Fracture Strength of Endodontically Treated Maxillary Premolars Supported by a Horizontal Glass Fiber Post: An In Vitro Study

Wassim Karzoun, DDS, MSc,*† Amid Abdulkarim, MSc, PhD, * Abdulaziz Samran, MSc, DMD,‡§ and Matthias Kern, DMD, PhD§

Abstract

Introduction: The purpose of this study was to evaluate the effect of a horizontal glass fiber post on the fracture strength of endodontically treated maxillary premolars with mesioocclusal-distal (MOD) cavities. Methods: Sixty extracted intact upper premolars were collected, treated endodontically (except for the control group), and divided into 5 test groups (n = 12) depending on the restoration type: G1 (control group, untreated teeth), G2 (MOD preparation without restoration), G3 (MOD preparation with resin composite restoration), G4 (MOD preparation with resin composite restoration and a horizontal fiber post inserted between buccal and palatal walls), and G5 (MOD preparation with a horizontal fiber post only). The specimens were stored in normal saline at 37°C for 2 months. Then specimens were quasi-statically loaded in a universal testing machine until fracture occurred. Failure loads were then analyzed with one-way analysis of variance, followed by multiple comparisons by using Tukey honestly significant difference test (α = .05). The mode of failure was determined by visual inspection. Results: Mean (standard deviation) failure loads for groups ranged from 411.8 N (±103.9) to 994.5 N (±147.3). One-way analysis of variance showed significant differences between fracture resistances of groups (P < .001). Tukey honestly significant difference test showed significant differences in fracture resistance within groups (P ≤ .05) except between the G1 (control group) and group G4 (P ≥ .05). All groups (except G4) had almost favorable fracture mode within the cervical third of the roots. Conclusions: Under the conditions of this in vitro study, a horizontal glass fiber post in a MOD cavity increased significantly the fracture resistance of the endodontically treated upper premolars. (J Endod 2015;41:907–912)

Key Words

Endodontically treated premolars, fracture resistance, glass fiber post, MOD cavity, resin cement

Root canal treatment is often necessitated by pulpal infection after hard tissue loss by caries or after tooth preparation for crowns. Endodontically treated teeth (ETT) have a higher risk of biomechanical failure than teeth with vital pulps (1). This is actually related to the loss of structural integrity associated with the access preparation that results in increased cuspal deflection during function, which leads to a higher occurrence of fractures (2). Several studies revealed that the ETT are less prone to fracture when less dental tissue is removed during treatment (3). In addition, the prognosis of ETT is influenced by different parameters such as amount of hard tissue loss (4), presence of a minimum of 1.5–2.0 mm ferrule height preparation (5), and post and core material used (6).

After root canal treatment is performed, there is often a high demand for the restoration of ETT (7). Different prosthetic techniques and materials have been reported for the restoration of ETT (3, 8). These treatment modalities include using a post and core (8), partial or full coverage crowns (9), and direct resin composites or amalgam fillings (10). Several post system techniques are available for the restoration of ETT. Fiber posts can be used because of their favorable physical properties (11). Placement of post is indicated when coronal structure is insufficient to support a core buildup (8). Sorensen and Martinoff (12) showed that full coverage crowns did not significantly improve the clinical success for anterior teeth, whereas they improved success rate for premolars and molars. The substantial loss of ETT structures during preparation might worsen the situation when endodontic treatment is associated with mesioocclusal-distal (MOD) cavities. From this point, adhesive restorations, with the potential to reinforce weakened tooth structure (13), seem to have an advantage over crowns, because the preparation of a crown might weaken the tooth as well.

A horizontal fiber reinforcement of the ETT might enhance the fracture resistance of these teeth. Therefore, the aim of this study was to evaluate a more conservative approach than the traditional procedures when restoring endodontically treated premolars (ETPs). The null hypothesis of the study was that the presence of a horizontal glass fiber post would not affect the fracture resistance of ETPs.

From the *Department of Fixed Prosthodontics, Faculty of Dentistry, Aleppo, Syria; †Department of Restorative Dental Sciences, Al-Farabi Colleges, Riyadh, Saudi Arabia; ‡Department of Fixed Prosthodontics, School of Dentistry, Ibb University, Ibb, Yemen; and §Department of Prosthodontics, Propaedeutics and Dental Materials, School of Dentistry, Christian-Albrechts University, Kiel, Germany.

Address requests for reprints to Dr Abdulaziz Samran, Department of Prosthodontics, Propaedeutics and Dental Materials, School of Dentistry, Christian-Albrechts University at Kiel, Arnold-Heller Strasse 16, 24105 Kiel, Germany. E-mail address: aasamran@gmail.com 0099-2399/$ - see front matter

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Test Groups

Sixty recently extracted caries-free upper premolars, which were removed for orthodontic reasons, were selected and then stored in 5% formol/saline solution at room temperature. The teeth were cleaned with a hand scaler and stored at room temperature during the study. Teeth with similar dimensions were assigned to 5 groups of 12 specimens. Buccopalatal and mesiodistal dimensions at the level of the cervical margin were recorded with aid of a digital caliper (Links Brand; Harbin Metering Instrument Works, Harbin, China). Analysis of variance (ANOVA) was used to determine any significant difference among the measurements of each group ($P \leq 0.05$). Endodontic access cavities were prepared as small as possible by using a water-cooled air turbine handpiece and round burs (Dia-Tessin; Vanetti SA, Gordevio, Switzerland). During root canal preparation the working length was set at 1 mm short of the apical foramen. The canals were prepared with a rotary system (X-Smart; Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer’s guidelines. Sodium hypochlorite solution (3%) was used to irrigate the canals throughout instrumentation. The root canals were dried with paper points (Spident; Meta Biomed Co, Incheon, Korea). The lateral condensation technique was used for the obturation of the prepared canals by gutta-percha cones (Spident) to the working length and sealed with eugenol-free resin sealer (AH Plus Sealer; Dentsply DeTrey, Constance, Germany). Subsequently, the access cavities were sealed with temporary filling material. To simulate the periodontal ligament situation, the roots were prepared in the roots to prevent dislodgement from the embedding material. To test the periodontal ligament situation, the roots were immersed into melted wax to a depth of 2 mm below the CEJ and oriented their long axes perpendicular to horizon by using a custom-made parallelometer. Notches were made with rounded diamond bur (Dia Tessin) with air-water spray. The MOD cavity preparation was performed to all teeth except control group teeth. Burs were replaced after 6 preparations to ensure high cutting efficacy. For teeth preparations, cylindrical diamond burs (Dia Tessin) under copious air-water cooling were used in a high-speed handpiece mounted on a custom-made parallelometer to standardize the preparation for all specimens. The teeth were assigned randomly to 5 groups of 12 teeth each as follows (Fig. 1): G1 (the teeth were left intact without any cavity preparation or root canal treatment and were used as control group), G2 (MOD preparation without restoration), G3 (MOD preparation with resin composite restoration), G4 (MOD preparation with resin composite restoration and a horizontal fiber post inserted between buccal and palatal walls), and G5 (MOD preparation with horizontal fiber post only).

Standard MOD cavities were prepared for all groups except G1. MOD cavities had a width of one third of intercuspal distance for occlusal portion preparation, and one third of buccopalatal dimension was used to determine the width of proximal boxes. A depth of 1 mm above CEJ was determined for cavity preparation. After finishing the preparation, all internal edges were smoothed and rounded. Only one operator was assigned to perform all the cavity preparations. The perforations in the teeth of G4 and G5 (for the horizontal glass fiber post) were made at the prominent point on the buccal and palatal surfaces at the middle space between mesial and distal. The holes were made with rounded diamond bur (Dia Tessin) with air-water spray. Burs were replaced after every 6 holes to ensure high cutting efficacy. Smear layer solvent gel (EDTA; Meta Biomed Co) was applied to the surface of all MOD cavities. Then the gel was removed by air-water spray. Glass-fiber posts (White Post DC no. 0.5; FGM Produtos Odontologicos Ltda, Joinville-SC, Brazil) of 1.4-mm diameter were airborne-particle abraded for 5 seconds at a distance of 30 mm with 50 μm alumina particles at 0.25 MPa (Aluminum Oxide Abrasive; Heraeus Kulzer, Hanau, Germany) and ultrasonically cleaned in 99% isopropanol for 5 minutes. The posts were brushed and fixed in place by using self-adhesive resin cement (RelyX Unicem; 3M/Espe, Neuss, Germany) and ultrasonically cleaned in 99% isopropanol for 3 minutes. The MOD cavities were etched by using 37% phosphoric acid (Meta Etchant; Meta Biomed Co) for 15 seconds, rinsed with water spray, and air dried. Then MOD cavities were bonded by using dentin bonding agent (SwissTEC; Coltene/Whaledent AG) according to the manufacturer’s instructions. Flowable composite (Opallisflow; Dentscare LTDA, Joinville-SC, Brazil)

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was first applied on root canal orifices and polymerized from proximal and occlusal areas.

Then resin composite (FiltekZ250 XT; 3M/Espe) was applied and polymerized following the incremental technique procedure. Then all teeth of groups were kept in physiological saline in an incubator at 37°C for 60 days. Materials used in the restorative procedures are listed in Table 1.

Loading of the Specimens

All specimens were quasi-statically loaded with a crosshead speed of 1 mm parallel to the long axis of the tooth in a universal testing machine (Instron Corp, Canton, MA) until they were fractured (Fig. 3). A cylindrical steel bar 6 mm in diameter and 10 mm long was used. The bar was in non-contact mode with any points on the resin composite. The failure load of the specimen was determined when the force-versus-time graph showed an abrupt change in load, indicating a sudden decrease in the specimen’s resistance to compressive loading. Specimens were visually examined for the type and location of failure, as well as the direction of failure.

Statistical Analysis

Data were explored for normality by using Anderson-Darling test, which showed that data were normally distributed. One-way ANOVA was used to compare fracture resistance means among the 5 groups, followed by multiple comparisons by using Tukey honestly significant difference (HSD) test (α = .05). The confidence level was 95%. Statistical analysis was performed with SPSS 18.0 (SPSS 18.0 for Windows; SPSS, Inc, Chicago, IL). According to the significance level (α = .05) and the sample size (n = 12), the test of choice had adequate power to detect statistical differences, which could be used to provide clinical recommendations.

Results

The mean values of the fracture resistance and standard deviations are displayed in Table 2. They ranged from 411.8 N (±104) to 994.5 N (±147.3). The highest fracture resistance was recorded for G1 (control group), and the lowest one was recorded for G2 (MOD preparation without restoration) (Fig. 4). One-way ANOVA revealed significant differences between groups (P ≤ .05). Further analysis with the Tukey HSD test showed that G1 (sound teeth) presented significantly higher fracture resistance values than the other groups except G4 (MOD preparation with resin composite restoration and a horizontal fiber post). G2 (non-restored) presented significantly lower values (P ≤ .05) than other groups. The fracture resistance values of G3 (MOD preparation with resin composite restoration) and G2 (MOD preparation without restoration) did not differ statistically.

The mode of failure was determined by visual inspection of all specimens. The type of fracture behavior and the frequency are illustrated in Figure 5. There were 2 typical root fracture modes, cervical third fracture (favorable mode) and middle and apical thirds (catastrophic mode). Almost all groups (except G4) had a favorable fracture.
mode (Table 3). G1 and G5 presented the highest incidence of favorable fractures, but specimens in G4 presented catastrophic fracture mode. The mode of failure in G3 and G4 was typically an oblique or vertical root fracture at the middle or apical third of the root, extending from bottom of the cavity down to the buccal surface, whereas the majority of fracture modes in the other groups were horizontal or oblique fractures extending from the dentin-core junction down to the facial or palatal surface of cervical third.

Discussion

The present study investigated the influence of a horizontal glass fiber post on the fracture resistance of ETPs. This technique is primarily for teeth in which no subsequent crown is planned, and there could be an esthetic compromise. The use of natural teeth is a reliable methodology in fracture testing and has also been attributed by many authors (5, 8, 14). Fracture resistance of the roots is one of the most important factors when restoring ETT that have lost a considerable amount of their crown tissue. A custom-made parallelometer was used to standardize the preparation for all specimens (5). The ETPs were loaded in a direction parallel to the longitudinal axis to distribute the stresses more evenly between the residual coronal wall and the restorative material, simulating a physiological occlusion. Glass fiber posts were selected because of their low elastic modulus similar to dentin so they can distribute the load forces evenly along the root (15, 16). Furthermore, these types of post systems have the advantages of superior esthetics, ease of retrievability, and simple application technique, allowing the clinician to complete the procedure in the same visit. Prefabricated fiber posts and composite resin buildup are a viable restoring technique for ETT (5). Several studies have tried to identify the best technique and materials to be used to increase the fracture resistance of ETT (8, 17, 18). A study by Grandini et al (19) reported that restoration of ETT with fiber posts and resin composites is a treatment option that in the short-term conserves remaining tooth structure. This investigation compared the fracture resistance of ETPs with different strategies of restoration that represented the clinical situations.

The null hypothesis that the presence of a horizontal glass fiber post would not affect the fracture resistance of crowned upper premolars had to be rejected. The horizontal glass fiber post had a significant influence on the final fracture resistance of ETPs ($P \leq 0.05$). The fracture resistance of the restored premolars ranged from 411.8 N (±104) for G2 to 994.5 N (±147.2) for G1 and can be compared well with previous in vitro studies (20–22). The current results show that ETPs restored with composite resin and a horizontal fiber post provide a mean fracture resistance of 961.3 N, which is similar to the control group with unrestored premolars with 994.5 N. The achieved fracture resistance can also be compared well with that of premolars restored with root canal posts and crowns tested in a comparable study design (5), where mean failure loads ranged from 680 N to 1085 N (depending on the ferrule height and the number of remaining walls).

In the present study, the control group (G1) showed statistically significantly higher fracture resistance than all other groups. These results might be explained by the fact that the preservation of tooth structure enhances the fracture resistance under occlusal loads of ETT (8). Several studies revealed that the sound tooth structure removed during tooth preparation affects its fracture resistance against loading (23, 24). On the other hand, the lowest fracture resistance values were found for G2 (MOD preparation without restoration). These results might be attributed to the fact that removing tooth structure and leaving it without restoration will weaken the tooth against loading. Studies showed that the main factor affecting the survival rate of ETT is substance loss (25, 26). In addition, the absence of adhesive restoration might weaken a tooth against the fracture load. Hence, the purpose of a restoration is not only to fill the cavity but also to strengthen the tooth and provide an effective seal between the cavity and mouth (27). G3 presented a higher fracture resistance (482.1 ± 72.9 N) than G2 (411.8 ± 104.9 N). This finding shows that the restoration of MOD with adhesive resin composites can replace the lost dentin and recover the resistance of the tooth against the fracture load to a good extent (21). The mean fracture loads recorded for G3 and G5 (428.1 ± 72.9 N and 656.1 ± 139.4 N, respectively) showed that resin composites alone (for G3) or horizontal glass fiber post alone (for G5) were not sufficient to sustain occlusal loads. Better results in

Table 2. Fracture Loads (N) (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean ± standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 (control group)</td>
<td>994.5 ± 147.3^AB</td>
</tr>
<tr>
<td>G2 (MOD preparation without restoration)</td>
<td>411.8 ± 104.0^C</td>
</tr>
<tr>
<td>G3 (MOD preparation with resin composite restoration)</td>
<td>482.1 ± 72.9^A</td>
</tr>
<tr>
<td>G4 (MOD preparation with composite restoration and horizontal fiber post)</td>
<td>961.3 ± 245.2^A</td>
</tr>
<tr>
<td>G5 (MOD preparation with transfixed fiber post only)</td>
<td>656.05 ± 139.4^A</td>
</tr>
</tbody>
</table>

Statistically different means ($P \leq 0.05$) are indicated by different superscript letters.
G4 (961.31 ± 245.21 N) were obtained by using both resin composite and a horizontal glass fiber post when restoring ETPs. These findings reveal that the extension of a horizontal glass fiber post through the buccal and palatal cusps strengthens the composite resin filling and through adhesion reinforces the cusps and enhances the fracture resistance of ETPs.

All groups (except G4) had almost favorable fracture mode, which means that the fracture occurred in the cervical third of the root, which is considered a restorable fracture in many clinical instances. This can be explained by the morphology of the MOD preparations, leaving limited amounts of residual tooth structure at level of the cervical margin of the specimens. Another reason could be the low elastic modulus of composite resin, which can transmit the load to adjacent dental structures. The concentration of stresses in the thin dentin of cervical area can lead to favorable fracture. Specimens in G4 had almost a catastrophic fracture mode. This can be explained by the fact that the presence of a horizontal glass fiber post reinforced the residual tooth structure in the coronal part. Because the modulus of elasticity of a glass fiber post is similar to that of dentin and the resin composite (11), the compressive load will be redistributed and prevented from discharging on the crown or in the cervical third of root. Therefore, the stress released was limited to middle and apical thirds of root, and the fracture occurred as a catastrophic mode. It has been suggested that glass fiber posts (28, 29) show reduced stress transmission to the root because of similar elasticity compared with dentin (30, 31). However, in light of recently published clinical studies showing higher failure rates with glass fiber posts than with zirconia ceramic posts and cast posts (32), validity of this concept might be questioned (32, 33).

In light of the results of this study, presence of a horizontal glass fiber post can increase the fracture resistance of ETPs against fracture load. As in many in vitro studies, it is difficult to extrapolate the results of this study directly to a clinical situation. A limitation in this study may be that a single load to fracture test was incorporated. To mimic the intraoral condition, further studies should be done with thermocycling and dynamic fatigue loading. In addition, placing the full coverage on ETT is not only to prevent fracture but also to prevent leakage that may cause secondary carious lesions. Composite restorations might be more prone to this unwanted outcome, especially when large amounts of defects are replaced with composite that may have significant shrinkage when cured. In this regard, long-term use of this method should be followed up in a clinical study.

Conclusions

Within the limitations of this study, a horizontal glass fiber post in a MOD cavity increased the fracture resistance of ETPs significantly.
TABLE 3. Fracture Mode of Each Group

<table>
<thead>
<tr>
<th>Fracture mode</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restorable</td>
<td>10 (83.3%)</td>
<td>6 (50%)</td>
<td>5 (41.6%)</td>
<td>3 (25%)</td>
<td>10 (83.3%)</td>
</tr>
<tr>
<td>Non-restorable</td>
<td>2 (16.7%)</td>
<td>6 (50%)</td>
<td>7 (58.4%)</td>
<td>9 (75%)</td>
<td>2 (16.7%)</td>
</tr>
</tbody>
</table>

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The authors deny any conflicts of interest related to this study.

References