns fabricated from celtra duo (GD) revealed cohesive failure within the cement with restoration surface covered with cement and the tooth having scattered cement particles covering the surface. (Fig.3)

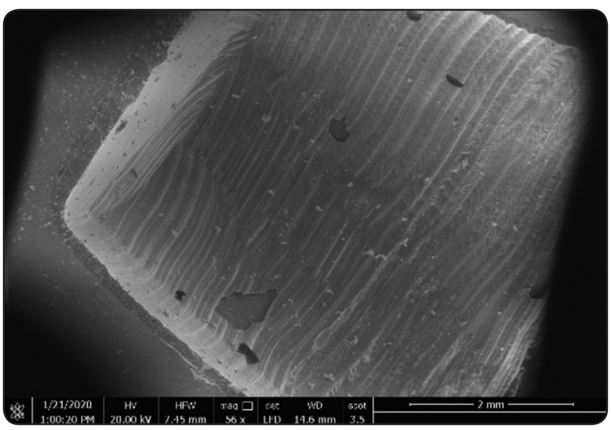

Fig. (1): SEM image showing the surface of the lithium disilicate surface totally covered with cement layer. The failure in this group was totally cohesive within the cement.

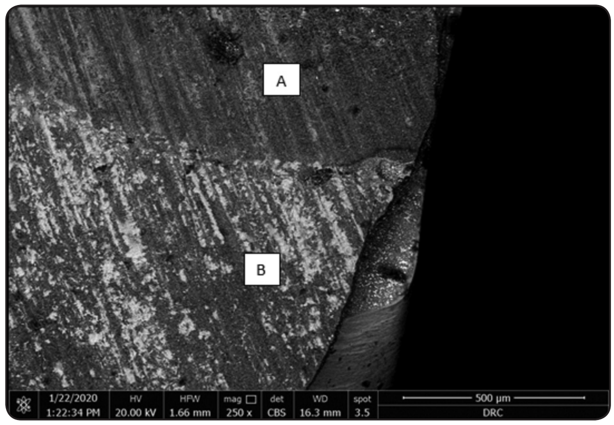

Fig. (2): SEM image shows very little amount of cement on the cerasmart surface in areas (B) and no cement at all in other areas (A). (Dark area shows the cerasmart surface and white spots resemble remnants of cement)

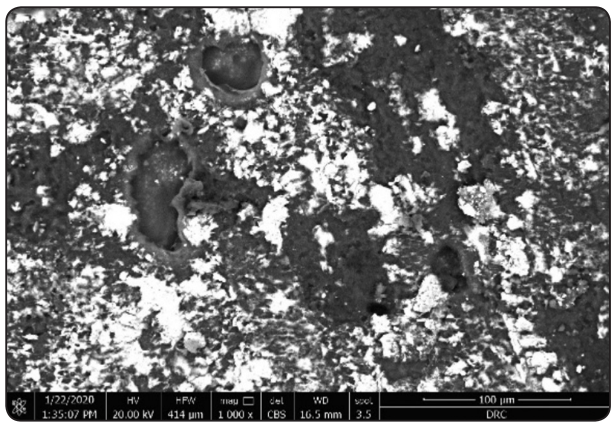

Fig. (3): SEM image showing the surface of celtra duo endocrown with heavy coverage of the cement surface to the surface. (Dark area represents the celtra duo surface; white particles indicate cement layer).

DISCUSSION

In-vitro test was used in this study since it overcomes the various limitations associated with clinical studies such as individual variations by designing a fully controlled environment. It provides guidelines about the load bearing capacity of different materials on prosthetic restorations such as crowns, endocrowns and veneers that give information close to the clinical situation [17].

Human teeth with comparable sizes were selected and used owing to their bonding characteristics, thermal conductivity, strength and modulus of elasticity that is close to the clinical conditions [18,4].

Maxillary premolars were selected in this study since the line of treatment of endodontically treated premolars needs further testing with different restoration designs and materials [19] .

Performance of endocrowns on premolar teeth in previous studies has shown to have non-satisfactory results in comparison to molars under occlusal forces. This was owed to the smaller surface area of premolars which may affect the bonding which is a mandatory factor in the construction of endocrowns[20].

Teeth were inserted inside epoxy resin blocks. Position standardization was ensured using a centralizing device which was used to insert the teeth vertically in the center of the epoxy resin block. Epoxy resin was used since its modulus of elasticity which is 12 GPa is close to that of the human bone 18 GPa [21].

As monolithic CAD/CAM-fabricated LDS ceramics have proven their suitability for single tooth restorations both in vivo and in vitro they were chosen as reference in this study over fiber post and composite core since this design has been the gold standard for endodontically treated premolar for the past years [22].

Hybrid materials presented in cerasmart was selected since it has stress absorbing characteristics which may improve flexural strength in addition to its good bonding properties which may compensate for the smaller surface area of premolars.

Celtra duo was used with premolars in this study for endocrown fabrication owing to its increased flexural strength due to the presence of zirconia which strengthens the material compared to lithium disilicate and elevates its fracture resistance.

Teeth were then decapitated perpendicular to the long axis 2mm coronal to the proximal cemento-enamel junction in order to simulate the condition of damaged endodontically treated premolars (23). The selected premolars were endodontically treated to simulate the clinical conditions with induced stresses [24].

Post spaces were prepared to a drilling depth of 10 mm from the decoronated surfaces. Each glass fiber post was reduced to the length of 13mm by reducing the coronal part with a diamond separating disc resulting in a dowel extending 3mm above the decoronated surface and posts were cemented according to the manufactures instructions using dual sure self-adhesive resin cement (Clearfil SA)[6,7].

Light core material was used for the fabrication of the core build up. The material was injected inside a celluloid crown to fabricate the core in a standardized manner [25].

As for the preparation of the samples to receive the full coverage E.max crowns, the circumferential ferrule axial height was 2mm with total convergence angle of 12^0 as recommended by Goodacre et al.[26] All axial walls had circumferential shoulder finish line of 1 mm.[27] Teeth preparation was done according to the mentioned above criteria using CNC milling machine for ensuring standardization.[12, 28]

As per the preparation of the endocrowns, the flat margin of the butt joint was standardized with a milling machine. The walls of the preparation were done with 6^odivergence was done for the first sample with the angle of a blue coded stone[1]. For the first sample, a layer of flat flowable composite of 1 mm depth measured with periodontal probe was injected and cured. Pulp chamber height was 3 mm in depth to improve the accuracy [9]. A duralay impression was taken for this first sample and casted into metal for further standardization of the samples.

CEREC MC XL milling machine which is a 4-axis milling machine giving the advantage of materials and time saving, was used in this study for all restorations for standardization of restorations[29].

A strict adherence to the bonding protocols for each type of preparation following manufacturers' instructions was done to insure the elimination of any variable during the bonding procedures.

A combination between self-adhesive cement and total etch technique of bonding was used during the study to ensure increased bond strength and high retention. In addition it acts as a buffering layer for stress absorption during load application consequently increasing the fracture resistance of the restorations [30].

Surface treatment of all restorations was done strictly according to the manufacturer's instructions.

Restorations were cemented using Total-Cem dual cure self-adhesive resin cement since resin cements ensure micromechanical and chemical adhesion to the tooth structure [31].

In vitro tests still remain an indispensable method to evaluate the performance of materials, and considering the available protocols, thermal cycling seems to be a valid in vitro method to accelerate the aging of restorative materials. Laboratory simulations of clinical service are often performed because clinical trials are costly and time consuming. Standardization of conditions is necessary to allow comparison of reports. In this study the number of cycles used was 2000 cycle's nearly equivalent to 6 months. Dwell times were 25 s. in each water bath with a lag time 10s. The low-temperature point was 5^0C. The high temperature point was 55^0C [15][32].

Cyclic loading and wet environment are the conditions encountered in the mouth during mastication. Therefore, the evaluation of the behavior of dental ceramics under cyclic stresses in water is a primary requisite for the sustainable success of all-ceramic restorations in dentistry. Since cyclic loading aids in propagation of flaws and cracks inside materials, it greatly affects fracture resistance tests in determining the effect of aging in oral simulated conditions [33].

Therefore it was more accurate and relevant to test the specimen under cyclic loading instead of mono-static load. Cyclic loading varies between studies in the amount of cycles and the number of months it represents. In this study 75,000 cycles were carried under 49 N load which was carried out by similar studies done by Studart et al. in 2007 and Nawafleh et al. in 2016 which was found to simulate 6 months period. [34] [16]

Compressive loading was applied to all samples using a universal testing machine using a load applicator in the form of a stainless steel round tip of a 3.4mm diameter centered in the occlusal surface between the buccal and lingual cusps while inserting a tin foil sheet in-between to achieve homogenous stress distribution and decrease the local force peaks at crosshead speed of 1mm/min. [21][35].

As regards to the fracture resistance values, maximal physiologic occlusal forces vary up to (500 N) depending on age, facial morphology and the site of the tooth inside the arch assumed by Lin et al. in 2006 and Jansen van Vuuren et al. in 2019 As for the premolar region, several previous studies agreed that the mean loading force ranged between 222 to 445N with an average of 322.5N. [36] [37] [38].

The null hypothesis of this study was rejected as the results showed that there was significant difference between fracture resistance values of GE: (IPS E.max CAD conventional crown retained by fiber post and core) that recorded fracture resistance value of (1866 +/- 399)N and groups GC: (Cerasmart endocrowns) and GD (Celtra Duo endocrowns) that recorded vales of (1045 +/- 122)N and (1377 +/- 307) N respectively.

The results of our study came in agreement with Bindl, et al. in 2005 who reported that the survival rate of CEREC endocrowns over almost 4 years was comparable to classically constructed crowns on molars (87.1%), but was inadequate for premolar crowns (68.8%). This may be explained by the fact that the available surface for adhesive bonding was larger on molars than on premolars. Moreover, the ratio between crown basis and crown height might cause higher leverage for premolar than for molar endo crowns. (39)

This was in agreement with Al shibri and El-guindy in 2017 who stated that IPS E.max CAD conventional crowns constructed on maxillary premolars with fiber post and core restoration showed higher fracture resistance than IPS E.max CAD endocrowns with no significant difference while Cerasmart endocrowns showed a higher mean fracture value than both IPS E.max CAD conventional crowns and endocrowns. (17)

Moreover, Forberger, N; Göhring, T N in 2008 concluded that the restoration of endodontically treated mandibular premolars with endocrowns performed inferiorly to post-and-core foundations when lithium disilicate-based ceramic crowns are indicated. He explained the results stating that the poorest marginal continuity between luting composite resin and tooth structure was measured for endocrowns after thermomechanical loading indicating a higher risk for clinical failures with endo crowns resulting from bacterial penetration, loss of retention and secondary caries, independent of the materials used. (40)

Also the results came in agreement with Abdel-Aziz and Abo-Elmagd in 2015 who compared the effect of endocrowns and glass fiber post-retained crowns on the fracture resistance of endodontically treated premolars prepared with or without ferrule. Their results showed that Glass fiber post and resin core and conventional lithium disilicate crown with ferrule recorded statistically significant ($p < 0.05$) higher fracture resistance than lithium disilicate endocrowns with ferrule. (41)

Again , Otto and Mörmann in 2015 stated that the 12 years survival estimate of the shoulder crowns showed that the survival rate for molars was 95% while it was estimated to be 94.7% for premolars. Meanwhile, endocrowns showed 90.5% survival rate formolars and 75% for premolars. Nevertheless, statistically, the differences between the survival estimates were not significant. (42)

On the other hand, Fages et al. in 2017 reported that there was no significant difference between the endocrown and crown restorations when used with molars. However, this might be owed to the large surface area of cementation and better stress distribution patterns of molars when compared to premolars. (43)

Nevertheless, other studies showed contradictory results as Jain et al.in 2019 stated that IPS E.max CAD endocrowns are more efficient in restoring endodontically treated mandibular premolars than IPS E.max CAD conventional crowns retained by fiber post and core. As for Biacchi and Basting in 2012 they reported that IPS E.max CAD endocrown restorations presented greater fracture strength than indirect conventional crowns associated with glass fiber posts and resin composite filling cores. For both groups, the failure pattern was characterized by fracture of the tooth associated with displacement of the restoration on the opposite side. (44) (45)

In this study, IPS E.max CAD was used for construction of both conventional crowns due to its high mechanical strength and being acid etched which gives it the ability to promote micromechanical interlocking with resin cement and bonded to the tooth interface.

In addition, Pegoretti et al. in 2002 reported that all teeth restored with glass fiber posts and crowns showed favorable or acceptable fracture patterns which might be owed to the modulus of elasticity of fiber-reinforced posts which is close to that of dentin, giving better stress distribution at the post–dentin interface.(46)

Fractured surfaces were assessed using scanning electron microscope. SEM results showed that for

IPS E.max CAD conventional crowns the failure was totally cohesive within the cement with both surfaces of the restoration and tooth cover with cement. As per the Cerasmart endocrowns, the failure was of the mixed type where cohesive failure within the cement was detected in multiple areas and adhesive failure between the restoration and the cement was detected in others. Celtra Duo endocrowns showed cohesive failure within the cement where the surface of the tooth and the restoration was covered with cement.

The results of the present study came in agreement with Mokhtarpour et al. in 2017 who stated that emax CAD had high bond strength when etched with 5% hydrofluoric. As for the mode of failure of cerasmart endocrowns, it was reported to be mixed type where cohesive failure was detected in the cement layer with increased amount of cement on the tooth surface. The images obtained from the scanning electron microscope indicated the lower bond strength of the material with the cement. (47)

The results of the present study came in agreement with Cekic-Nagas et al. in 2016 who revealed that cerasmart had low bond strength which they attributed to the micro-structural composition that has low inorganic filler content compared to other ceramics which in turn affects the bond strength of the material. However, the results of this study was opposed by Capa et al. in 2019 who stated that cerasmart has adequate micro-tensile bond strength owing to the filler matrix composition and microhardness that facilitates the materials mechanical roughening which aid in the mechanical interlocking with the cement. (48)(49)

As per the celtra duo endocrowns, the failure mode in this group was found to be of the mixed type, where sample examination under the scanning electron microscope showed cohesive failure in the cement layer with increased amount of cement on the restoration surface indicating good bond strength of the material.

The results of the present study came in agreement with Itthipongsatorn and Srisawasdi in 2019 who stated that micro shear bond strength of fired celtra duo was high owing to the firing process that has a positive impact on the healing of the natural flaws and zirconia crystals consequently improving the mechanical properties however still being etchable. (50)

This also agreed with Liebermann et al. in 2019 who reported that the tensile bond strength of celtra duo was higher than that of IPS E.max CAD this was explained by the presence of MDP in the bond used in the study which enhances the bond strength with zirconia containing materials. (51)

Diniz et al.in 2019 conducted a study reporting that celtra duo showed high bond strength when being used with 5% hydrofluoric acid etching similar to what was used in the present study and also stated that additional firing cycles increased the materials bond strength. (52)

Limitations of the present study were being an in-vitro study and the thermomechanical aging only simulated 6 months in the oral cavity.

CONCLUSIONS

Within the limitation of this study the following could be drawn:

1. All fracture resistance values obtained were far beyond the maximum masticatory force that the maxillary premolar region can withstand.
2. Conventional post, core and conventional crown treatment option remains the gold standard for treating endodontically treated maxillary premolar, nevertheless endocrown restorations on premolars needs further research for being a viable restoration in this condition.
3. Favorable fracture mode was detected with conventional crown retained by post and core while catastrophic fractures were reported with endocrown restorations.

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