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Fracture Strength and Retention of All-Ceramic Endocrowns Luted Using Two Different Resin Cements

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ABSTRACT

Purpose: The purpose of this in vitro study was to evaluate and compare the fracture resistance and retention of CAD/CAM endocrowns and conventional glass fiber post supported crowns. **Materials and Methods:** Sixty-four (N=64) sound mandibular molars were endodontically treated and randomly assigned into 2 groups (n=32 each) according to the type of restoration constructed; **Group (E):** Endodontically treated teeth restored with IPS e.max CAD, lithium disilicate based, endocrowns and **Group (P):** Endodontically treated teeth restored with glass-fiber posts, composite cores and IPS e. max CAD crowns. Samples of each group were further subdivided into 2 subgroups (n=16 each) according to the type of adhesive resin cement used. the samples were thermocycled (2000 cycle, between 5°C-55°C). Samples were mounted in a universal testing machine and loaded to failure at a crosshead speed of 1.0 mm / min. The failure loads were recorded. Data were analyzed using one-way analysis of variance (ANOVA) and Tukey's post hoc significance difference tests. Differences were considered significant at $P<0.05$. The pull-out test was performed on a universal testing machine and the values obtained were statistically analyzed by analysis of variance using one-way analysis of variance (ANOVA)) and multiple comparison test of Tukey, with level of significance at $P<0.05$. **Results:** Statistical analysis using two-way analysis of variance (ANOVA) test revealed no statistically significant difference in failure load among the four tested subgroups (at $P< 0.05$). Endocrowns recorded statistically significant mean higher fracture load values (1729.91N±407.9) compared to post retained crowns, (1435.84±405.2). Statistical analysis using two ways analysis of variance (ANOVA) test revealed a statistically significant difference in debonding load among the four tested subgroups (at $P<0.05$). Tukey's post hoc test revealed a significant difference between each two subgroups. The highest mean debonding load was recorded in the subgroup (PR) (96.98N±4.47), whereas the least value was recorded in the subgroup (EM) (49.48N±3.81). **Conclusions:** lithium disilicate based endocrown restorations increase the fracture resistance of endodontically treated molars compared to conventional crowns associated with glass fiber posts and resin composite filling cores.

KEYWORDS

Endocrown _ CAD/CAM _ FRCs _ Fracture strength_ Endodontically treated teeth

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INTRODUCTION

Endodontically treated teeth (ETT) are considered at a higher risk of fracture compared to intact sound teeth as a consequence of lost tooth structure following the pathological processes and endodontic treatment [1]. This biomechanical alteration inflicts a negative impact on the long-term prognosis of restoration of these teeth. [2,3] That's why when considering the restoration of devitalized teeth, dental materials utilized should be able to replace lost tooth substance, ensuring mechanical, functional and aesthetic performance in addition to perfect coronal seal.

The fiber-reinforced posts are made of continuous fibers, which may be unidirectional, braided or woven, embedded in a resin matrix. These fibers have been used to reinforce endodontic posts. [4] The fiber-reinforced posts possess a number of advantages that include; biocompatibility, high flexure and fatigue strengths, high resistance to corrosion, a modulus of elasticity similar to that of dentin of the tooth, retrievability and the ability to form a single bonded "mono-block" complex within the root canal. [5,6,7]

During restoring endodontically treated teeth using post retained restoration, the clinician is sometimes confronted with the problem of inadequate interocclusal space. This situation is often further complicated by the absence of adequate remaining tooth structure for preparation of the ferrule. There have been different solutions in the clinical practice to this problem. The so-called Richmond crown was introduced several decades ago with a single-unit metal structure which was produced by casting; comprising the crown and the post in a single unit in a cap- or stand-shape. However, the solution was abandoned relatively quickly due to the complicated and often impossible removal. Only the idea of single-unit restorations was kept for future development of restorative materials and technologies. [8]

The first study published on endocrown restorations (or adhesive endodontic restoration) was conducted by a study that described the ceramic monoblock technique for teeth with extensive loss of coronal structure. [9] However, it was **Bindl and Mormann** [10] who named this restorative procedure "endocrown" **in 1999.** The endocrown is a total porcelain crown fixed to a de-pulped posterior tooth, and anchored to the internal portion of the pulp chamber and to the cavity margins, thus obtaining macro-mechanical retention (provided by the pulpal walls), in addition to micro-retention (by using adhesive cementation). [11]

Furthermore, the endocrown had been further described as the restorative option for endodontically treated molars. [12] It consists of full coverage crown attached to a protruding retention section that sits tightly inside the pulp chamber of the endodontically treated tooth. The restoration lacks intraradicular anchorage allowing the construction of the crown and core as a single unit fabricated from various all ceramic materials. [12] The surfaces available within the pulp chamber obtain stability and retention of the restoration through adhesive bonding. [13] This type of restoration can be fabricated through computer-aided design/computer aided manufacturing (CAD/CAM) technology, providing the possibility for chair-side design and fabrication. [14]

The advantages of endocrowns over foundation restorations can be summarized as follows: they reduce the interfaces of the restorative systems, they have ability of restoring teeth with insufficient vertical dimension, they can restore badly broken down teeth while preserving the maximum tooth structure rendering more efficient and aesthetic results and they also reduce the need for macro-retentive geometry. [15]

Endocrowns are relatively new and few professionals feel confident about performing this procedure. Nevertheless, they are easy and quick to perform, compared with traditional single crowns with posts and cores. The success and longevity of the endocrowns are directly related to the correct preparation of the tooth, the selection of the most suitable ceramic and the choice of bonding material, since adequate adhesive cementation is absolutely necessary for the success of this restorative treatment. [16]

A wide collection of ceramic materials had been available for CAD/CAM technology, ranging from feldspathic ceramics and leucite containing glass ceramics to high-strength lithium disilicate glass ceramics and zirconium oxide. [17]

Reinforced, acid etchable dental ceramics have been the materials of choice for the fabrication of endocrowns, because they guarantee the mechanical strength needed to withstand the occlusal forces exerted on the tooth, as well as the bond strength of the restoration to the cavity walls. [18,19] A monolithic restoration (also known as a full contour restoration) is one that is manufactured from a single material for the full anatomic replacement of lost tooth structure. Additional staining, followed by glaze firing may be performed to enhance the appearance of the restoration. For decades, monolithic restoration has been the standard for inlay and partial crown restorations manufactured by both pressing and computer-aided design and manufacturing (CAD/CAM) techniques. A limited selection of monolithic materials is now available for dental crown and bridge restorations. [17]

The present study therefore aimed at comparing the fracture resistance and the retention of e.max CAD endocrowns with conventional crowns supported by glass fiber posts and composite cores using two types of adhesive resin cements

MATERIAL AND METHODS

Preparation of tooth samples:

Sixty-four (N=64) mandibular molars with completed roots, free of cracks or fracture were collected cleaned and stored in saline. To standardize the size of the selected teeth a digital caliper (S235, Sylvac, Switzerland), was used to measure the bucco-lingual and mesio-distal dimensions of each molar at the level of the cemento-enamel junction. A silicon index (Zeta plus, 3M ESPE, Germany) was taken for each tooth to standardize the shape and size of the cores in half of the samples.

Teeth were sectioned 2 mm above the cementoenamel junction (CEJ) perpendicular to the long axis of the tooth. Each tooth was individually embedded vertically in epoxy resin using PVC rings as molds. All teeth were endodontically prepared using rotary files (Dentsply Maillefer, Switzerland) then filled with gutta percha (Dentsply Maillefer, Switzerland) using lateral compaction technique.

All endodontically treated teeth (N=64) were randomly divided into 2 groups (n=32 each) according to the type of restoration: **Group (E):** Endodontically treated teeth restored with IPS e.max CAD/CAM endocrowns. **Group (P):** Endodontically treated teeth restored with glass-fiber posts, composite cores and IPS e. max CAD/CAM crowns.

Samples of each group were further subdivided into 2 subgroups (n=16 each) according to the type of resin cement used: **Subgroup (R):** Samples were cemented using Rely X Ultimate Clicker total etch adhesive resin cement**. Subgroup (M):** Samples were cemented using Multilink speed self-adhesive resin cement.

Endocrown Preparation, group (E):

A special milling machine (Centroid CNC, Milling machine, USA), was used for standardized teeth preparations. The endodontic access cavities were prepared with diamond stone ((Dentsply Maillefer, Switzerland) with 8^{o}-10^{o} coronal divergence, the depth of the central retention cavity measured 3.5±0.5mm from decapitation level. [20] Extracoronally, the remaining vertical portion of the crown was prepared with diamond stone (Dentsply Maillefer, Switzerland). The preparation included a 1 mm wide, circumferential 90^o shoulder margin with rounded internal line angles, located 1 mm above the cementoenamel junction leaving a 1mm ferrule. The external convergence angle was adjusted at 8^o-10^o. The remaining thickness of dentin walls (2±0.5 mm) was measured by digital caliper.

Preparation of endodontically treated teeth for post and core supported crowns, group (P):

All samples of group (P) were prepared to receive Rely X tapered glass fiber posts (Dentsply Maillefer, Switzerland) with 1.5 mm diameter, using low speed hand piece mounted in a parallelometer (AF30, Nouvag, Switzerland). For samples of subgroup (R), the glass fiber posts were cemented using Rely X Ultimate Clicker total etch adhesive resin cement (3M ESPE, St Paul, MN, USA.), while for samples of subgroup (M), glass fiber posts were cemented using Multilink speed self-adhesive resin cement (Ivoclar Vivadent, Schaan, Liechtenstein),

All cementing procedures were done following the respective manufacturer recommendations under a constant load of 2Kg weight using load applicator.

Core fabrication

The silicon indices recorded were used to reconstruct samples of group (P) into their full anatomical shape using CharmCore dual-cure (ELI-DENT, Smi Nongshim-ro, south korea) core build up material.

The Centroid milling machine, was used for standardized preparations of reconstructed samples of group (P) using the attached slow-speed straight hand-piece. The axial walls of each reconstructed tooth were prepared with a circumferential 90^o shoulder margin, 1 mm wide with rounded internal line angles, located on sound tooth structure 1 mm above the cementoenamel junction leaving a 1 mm ferrule, and with 8^o- 10^o convergence angle using diamond stone (Dentsply Maillefer, Switzerland).

Laboratory procedures

To obtain a three-dimensional image for each prepared tooth on the computer screen of the Cerec inLab system (Sirona Dental System, Bensheim, Germany); the prepared tooth was sprayed with an optical reflection powder (Cerec propellent powder, Vita Zahnfabrik, Germany) and scanned using the In-Eos blue scanner (Sirona dental systems, Gmbh FabrikstraBe, Bensheim). The restorations (endocrowns and conventional crowns) were designed and fabricated with CAD/CAM Cerec in-Lab machine using IPS e.max CAD/CAM blocks (Ivocalr Vivadent, Germany).

The milled bluish partially crystallized IPS e.max CAD restorations were subjected to a crystallization procedure according to the manufacturer recommendations.

Bonding procedure

Restoration surface treatment:

The internal surfaces of e.max CAD restorations were etched with 5% hydrofluoric acid (Ultradent, Sout Jordan, Utah, USA) applied for 20 seconds. After etching, each restoration was ultrasonically cleaned in water for five minutes, then dried with oil-free air. Silane coupling agent (Ultradent, Sout Jordan, Utah, USA) was applied to the intaglio surface for 60 seconds and then air dried.

Cementation using Rely X total etch cement (subgroup R)

- ***Tooth surface treatment:***

All samples' bonding surfaces were thoroughly cleaned with water and dried with air to remove any residual debris. 32% phosphoric acid etching gel (3M ESPE, St Paul, MN, USA) was applied for 15 seconds with syringe tip.

- ***Application of Rely X ultimate total etch cement:***

The required amount of cement was mixed according to the manufacturer recommendation and applied to the fitting surface of the restoration and tooth surface. The restoration was seated and the excess was removed. The sample was placed under 2kg weight in the load applicator then the cement was light cured for 20 seconds at each surface.

- *Cementation using Multilink self-adhesive cement (subgroup M):*

The desired amount of cement was dispensed from the automix, and applied on the fitting surface of the restoration and the untreated tooth surface, then the restoration was seated using 2kg weight. The excess cement was removed and the cement was light cured at 20 seconds for each surface.

Thermal cycling

All samples were subjected to a thermocycling procedure in automated thermocycling machine. Samples were thermocycled for 2000 cycle, between 5°C-55°C, with a dwell time 25 seconds

Testing procedures:

1. Fracture Strength (Fracture load) determination:

Each sample was individually mounted to the lower compartment of a universal testing machine (LRX-Plus, Lloyd Instruments, UK) and subjected to a static increasing compressive load (1mm/min) applied vertically to the occlusal surface until fracture. Fracture loads were recorded in Newton.

2. Retention test: (Debonding load determination):

Each sample was individually mounted to the lower compartment of a universal testing machine (LRX-Plus, Lloyd Instruments, UK) while each restoration was connected to the upper movable compartment of the testing machine by orthodonic wire loop through the lateral projection of the restoration. A tensile load with pull out mode of force was applied via the machine at a crosshead speed of 5 mm/min. The load required for debonding was recorded in Newton.

Statistical analysis

Statistical analysis was performed with SPSS 16.0 (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows. Unpaired t test was used for comparison between the two groups and between subgroups of each group. Two ways analysis of variance (ANOVA) test was used for comparisons between all subgroups, to study the significance of the difference caused by the interaction of the type of crown and the adhesive type. Tukey's post hoc test was used for pair-wise comparison between subgroups when ANOVA test revealed a significant difference.

RESULTS

Fracture load results

Two-way analysis of variance (ANOVA) test revealed statistically insignificant difference in fracture strength among the four tested subgroups (at P< 0.05). The highest mean failure load was recorded in subgroup (ER) (1802.35±509.44), whereas the least value was recorded in subgroup (PM) (1354.84±506.86). Values are presented numerically in table (1).

In addition, endocrowns, group (E) recorded statistically significant mean higher fracture load values (1729.91N±407.9) compared to post retained crowns, group (P), (1435.84±405.2).

Debonding load results

The highest mean debonding load was recorded in subgroup (PR) (96.98N±4.47), whereas the least value was recorded in subgroup (EM) (49.48N±3.81). Statistical analysis using two ways analysis of variance (ANOVA) test revealed a statistically significant difference in debonding load among the four tested subgroups (at P<0.05).

Table (1): *The P-value (two-way ANOVA) for the mean failure loads (N) of the four tested subgroups*

Subgroups	Endocrowns luted with Rely X Ultimate clicker (ER)	Endocrowns luted with multilink speed (EM)	Post retained crowns luted with Rely X ultimate clicker (PR)	Post retained crowns luted with Multilink speed (PM)
No of samples	8	8	8	8
Mean (N)	1802.35	1657.46	1516.84	1354.84
SD	509.44	318.95	310.04	506.86
P-value	1^{ns}			

ns= non-significant at P<0.05

Table (2): *The P-value (two-way ANOVA) for the mean debonding loads (N) of the four tested subgroups*

	Endocrowns (E)		**Post crowns (P)**	
	ER	**EM**	**PR**	**PM**
No of samples	8	8	8	8
Mean(N)	73.45	49.48	96.98	85.74
SD	7.96	3.81	4.47	5.21
P value	<0.0054*			

**significant at p<0.05. Tukey's post hoc test: means with different superscript letters are significantly different*

Tukey's post hoc test revealed a significant difference between each two subgroups. Value sare presented numerically in table (2). In addition, statistically significant higher debonding mean values (91.36N ±7.48) were recorded for post retained crowns, group (P) compared to endocrowns group, group (E) (61.47N ±13.94).

DISCUSSION

The restoration of endodontically treated teeth with extensive tooth loss and minimal macro-retentive features is of particular clinical interest. Although the use of post and core followed by placement of full coverage crown has been the classical approach for restoring endodontically treated teeth, this rationale has changed as the era of adhesive dentistry initiated the concept of tooth conservation.

Based on this rational, the line of treatment for endodontically treated teeth has shifted to include a new, more conservative restoration which depends in its retention on adhesion. Endocrowns take advantage of recent developments in adhesives, ceramics, and CAD/CAM technologies in an approach that is based mainly on a "decay oriented design concept".[21]

The present study was conducted to compare the fracture strength and retention of lithium disilicate based endocrowns to those of glass-fiber reinforced post and composite core retained lithium disilicate based crowns, using total etch and self-adhesive resin cements.

The results obtained in this study showed that endocrowns recorded statistically significant higher mean fracture load than post and core supported crowns. This result was in agreement with other studies which observed higher fracture loads for endocrowns compared to fiber post and core supported crowns. [13,19,22]

The root resistance to fracture is directly related to the volume of remaining dentin. [23] Study was reported that thicker root dentin walls significantly increase the fracture resistance of endodontically treated teeth. [24] Endocrown preparation preserves root tissue and limits internal preparation of the pulp chamber to its anatomic shape depending on the high bonding capacity of lithium disilicate ceramics to the dental structure. [20]

Higher fracture strength values of endocrowns group may also be attributed to the thickness of the ceramic occlusal portion of endocrowns. In vitro studies have shown that the fracture resistance values of glass ceramic crowns increase with increasing occlusal thickness. [25] This assumption was verified by a study that reported that the fracture resistance of endocrowns with an occlusal thickness of 5.5mm was two times higher than that of ceramic crowns with a classic preparation and an occlusal thickness of 1.5mm. [14]

In addition, endocrowns reduce the effect of multiple interfaces in the restorative system compared to post and core supported crowns which are characterized by the presence of multiple interfaces between the components of this restorative system. This reduction in the number of interfaces results in better stress distribution; as stress concentration at the interfaces which represent the weak point of the restorative system is well documented. [21] A Study stated that the stresses within the restoration are increased with the increase in number of adhesive interfaces. [26] The smaller number of bond interfaces probably makes the dentin/enamel/ceramic group more resistant when compared with the dentin/enamel/post/resin/ceramic group. [19]

In addition, endocrowns comprising both the crown and core as a single unit, was suggested to provide a monoblock effect. [23]

Regarding the retention, the results in this study showed that the post retained crowns, group (P), reported statistically significant higher mean debonding load values (91.36N±7.48) than endocrowns (61.47N±13.94). Intra-radicular posts had long been considered as a mean for retention of extra-coronal restorations. [19] Being anchored inside the root canal; posts supply the prosthetic crown with macro-mechanical retention compensating for lost tooth structure. Endocrowns gain macro mechanical retention from the extension inside the pulp chamber. [27] When comparing endocrowns and posts with respect to the amount of involved tooth structure for bonding; post retained crowns utilizes larger amounts of bonded tooth structure through extension inside the root canal. [28]

Moreover, as fiber reinforced posts are composed of resin matrix and fibers, bonding to resin based cements and composite cores is expected to be high compared to the bonding between the resin cements and glass ceramics. [28]

Regarding type of cement; the results obtained in this study showed that Rely X Ultimate clicker resin cement resulted in statistically significant higher debonding load values than Multilink speed self-adhesive resin cement in both groups. These findings were in agreement with other studies were reported superior bond strength values of total etch resin cements compared to self-adhesive resin cements. [29,30,31] Total etch cements rely on a separate etching procedure to remove the thick surface smear layer and smear plugs in dentinal tubules formed during preparation allow more effective micromechanical retention of resin based cements. [32]

CONCLUSIONS

Within the limitations of this study and for the tested materials, the following could be concluded:

- The rational of restoring endodontically treated teeth can be extended to include glass ceramic endocrowns.
- Endocrowns and post retained crowns can be used safely in terms of fracture strength as both have values which exceed the physiologic requirements.
- Higher fracture strength values can be obtained with glass ceramic endocrowns if good bonding is guaranteed.
- Luting endocrowns with total etch cements is more reliable than using self-adhesive cements in terms of both fracture strength and retention.

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