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Evaluation of Fracture Resistance and Retention of different CAD/CAM Endocrowns Materials Luted to Maxillary Premolars

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ABSTRACT: Objective: An in-vitro study evaluating the retention and fracture resistance of endo-crown restorations fabricated from different CAD/CAM materials luted to maxillary premolars. Materials and methods: Forty-two endodontically treated maxillary premolars were prepared in a standardized method to be restored with endo-crown restorations using different materials. They were divided into three main groups (n =14) according to the material used to fabricate endo-crown restorations: Endo-crowns of Group Z (Yttria-partially stabilized zirconia ceramic, Zolid FX), Group P (Poly-ether-ether-ketone, PEEK), and Group E (Lithium disilicate, IPS e. max CAD). Each group was further subdivided into two subgroups (n=7) according to the test: ZF, PF and EF groups to evaluate fracture resistance and ZR, PR and ER groups to evaluate retention. After proper surface treatment for all endo-crowns, the restorations were cemented using self-adhesive resin cement (Rely X U200). All specimens were thermo-cycled for 5000 cycles in a water bath between 5º C and 55º C. Universal testing machine was used to evaluate the retention and fracture resistance of each material, and all possible failure modes were detected. One-way ANOVA and Tukey's post hoc significant difference test were used to analyze the data. Result:There was a significant difference in fracture resistance between three different materials ($P < 0.05$). The highest mean fracture load value (1488±168.92N) was recorded for the ZF group, while the lowest value (593.71±79.99N) was recorded for the BF group. Statistically, there was a significant difference in the retention between three different materials ($P < 0.05$). The highest mean retention value (73.51±9.89N)was recorded for the ER group, while the lowest value (29.37±3.37N) was recorded for the BR group. Conclusions: Within the limitations of this in-vitro study, we could conclude that: 1) In terms of fracture resistance, zirconia endo-crowns are better than E.max and PEEK endo-crowns. However, using PEEK for the same purpose recorded a restorable mode of failure that avoided the possibility of tooth fracture. 2) E.max endo-crowns are recorded the highest meanvalue of de-bonding, followed by zirconia and PEEK endo-crowns, respectively.

KEYWORDS: Endodontically treated teeth, CAD/CAM, Endo-crowns, Maxillary premolars, Retention, and fracture resistance.

I. INTRODUCTION

The endodontically treated teeth (ETT) have structural and physical changes that in turn influence properties of dentine such as modulus of elasticity, microhardness, and fracture toughness, so treatment of non-vital dehydrated teeth should aim to protect and strengthen the remaining tooth structure.[1, 2]

Endo-crown is a conservative treatment modality to restore ETT that uses the pulp chamber as a source of retention. [3] In 1995, Pissis was the pioneer of a technique that used porcelain post and crown as one unit, called the mono-block porcelain technique, to replace conventional metal post and core. [4] But the term "endo-crown" was released for the first time by Bindl and Mormann as an adhesive endodontic crown, and it was as a total ceramic crown fixed to a non-vital tooth. [5]

It is defined as a bonded restoration that consists of a coronal portion and an apical projection fixed to the pulp chamber to obtain macro-mechanical retention, while the adhesive resin cement acts as micromechanical retention. [6] Endo-crown is indicated to restore teeth with insufficient vertical dimension or badly broken teeth to preserve the maximum amount of tooth structure and also for short clinical crowns. In addition, they are mandatory in teeth with severely curved and obliterated roots and in teeth with inadequate ferrules. [7]

The design of the preparation of the endo-crown should provide sufficient stability, structural durability and retention of the restoration. Endo-crowns strictly adhere to this rational preparation, which includes equai-gingival or supra-gingival circular butt joint margins while retaining as much enamel as possible to improve adhesion. Endo-crowns enter the pulp chamber only, in which the shape of the pulpal chamber ensures stability and retention with no need for further preparation. The saddle form of the pulpal floor improves stability. [8]

The question that still needs to be answered is how suitable it is to restore endodontically treated premolars (ETPM) by endo-crown restoration. Numerous studies stated that those teeth have a high fracture incidence, especially maxillary ones, as a combination of compressive and shearing forces are applied to them, making them more liable to fracture. [9]

A wide range of ceramic materials had been available for CAD/CAM technology from glass-ceramics to polycrystalline ceramic and Poly-ether-ether-ketone (PEEK). Zirconia can be used for endo-crown restoration. [10]However, it differs from glass ceramics as it is not liable to acid etching technique, so it doesn't have the advantages of the adhesive bonding procedure.[11] PEEK is a semi-crystalline linear aromatic high-performance thermoplastic polymer. [12]Research also has proposed that PEEK can be used in making crowns as its tensile strength is 80 MPa which is close to those of dentin at 104 MPa and enamel at 47.5 MPa.In addition, PEEK can be used as endo-crown restorations. [13, 14]

The final critical step in restoring teeth with indirect restorations is cementation. The long-term performance and longevity of restorations depend on the success of bonding between restorative materials, adhesive agents, and tooth substrate. Self-adhesive resin cement was introduced and obtained popularity rapidly. They are polymerizing cement that can bond to tooth structure without needing to pretreat by etching, primer, or bonding agent, so cementation is done in one step. [15]

The performance longevity of the endo-crowns depends on many factors: proper case selection, proper preparation, and choice of suitable restorative materials and suitable adhesive cementation are necessary for the success of this restorative treatment.

The current study aimed to evaluate the retention and fracture resistance of different Endo-crown restorations fabricated from different (CAD/CAM) materials luted to maxillary premolars. The Null hypothesis was that no effect of different CAD/CAM materials on fracture resistance and retention of an endo-crown restoration.

II. MATERIALS AND METHODS

1. Teeth selection and storage

The Dental Research Ethics Committee at Mansoura University's Faculty of Dentistry gave its approval to this study (approval number: A06060819). Forty- two recently extracted human maxillary premolars were selected from the Department of Oral Surgery Faculty of Dentistry Mansoura University. The reasons for teeth extraction varied from periodontal disease, mobility of teeth due to systemic diseases such as diabetes, or extraction for an orthodontic reason. All teeth were stored in saline solution at room temperature to avoid dehydration.

2. Endodontic treatment

The access cavity was done by using water-cooled high-speed round bur (No.271) following the morphology of the pulp chamber. The root canals were prepared till rotary file size F2 (Protaper, Dentsply, Maillefer, Switzerland). Resin sealer (ADSEAL, Meta-Biomed, Korea LOT ADS2104141) was used to coat the Gutta-percha cone and placed into the root canal then lateral condensation by using a spreader. The red hot condenser was used to remove excess Gutta-percha.

3. Specimens fixation and preparation

All teeth were centralized in the resin epoxy blocks (Kema Epoxy 150, Egypt) at 2 mm below the cemento-enamel junction (CEJ) by using a special centralization device. A dental surveyor (Surveyor, Marathon-103, Saeyang Company) was used to standardize all preparations of all specimens. The crowns were reduced horizontally by using a super coarse diamond disctill the level of 2mm coronal to CEJ. The pulp chamber was prepared to the depth of 4mm from decapitated level with 8º divergence walls.

4. Specimens grouping

All specimens were divided into three groups according to the material used in Group Z: Zirconia endo-crowns, Group P: PEEK endo-crowns, and Group E: E.max endo-crowns. Then each group was subdivided into two subgroups according to the test: ZF, PF and EF groups to evaluate fracture resistance and ZR, PR and ER groups to evaluate retention.

5. Fabrication of the restoration

The optical impression of prepared teeth within their epoxy resin blocks was taken by Amann Girrbach scanner (Ceramill Map 400 scanner) by placing them on its scanning tray. CAD/CAM software (Ceramill Mind, Amann Girrbach) was used to design all endo-crown restorations. The endo-crown height to the buccal cusp tip was 6.9 mm and to the palatal cusp tip was 6.6 mm to standardize forms of all restorations with cement space 50µm.

Special design was done to the retention groups to allow pull-out and evaluation retention of the restorations. Specific mesial and distal extensions were added to the restorations with standard dimensions for all specimens: extension thickness 4.5 mm, Bucco-palatal 6 mm, and laterally 5 mm (Figure 1).

Figure 1: Adding a special extension to restoration with dimensions6× 4.5× 5 mm.

The milling procedure was performed by dry/wet five-axis milling machine (Ceramill motion 2 (5x) (Amann Girrbach, Germany). Wet milling was done for the Lithium Disilicate group: IPS E.max CAD (ingots: LT A2/ C14). However dry milling was used for zirconia group Ceramill Zolid fx ML (blank: A2/A3 98×14 N) and PEEK group (blank: Bre CAM BioHPP).

For all PEEK specimens, STL files were sent to a 3D printer (RASDENT 3D PRINTER-model S) and fabricated master endo-crown from resin wax (FTD Red Castable Blend– 50um). Each master endo-crown was inserted into its corresponding tooth then transparent silicon was injected around them to make a mold (Figure 2). The master endo-crown was removed and placed with a PEEk core and injected composite around it (Figure 3).

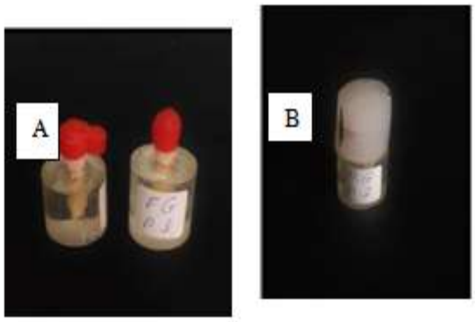

Figure 2: A. Master endo-crowns on their corresponding teeth.
B. Silicon mold after setting.

Figure 3: PEEK core within silicon mold.

6. Cementation procedures

Fitting surfaces of all zirconia endo-crowns were sandblasted by alumina oxide particles (50µm, 2.5 bar, 10 sec, 10 mm distance). Then all restorations were cleaned and single bond adhesive was applied. While the internal surface of PEEK endo-crowns was sandblasted by alumina oxide particles (110µm, 2.5 bar, 10 sec, 10 mm distance). Then all restorations were cleaned and followed by the application of Visio. Link primer on the surface. The internal surface of E.max endo-crowns was etched for 20 sec with 9 % hydrofluoric acid gel, then washed for 20 sec. Then silane coupling agent was put to the surface and allowed to react for 60 sec till dry. The enamel surface of all prepared teeth was selectively etched with 37% phosphoric acid for 30 sec, washed with water-air spray for 30 sec, and dried for 5 sec with oil-free air. RelyX U200 (self-adhesive resin cement) was applied on prepared teeth by using the auto- mix tip and then therestoration was seated in its place by static finger pressure then the especially loading device was used (Figure 4).

Figure 4: Endo-crown restoration under constant load in a special loading device.

7. Thermal cycling

To mimic intra-oral conditions, all specimens were subjected to a thermo-cycling step in an automated thermo-cycling simulation machine (Thermocycler, Robota, Alexandria, Egypt). They were thermo-cycled for 5000 cycles in a water bath between 5 ºC and 55ºC with dwell time 20 sec and 5 sec as transfer times between baths.

8. Fracture and Retention tests

Fracture test: each specimen was mounted individually to the lower compartment of the universal testing machine. Compressive vertical load with a cross head speed of 0.5 mm/min was applied on the occlusal surfaces at the central fossa till a fracture occur. Newton (N) unit was used to record the fracture load. Retention test: each specimen was mounted individually to the lower compartment of the machine and restoration was attached to the upper compartment by orthodontic wire through lateral extensions of the restoration. The amount of load required to debond the restoration was measured in Newton (N).

9. Statically analysis:

Data were evaluated statistically using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. The Shapiro–Wilk test was used to determine whether the data was normal. Continuous variables were presented as mean ± SD (standard deviation). Data analysis was performed in several steps. Initially descriptive statistics for each group result. The effect of each variable was shown using a one-way ANOVA test (fracture resistance and retention of different materials). For numerous comparisons between groups, Tukey (HSD) honest significant difference was used.

III. RESULT

The highest mean fracture load value (1488±168.92N) was recorded for the ZF group followed by the EF group (939.79±81N) while the lowest value (593.71±79.99N) was recorded for the PF group. Statistically, analysis using the ANOVA test appeared a significant difference between threedifferent tested groups at ($P< 0.001$) as shown in (Table 1).

The highest mean de-bonding value (73.51±9.89N) was recorded for the ERgroup followed by the ZRgroup(39.67±5.86N) while the lowest value(29.37±3.37N)was recordedfor the PRgroup. Statistically, analysis using the ANOVA test appeared a significant difference between three different tested groups at ($P< 0.001$) as shown in (Table 2).

Table (1): Comparison of fracture resistance between studied groups:

	Zirconia n=7	**PEEK n=7**	**E max n=7**	**Test of significance**
Fracture resistance Mean ±SD	1488.01±168.92^{ab}	593.71±79.99^{ac}	939.79±81.0^{bc}	F=102.91 P<0.001*

Table (2): Comparison of retention between studied groups:

	Zirconia n=7	**PEEK n=7**	**E max n=7**	**Test of significance**
Retention Mean ±SD	39.67±5.86^{ab}	29.37±3.37^{ac}	73.51±9.89^{bc}	F=78.02 P<0.001*

IV. DISCUSSION

The null hypothesis of this study was rejected because the different CAD/CAM materials had a statistically significant effect on both fracture resistance and retention.

With the recent improvements in adhesive dentistry and new ceramic materials, more conservative treatment techniques such as endo-crown have been introduced to restore ETT due to a macro-retentive design if there are adequate tooth surfaces for bonding. [16]

In this study, natural teeth were selected to mimic the clinical situation in terms of architecture, size, morphology, and bonding properties, all of which are favorable to adhesive restorations.Epoxy resin material was used as embedding material around the roots of teeth because its modulus of elasticity is near to that of human bone. [17]

Maxillary premolars were used to evaluate the success rate of different restoration materials restoring such teeth with their unique anatomy together with special morphology that is more susceptible to fracture under occlusal loads and cusp deflection. [18]

All teeth were cut at the right angle to the long axis of each tooth 2mm coronal to CEJ proximally to mimic the condition of the compromised severely damaged ETT premolars. [19]Butt joint preparation design was chosen to preserve the outer enamel layer around all margins, which is effective in decreasing micro-leakage at the restoration-tooth interface and thereby reducing shear stresses. Furthermore, the design of butt joint preparation was able to eliminate the prismatic and inter-prismatic crystals, allowing for better enamel etching and tooth restoration bonding. [17]

RelyX Unicem (self-adhesive resin cement) was used in this study as its technique of application was easier, faster, and had low sensitivity.Self-adhesive resin cement in combination with the total-etch bonding technique was selected as it is the gold standard technique to get optimum bonding. [20]

To obtain excellent bond strength of Zirconia restorations, the internal surface was treated with airborne-particles abrasion (Al_2O_3) followed by the application of adhesive containing MDP phosphate monomer (10-methacryloyloxydecyl dihydrogen phosphate). Casado et al. (2017) [21] stated that using Rely X U200 in combination with adhesive containing MDP monomers gave the highest bond strength among other groups. MDP was provided direct bi-functional adhesion with Bis–GMA matrix and metal oxides, resulting in a stronger chemical bond between surfaces.

Airborne-particles abrasion (Al_2O_3) was used to obtain micro-roughness of the PEEK surface then methyl methacrylate monomer (Visio. Link) was painted on the surface to increase wetting of the veneering material with an adequate chemical bond. Lee et al. (2017) [22] stated that when bonding PEEK material to composite resin, the combination of surface treatment of air-abrasion and MMA or MDP-containing bond materials are recommended.

Results of the fracture resistance test showed that the highest mean fracture load value (1488±168.92N) was recorded for the ZF group followed by the EF group (939.79±81N) while the lowest value (593.71±79.99N) was recorded for the BF group.

Results of this study were in agreement with those Elashmawy et al. (2020) [10]reported thatthe fracture resistance of endo-crown fabricated from zirconia material is higher than those fabricated from lithium disilicate and PEEK despite using molar teeth instead of premolar and chewing simulator to simulate the chewing process in the oral cavity. They attributed that to the difference in bending properties of materials that were used.

Ahmed et al. (2021)[23] supported the outcome of this study as they found a significant increase in fracture resistance of zirconia than lithium disilicate and attributed this to the microstructure of the restorative materials which affects the survivability and fracture strength of restorative materials and abutment tooth itself.

Results of retention showed that the highest mean de-bonding value (73.51±9.89N) was recorded for the ER group followed by the ZR group (39.67±5.86N) while the lowest value (29.37±3.37N) was recorded for the BR group.

The results of this study were in agreement with those of Riyad et al. (2020) [17] whoreported thatendo-crowns fabricated from lithium disilicate material have a de-bonding value higher than PEEK material despite using IPS-Emax press and Bio HPP granules instead of CAD/CAM materials. Elashmawy et al. (2021) [24] are also in agreement with this study as they reported the endo-crown fabricated from lithium disilicate had a higher mean of retention value followed by zirconia endo-crown. While the lowest value was recorded for the PEEK group.

V. CONCLUSIONS

Within the limitations of this in-vitro study, we could conclude that:

1) In terms of fracture resistance, zirconia endo-crowns are better than E.max and PEEK endo-crowns. However, using PEEK for the same

purpose recorded a restorable mode of failure that avoided the possibility of tooth fracture.

2) E.max endo-crowns are recorded the highest mean value of de-bonding, followed by zirconia and PEEK endo-crowns, respectively.

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