EFFECT OF ENDOCROWNS AND GLASS FIBER POST-RETAINED CROWNS ON THE FRACTURE RESISTANCE OF ENDODONTICALLY TREATED PREMOLARS

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ABSTRACT

Purpose: The purpose of this in vitro study was to compare the effect of endocrowns and glass fiber post-retained crowns on the fracture resistance of endodontically treated premolars prepared with or without ferrule.

Materials and Methods: Twenty sound mandibular premolars were endodontically treated. They were randomly assigned into 4 groups (n=5), in which, teeth were prepared to receive all-ceramic restorations. Group 1: Endocrown without ferrule. Group 2: Endocrown with (1 mm wide shoulders and 2 mm axial wall heights) ferrule. Group 3: Glass fiber post and resin core and conventional crown without ferrule. Group 4: Glass fiber post and resin core and conventional crown with ferrule. The lithium disilicate all-ceramic restorations (IPS E-max press, Ivoclar-Vivadent) were made by injection technique and adhesively cemented (Variolink N, Ivoclar Vivadent). Specimens were mounted in a universal testing machine (Model LRX-plus; Lloyd Instrument Ltd., Fareham, UK). Each specimen was loaded to failure at a crosshead speed of 1.0 mm / min. Mode of failure was also examined. 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.

Results: One way ANOVA test showed that group (4) recorded statistically significant (p <0.05) highest mean value (1262.71±277.8 N) followed by group (2) (1139.7±227.94 N) then group (1) (725.73±137.89 N). Group (3) recorded the lowest statistically significant (p <0.05) mean value (588.17±94.11 N). Pair-wise Tukey’s post-hoc test showed non-significant (P>0.05) difference between 2 and 4 groups.

Conclusions: Within the limitations of this study, the presence of ferrule increased the fracture resistance of endodontically treated premolars restored with either endocrown or glass fiber post-and core and all-ceramic crown than those without ferrule.

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INTRODUCTION

Usually the mutilated tooth is structurally weakened due to caries, repeated restorations and/or fracture. It is also weakened by the endodontic steps including the access cavity and the restorative techniques required to rebuild the missing tooth structure. Due to the substantial loss of tooth structure in an endodontically treated tooth, it requires special considerations for the final restoration. These considerations involve; ensuring adequate restoration retention, maximum tooth fracture resistance and esthetic needs in some cases.

To restore such a tooth, a post and core foundation is needed onto which a full crown is retained and cemented. Glass fiber posts were introduced to bond to both the composite core and root canal and provide a natural esthetics. As regard to the modulus of elasticity compared with the dentin, the glass fiber post has a better performance than other metallic posts in terms of stress distribution, which minimizes the risk of root fracture. However, the placement of posts inside the root canals dictates the removal of additional dental structure and may involve a risk of root perforation.

In clinical cases for instance; an excessive loss of coronal hard tissue, limited inter-arch space, and dilacerated or short roots, traditional post-and-core rehabilitation is impossible. Nowadays, the field of adhesive dentistry promotes a ceramic coronal restoration of these cases by onlay and overlay using the pulp chamber extension as a retention foundation without the needs of for intra-radicular posts, as is the case of endocrowns.

The endocrown is an acid etchable ceramic crown (such as lithium disilicate-based ceramics) anchored to the pulp chamber and cavity margins of endodontically treated posterior tooth obtaining a macro mechanical retention by the pulpal walls and micro retention using an adhesive resin cement. The preparation design for endocrown comprises a cervical circumferential butt margin and a central retention cavity inside the pulp chamber with or without a ferrule and constructs both the crown and core as a single unit.

Performing the clinical procedures of endocrown is simpler and faster than the traditional single crown with post and core and have been reported clinically a successful restoration for endodontically treated molars.

However, a controversy exists concerning the restoration of endodontically treated premolars. Some findings observed that the premolars compromised the mechanical properties of the endocrown and presented more failures. Others recommended that, the endocrown should be considered as an alternative approach for restoring endodontically treated premolars as the findings revealed similar performance with conventional crown.

The purpose of this current study was to compare the fracture resistance of endodontically treated premolars prepared with or without ferrule and restored with laboratory manufactured lithium disilicate endocrowns and glass fiber post-retained conventional crowns.

MATERIAL AND METHODS

Preparation of tooth specimens

Twenty caries free of recently extracted human mandibular premolars were selected for the study. The dimensions of the teeth were measured with a calibre. The average values were measured at the level of cemento-enamel junction; (15 mm root length, 8 mm bucco-lingual, and 5 mm mesiodistal). The teeth were cleansed and stored in saline solution at room temperature immediately after extraction.

All teeth were prepared endodontically using rotary files (Protaper, Dentsply, Maillefer, Switzerland). After intermittent irrigation, the root canals were dried with paper points (Spident, Incheon, Korea). All canals were restored by a lateral compaction technique with gutta-percha
cones (Protaper, Dentsply, Maillefer, Switzerland) and eugenol-free root canal sealer (AH Plus, Dentsply, De tray, Germany).

The teeth samples were divided randomly into four groups of five specimens each (n=5). All teeth were sectioned 3 mm coronal to the cemento-enamel junction and then assigned to receive one of the selected preparation designs and all-ceramic restorations; (figure 1)

Group 1: Endocrown without ferrule preparation.

Group 2: Endocrown with ferrule preparation.

Group 3: Glass fiber post and resin core and all-ceramic crown without ferrule preparation.

Group 4: Glass fiber post and resin core and all-ceramic crown with ferrule preparation.

Post-space preparation, cementation and core-build up:

The ten teeth of group (3) & (4) were received glass fiber posts size no.1 (Glassix+plus, Nordin, Switzerland) and a resin composite filling core (Tetric Ceram, Ivoclar Vivadent, Liechtenstein). After coronal sectioning, the gutta percha was removed using a pilot reamer of the post system to the length of 12 mm from the preparation margins. A post space was prepared with the corresponding calibrating drill (size no.1) included in the post system. The canals were etched with 36% phosphoric acid (Total Etch, Ivoclar Vivadent, Liechtenstein) for 15 seconds. The canals were thoroughly rinsed with sterile water, dried with compressed air and paper points. A light cure, adhesive agent (Tetric N-Bond, Ivoclar Vivadent, Liechtenstein) was applied inside the root canal using a micro brush. The adhesive was rubbed to canal walls for 10 seconds and the excess solvent was removed with gentle oil free compressed air for 1-3 seconds and light cured for 20 seconds according to manufacturer instructions.

A silane coupling agent (Silane, Ultradent, South Jordan, Utah, USA) was applied on the post surface for one minute and then gently air dried for 5 seconds. The post was luted with the same bonding agent using the brush, the excess solvent was removed and the adhesive was cured for 20 seconds. The base and catalyst of dual cure resin cement (Variolink N, Ivoclar Vivadent, Liechtenstein) were mixed properly and applied for post cementation.

Each post was cut to 4 mm from the cemnto-enamel margin. The core build up was made incrementally till the predetermined dimensions. The final layer was placed using a transparent matrix to allow for shape standardisation between samples. The core height was adjusted to 3 mm. All the margins and the angle of convergence were adjusted and standardized for conventional crown preparation.

Preparation for endocrown:

All ten teeth of group (1) & (2) were prepared for endocrown restorations. After coronal sectioning to prepare a circular butt margin, a central retention inlay-type cavity was prepared in the pulp chamber with an oval anti-rotational shape and a depth of 5 mm from the cavo-surface margin\textsuperscript{14}. The internal line angles were rounded and smoothed.

Fig. (1) Schematic representation of the different groups 1) No ferrule with endocrown, 2) A ferrule with endocrown, 3) No ferrule with glass fiber post and resin core and all-ceramic crown. 4) A ferrule with glass fiber post and resin core and all-ceramic crown.
In group (2) & (4), the teeth were further prepared for 1 mm shoulder finish line and 2 mm circumferential ferrule axial wall heights using a rotary diamond stone.

**Laboratory procedures:**

For each prepared sample of endocrowns and conventional crowns, an individual impression was made by poly-vinyl siloxane impression material (Virtual, Ivoclar-vivadent) and stone die (type IV) was fabricated. All the crowns were constructed from wax (GEO, Renfert GmbH, Germany) with the same heights and dimensions and prepared for ceramic crown pressing by the injection technique according to the manufacturer’s instructions and materials. The ceramic material for crowns fabrication was IPS E-max (Ivoclar-Vivadent).

**Bonding procedure**

The fitting surface of the all-ceramic crowns, either conventional crowns or endocrowns were etched with 9.5% buffered hydrofluoric acid gel (Porcelain etch, Ultradent South Jordan, Utah, USA) for one minute, washed thoroughly and dried. The etched surface of each crown was silanized (Silane, Ultradent, South Jordan, Utah, USA) for one minute and then dried followed by adhesive agent (Tetric N-Bond, Ivoclar Vivadent, Liechtenstein) and light curing for 20 seconds. The adhesive system was applied on the prepared surface of teeth. Then, each crown was cemented to its corresponding tooth sample using dual cure resin cement (Variolink N, Ivoclar Vivadent, Liechtenstein). Excess cement was removed immediately with a microbrush and light cured.

The root of each tooth was thinly covered with a layer of a light body silicone based impression material (Speedex, Coltene whaledent, Switzerland) to simulate the thickness of periodontal ligament.

In order to mount the root of each sample in the universal testing machine, an acrylic resin block was made. A specially designed longitudinally split Teflon square mould was constructed with 15 mm width and 20 mm length to accommodate the acrylic resin block. An auto polymerizing resin powder (Acrostone, Acrostone dental factory, Industrial zone, Cairo, Egypt) was mixed with monomer and poured inside the mould. Each specimen was embedded into the filled mould along its long axis using a surveyor (Ney Surveyor, Dentsply, USA) and 2 mm below the cervical line of the root was left exposed. After complete hardening of the acrylic resin, the block was removed from the mould.

**Fracture resistance testing**

Each specimen along with the acrylic resin block was mounted into a custom-made carrier with an inclination of 45 degrees and then loaded to failure using a universal testing machine (Model LRX-plus; Lloyd Instrument Ltd., Fareham, UK) (figure 2). The upper plate of the machine included a steel rode with a round tip with a diameter of 3.6 mm placed at the centre of the occlusal surface of the crown of each specimen. A 0.5 mm tin foil sheet was placed between the rode and crown to ensure even stress distribution and minimize the transmission of local force peaks on the ceramic surface. The samples were subjected to a slowly increasing compressive load at a constant crosshead speed of 1.0 mm per minute until an audible crack or fracture occurred. Load was automatically recorded in Newton (N).
Data were recorded using computer software (Nexygen-MT 4.6; Lloyd Instruments) and analyzed statistically with one way analysis of variance (ANOVA) and Tukey’s post hoc significance difference tests. Differences were considered significant at $P<0.05$.

After loading, mode of fracture for each specimen was examined using a digital microscope (Scope Capture Digital Microscope, Guangdong, China) at $\times 25$ magnifications and classified according to the following descriptions:

I] Debonding of all ceramic restoration without fracture.

II] Fracture of the restoration without fracture of the tooth (favourable failure).

III] Fracture of the restoration/tooth complex above the level of tooth root embedded in the resin block (acceptable failure).

IV] Fracture of the restoration/tooth complex inside tooth root embedded in the resin block (catastrophic failure).

RESULTS

Mean fracture resistance and standard deviations (SD) of the tested groups are recorded and displayed in table (1) and graphically drawn (figure 3).

As indicated by one way ANOVA test, it was found that group 4 (Fiber post and conventional crown with ferrule) recorded statistically significant ($p<0.05$) highest mean value (1262.71±277.8 N) followed by group 2 (endocrown with ferrule) (1139.7±227.94 N) then group 1 (endocrown without ferrule) (725.73±137.89 N). Group 3 (Fiber post and conventional crown without ferrule) recorded the lowest statistically significant ($p<0.05$) mean value (588.17±94.11 N).

Pair-wise Tukey’s post-hoc test showed non-significant ($P>0.05$) difference between (2) and (4) groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Tukey's rank</th>
<th>ANOVA</th>
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<tbody>
<tr>
<td>1</td>
<td>725.73</td>
<td>137.89</td>
<td>B</td>
<td>P value &lt;0.0001*</td>
</tr>
<tr>
<td>2</td>
<td>1139.7</td>
<td>227.94</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>588.17</td>
<td>94.11</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1262.71</td>
<td>277.80</td>
<td>A</td>
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</tr>
</tbody>
</table>

Different letter indicating significance ($p<0.05$) ; significant ($p<0.05$)

The favourable (type II) and acceptable (type III) failure modes were predominant in this study. While, debonding of all ceramic restoration without fracture (type I) and catastrophic failure (type IV) were not occurred (figure 4).
DISCUSSION

Glass fiber post system became popular because of its esthetic properties, and simple technique. However, the ceramic endocrown restoration is considered to some clinician an alternative treatment to post-and-core and conventional crown in endodontically treated posterior teeth. It can conserve the remaining tooth structure, reduce the need for macro-retentive geometry, and provide a more esthetic result being constructed from ceramic.

Recently, endocrown restoration became the subject of many studies. It has been considered a restorative option for posterior endodontically treated and badly damaged molars. Some clinicians suggested the concept of endocrown restoration for restoring the endodontically treated premolars.

The results of this study showed that group 4 (fiber post with ferrule) recorded the highest fracture resistance of all groups and there was no significant difference with group 2 (endocrown with ferrule). This result was in agreement with the study of Forberger and Göhring. They also evaluated the marginal continuity and fracture behavior of both lithium disilicate crowns with different types of post and core and endocrown in endodontically treated premolars. They concluded that the restoration of endodontically treated mandibular premolars with endocrowns cannot be recommended over treatment using post-and-core foundations.

Lin CL et al. observed the favourable performance of endocrown restorations in premolars by using the finite element method. In other in vitro studies, they found that the endocrown and conventional crown restorations for endodontically treated premolars did not significantly differ from each other. They explained that the endocrown restorations recorded the low stress values because endocrown include both the crown and core as a single unit which decrease the effect of multiple interfaces. As well, thickening of the ceramic occlusal portion compared to the conventional crown.

On the other hand, Bindl and Mörmann evaluated the clinical performance of 208 endocrowns cemented to premolars and molars and observed that the premolars presented more failures than the molars. They referred this to the smaller surface area of premolars for adhesion compared with molars. Moreover, premolars have greater crown height, which compromises the mechanical properties of the endocrown.

In groups 2 and 4, a ferrule effect was attained by extending the future restoration margin 2.0 mm below the foundation limit according to the recommendation of Sorensen and Engelman.

Sometimes, in many clinical cases, the extensive loss of tooth structure of endodontically treated tooth may preclude the use of ferrule. In group 1, the premolars were restored with endocrowns without ferrule to simulate the restorative approaches for badly damaged teeth, which do not allow the use of ferrule. However, the fracture resistance of group 4 (fiber post with ferrule) was significantly higher than group 1 (endocrown without ferrule). This result was in accordance with Schmidlin et al. who indicated the importance of ferrule in increasing the fracture resistance.
resistance of the endodontically treated tooth. Also, Ma OS et al \(^\text{18}\) reported the value of ferrule which increases fracture strength and minimizes loss of bond of prosthetic restorations. This also explained the result of group 4 (fiber post with ferrule) which recorded a higher significant fracture resistance than group 3 (fiber post without ferrule).

In this study, Lithium disilicate – based ceramics was used for construction of both conventional crowns and endocrowns due to its high mechanical strength and being acid etched; it can promote micromechanical interlocking with resin cement and bonded to the tooth interface \(^2\). The adhesive property of this kind of ceramic material explained the absence of failure mode type (I); debonding of either endocrown or conventional crown without restoration fracture.

All samples restored with glass fiber posts showed favourable or acceptable fracture patterns. This might be due to the modulus of elasticity of fiber-reinforced posts which close to that of dentin, resulting in a better stress distribution at the post–dentin interface \(^19\). Also, the same results occurred in the samples of endocrown. Since the stresses were concentrated at the cervical area and the outer root surface, a cohesive fracture of the endocrown ceramic material, which remained attached to the fractured segment of cervical root, thus indicating good bond strength between lithium disilicate material and tooth structure. As well, this explains why samples did not show catastrophic failures.

**CONCLUSIONS**

**Within the limitations of this study we can conclude that:** Both endocrown and glass fiber post-and core and all-ceramic crown with ferrule increases the fracture resistance of endodontically treated mandibular premolars more than that without ferrule and the endodontically treated mandibular premolars should not be restored with endocrown in the absence of ferrule.

**REFERENCES**


18. Ma OS, Nicholls JI, Junge T, and Phillips KM.: Load fatigue of teeth with different ferrule lengths, restored with fiber posts, composite resin cores, and all-ceramic crowns. J of Prostheth Dent. 2009; 102; 229-34.


