Effect of fiber post length and bone level on the fracture resistance of endodontically treated teeth

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This study evaluated the combined influence of horizontal bone loss and post length on the fracture resistance of endodontically treated teeth (ETT). Twenty premolars were endodontically treated and divided into four groups of two different post insertion depths (5 and 7 mm) and two alveolar bone levels from cement-enamel junction (2 and 5 mm). After posts (RelyX Fiber Post) were cemented using a self-adhesive resin cement (RelyX Unicem Aplicap) and cores were built up (Filtek Supreme XT Universal Restorative, 3M ESPE, USA), cobalt-chrome copings were luted to each prepared tooth. All specimens were subjected to thermocycling and mechanical loading until fracture occurred. Mean fracture loads (N) were 1,445±342.2 (2 mm bone level/5 mm depth), 1,516±413.4 (2 mm bone level/7 mm depth), 1,736.4±1113.8 (5 mm bone level/5 mm depth), 1,038.6±600.2 (5 mm bone level/7 mm depth). No significant differences were found. Therefore, bone level and post length did not seem to influence the fracture resistance of ETT.

Keywords: Fiber post, Endodontically treated teeth, Fracture resistance, Tooth reconstruction, Cobalt-chrome crown

INTRODUCTION

Endodontic treatment (ET) is indicated when the nerve of a tooth becomes infected by extensive dental decay or pulpal pathology, or damaged by fracture, trauma, extensive dental work or iatrogenic loss of tooth structure¹. After ET, adequate restoration of pulpless teeth is critical to ensuring the longevity of treated teeth. Due to extensive loss of coronal tooth structure, endodontically treated teeth (ETT) are typically restored with a post and core restoration and a full coverage crown.

Posts can weaken teeth, and the increased fracture susceptibility of teeth restored with posts has been attributed to factors such as the amount of remaining tooth structure and root canal post characteristics—namely, post dimensions and material²-⁴. Clinicians are increasingly opting for post materials that have an elastic modulus similar to that of dentin, which creates homogenous stress distributions and reduces the incidence of catastrophic root fractures⁵-⁸.

Post space preparation is another major factor at play in the fracture resistance of ETT. Over-preparing the canal space for a large post or inserting a post too deeply can decrease the fracture resistance of ETT or affect their apical seal⁹-¹². Traditionally, it is suggested that the post length be at least equal to the height of anatomic crown¹³. However, post insertion depth is one of the most controversial issues in restorative dentistry and experimental data available from literature are discordant. A numerical simulation of maxillary central incisors restored with different post lengths failed to show the influence of post length on the biomechanics of restored teeth¹⁴. In another study, however, incisors restored with very short fiber posts (4 mm) showed lower fracture resistance than the longer ones of 12 mm and 8 mm, but no statistical difference was found between the latter two lengths¹⁵.

Attention is also turned to the influence of alveolar bone support on prosthodontic treatment outcome. It is generally accepted that a reduction of periodontal support worsens the prognosis of a treated tooth¹⁶. However, the morphology of periodontium with reduced structural support has not been well understood in relation to clinical functions, such as load-bearing capability.

The purpose of this in vitro study was to assess the combined influence of horizontal bone loss and post length on the fracture resistance of ETT. The null hypothesis was that there would be no differences in the fracture resistance and failure mode of teeth with different alveolar bone heights and restored with fiber posts of different lengths.

MATERIALS AND METHODS

Human teeth preparation

Twenty single-rooted mandibular premolars with mature apices, extracted for periodontal or orthodontic reasons, were collected after excluding teeth with caries and/or previous restorations, root resorption or dental anomalies. Absence of cracks was examined and confirmed under transillumination. Only teeth with an average length of 22±1 mm, buccal-lingual dimension of 7±1 mm, and mesial-distal dimension of 9±1 mm were selected. After carefully removing dental plaque, calculus, and periodontal tissues with ultrasonic instruments and curettes, a silicone impression was taken of the anatomic crown of each tooth.

Teeth were cleaned and stored in 0.1% thymol
solution for a maximum of 4 weeks until use. Using a double-sided diamond disk (KOMET Italia Srl, Milano, Italy) in a slow-speed handpiece and cooled with air/water spray, the coronal portion of each tooth was sectioned perpendicular to the long axis at 16 mm from the root apex.

Post space preparation
Canal length was visually determined by placing a #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) in the root canal until its tip was visible from the apical foramen. Working length was established to be 1 mm short of the apex. All root canals were prepared to size 30 using stainless steel K-files (Dentsply Maillefer) and rotary Ni-Ti instruments (ProTaper Universal, Dentsply Maillefer). Instrumentation was performed strictly according to manufacturers’ instructions. Between each instrument change, root canals were alternately irrigated with 5.25% sodium hypochlorite at 37°C and 10% ethylenediamine tetraacetic acid solution. All teeth were obturated using the vertical condensation technique with warm gutta-percha and a root canal sealer (Pulp Canal Sealer, Kerr, Orange, CA, USA).

Obturated specimens were randomly assigned into four groups (n=5) of two different post insertion depths (5 and 7 mm) and two alveolar bone levels (2 and 5 mm) from the cement-enamel junction (CEJ) (Fig. 1, Table 1). Using a handpiece at 800–1,220 rpm, gutta-percha was progressively removed with a drill sequence until drill No. 2 (3M ESPE AG, Germany), in strict accordance to manufacturer’s instructions. To allow for two post insertion depths of 5 and 7 mm, a translucent glass fiber post (GFP; Size #2 RelyX Fiber Post, 3M ESPE AG, Germany) was inserted into the root canal and cut to the adequate length with a diamond bur to leave 5 or 7 mm above the CEJ and to cover its occlusal surface with at least 2 mm of resin composite.

Post and core placement
Posts were carefully cleaned with ethanol and dried with air free of water and oil. A self-adhesive resin cement (RelyX Unicem Aplicap, 3M ESPE, Germany) was applied into the post space in an apical-coronal direction using the provided elongation tip. Posts were seated into the root canals, and excess cement was removed using a microbrush dipped in a bonding agent. Resin cement was light-cured through the coronal portion of the cemented post for 40 s using a halogen curing light (Optilux 501, SDS/Kerr, USA).

After light-curing for 40 s, excess cement was removed by using an Arkansas bur mounted on a slow-speed handpiece. After etching enamel for 30 s and dentin for 10 s, a dental adhesive (Adper Scotchbond 1 XT, 3M ESPE, USA) was applied with a clean microbrush for 20 s, gently dried, and light-cured for 20 s. Core was built up using a microhybrid resin composite (Filtek Supreme XT Universal Restorative, 3M ESPE, USA). The silicone impressions, previously taken of each tooth, were used as a template for the complete crown build-up. Using a standardized incremental composite build-up technique, resin composite was light-cured at 1-mm increments until the complete crown was rebuilt in accordance to the silicone template.

The root of each tooth was embedded in a self-curing acrylic resin block (ProBase, Ivoclar Vivadent AG, Liechtenstein) in a stainless steel cylinder, up to 2 mm (n=10) or 5 mm (n=10) below the CEJ and with its long axis perpendicular to the base of the block. Using a microbrush, a thin layer of glycerin was applied on the dental root to facilitate specimen removal before resin completed the polymerization. At the first sign of polymerization, each tooth was carefully removed from the resin block. When resin polymerization was completed, a light-bodied consistency polyether impression material (Permadyne Penta L, 3M ESPE, USA) was injected into the acrylic resin root cylinder. Tooth was manually inserted back into the root cylinder and held until complete setting of the impression material. In this way, each dental root was covered with a standardized polyether layer of 200–400 μm thickness to simulate a periodontal ligament.

Using a cylindrical diamond bur mounted on a surveyor, each tooth was prepared for a 0.6 mm circumferential chamfer and a total occlusal convergence angle of 10° between axial walls. Finishing line was at the CEJ level, and a ferrule effect of 2 mm was created (Fig. 2). Silicone impressions were used to verify the amount of tooth reduction. Each tooth was scanned using a CAD system (3M Lava Scan ST, 3M ESPE, Germany).
USA), and cobalt-chrome copings of 0.6 mm thickness were fabricated by laser sintering. Each coping was luted to the tooth abutment using RelyX Unicem (3M ESPE, USA) according to manufacturer's instructions.

**Thermocycling**
To simulate the oral environment, specimens were stored in an incubator, ranging from 24 to 72 h, at 37°C in 90% humidity until thermocycling commenced. Restored teeth were subjected to 1,500 thermal cycles in water baths of 5°C and 60°C alternately with a 20-s dwell time for each bath.

**Mechanical loading**
After thermocycling, mechanical loading was performed on each specimen in a universal testing machine with 1,500 load cycles between 10 N and 100 N at a crosshead speed of 4 mm/min and in a direction parallel to the long axis of the tooth (Fig. 3).

After mechanical loading, fracture resistance was measured using a universal testing machine (Triaxial Tester T400 Digital, Controls srl, Cernusco sul Naviglio, Italy). Each specimen was positioned in a metal holder with the long axis of the tooth inclined at a 45° angle to the load direction. Linear compressive load was applied with a crosshead speed of 1 mm/min at the central fissure of the occlusal surface in the direction of the buccal cusp until failure. Maximum breaking load in Newtons (N) was recorded for each specimen by a computer (Digimax Plus, Controls srl, Cernusco sul Naviglio, Italy) connected to the loading machine.

After mechanical failure, all specimens were perfused with Indian ink to highlight the fracture lines. Mode of failure was classified as “restorable” or “unrestorable”, and failure mode at macroscopic view was determined by visual inspection. Specimens which presented the appearance of a root fracture were classified to have “unrestorable” fracture mode. All root fractures were classified as horizontal, oblique, or wave-like according to the fracture pattern. Fractures were also classified according to post exposure and post fracture. In the case of microcracks, fracture patterns were assessed using a stereomicroscope (Zeiss OPMI 1, Zeiss, Oberkochen, Germany) at 10x magnification.

**Statistical analysis**
Data were statistically analyzed using the SPSS software. The Kolmogorov-Smirnov test was used to verify the normality of data distribution. Fracture load data were analyzed with one-way analysis of variance (ANOVA) followed by Tukey's post hoc test for comparisons. Failure modes were compared using Pearson’s Chi-square test. Level of significance was set at $\alpha=0.05$.

**RESULTS**
Table 2 present the mean fracture loads of the four groups of specimens. One-way ANOVA and Tukey’s post hoc test revealed that there were no statistical differences among the groups ($p>0.05$).

Table 3 shows the distribution of fracture data according to fracture pattern, post exposure, and post fracture. All fractures were “unrestorable”, and Chi-square test showed no statistical differences in fracture pattern among the groups. Figure 4 shows a representative view of a specimen with horizontal fracture.
**Table 2** Mean fracture loads (±standard deviation) of the four groups of specimens

<table>
<thead>
<tr>
<th>Group</th>
<th>Bone level/Post length</th>
<th>Mean±SD (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 mm/5 mm</td>
<td>1,445±342.2A</td>
</tr>
<tr>
<td>2</td>
<td>2 mm/7 mm</td>
<td>1,516±413.4A</td>
</tr>
<tr>
<td>3</td>
<td>5 mm/5 mm</td>
<td>1,736.4±1113.8A</td>
</tr>
<tr>
<td>4</td>
<td>5 mm/7 mm</td>
<td>1,038.6±600.2A</td>
</tr>
</tbody>
</table>

Same superscript letter indicates no significant difference.

**Table 3** Distribution of specimens according to fracture pattern, post exposure, and post fracture

<table>
<thead>
<tr>
<th>Fracture pattern</th>
<th>Horizontal</th>
<th>Oblique</th>
<th>Wave-like</th>
<th>Post exposure</th>
<th>Post fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mm/5 mm</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2 mm/7 mm</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5 mm/5 mm</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5 mm/7 mm</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

**DISCUSSION**

This in vitro study investigated the combined influence of bone level and post length on the fracture resistance of ETT restored with GFP and covered with a metal coping. Since there were no significant differences among the four specimen groups, the null hypothesis was accepted.

To date, no clinical studies which evaluated the performance of ETT restored with GFPs have included bone level as a variable —thus no clinical data are available on this issue. Among experimental studies, the effect of different bone levels on fracture resistance of teeth restored with endodontic posts is poorly investigated, yielding discordant data. In the present study, two variables were considered: insertion depth of GFP (5 or 7 mm from CEJ) and the level of immersion in the resin block to simulate different bone levels. Two bone levels were chosen, namely 2 or 5 mm below the CEJ, to simulate normal and diminished bone levels respectively.

For endodontically treated premolars, it is a common practice to be restored with a full coverage crown. Therefore, cobalt-chrome copings were fabricated and luted to the restored teeth in this study. Specimens were also subjected to thermal cycling and mechanical loading before the fracture test in this study because these two regimes are a recognized method to induce fatigue.

Traditionally, a reduced bone level around a tooth is believed to worsen its prognosis since it requires only a lower load to bring it to fracture. A recent finite element study seemed to confirm this traditional belief, showing that stress at the cervical region in the periodontal ligament increased with bone height reduction. A study by Naumann et al. —which investigated the fracture resistance of extracted maxillary incisors restored with GFPs, all-ceramic crowns, and three different bone levels (no horizontal bone loss, 25% and 50% of horizontal bone loss) —also showed that teeth with a greater bone loss had an increased risk of failure. On the other hand, a study by Komada et al. —which investigated the fracture resistance of extracted mandibular premolars restored with different post materials, no crowns, and two different bone levels (2 or 5 mm below CEJ) —found no significant differences in fracture resistance between the two levels of bone loss. A study by Ni et al. —which investigated the fracture resistance of single-rooted premolars restored with GFPs, metal alloy crowns, and two different bone levels (2 or 6 mm below CEJ) —also found no statistical differences in fracture resistance between the different bone levels. In the present study, results did not show any difference in terms of fracture resistance between different bone levels.

On the effect of post length, results of the present study showed no differences in fracture resistance according to different post insertion depths. A survey of published literature showed that the same result was obtained with GFPs by several studies. However, short GFPs seemed to adversely affect the fracture
resistance of ETT\cite{13,27}. Adanir and Belli found that maxillary central incisors restored with short posts (i.e., shorter than clinical crown height) demonstrated root fracture under low loading forces\cite{29}. Therefore, unless the post is very short, such as only 3 or 4 mm long, post length had no influence on the fracture resistance of ETT under static loading, as confirmed by the results of the present study. This meant that a longer post would not affect the fracture resistance of ETT, even with reduced bone support.

In the present study, the most important factor affecting the fracture resistance results could be attributed to the same ferrule height for all test groups. Several factors play a key role in the long-term survival of ETT, and the presence of a ferrule of 1.5–2 mm is highly recommended to ensure successful clinical outcome\cite{29-31}. Results of the present study seemed to suggest that the influence of the ferrule was greater than those of the post length and bone level. Further studies should be carried out to investigate the effects of different ferrule heights in conjunction with different bone levels and post lengths.

In the clinical setting, the decision to restore or extract a tooth depends on whether the type and depth of fracture presents a restorable or unrestorable fracture. Generally, teeth restored with GFPS are more likely to present restorable fractures than other post materials, such as metal posts\cite{32}. This is because GFPS have an elastic modulus closer to that of dentin. Among teeth restored with GFPS of different lengths, it seemed that post length did not affect fracture type\cite{25}.

Data on the influence of bone level on fracture type are conflicting, thus rendering the role of bone support debatable. Komada et al.\cite{23} and Ni et al.\cite{28} found that specimens with bone loss showed more unrestorable root fractures than those with normal bone level. Naumann et al.\cite{23} obtained less uniform data, with different fracture types exhibited for different levels of bone loss. In the present study, there were no differences in fracture mode between different post lengths or bone levels: all fractures were unrestorable. This could be explained by the elevated loads exerted on the restored teeth. It was probable that the metal copings increased the fracture resistance of restored teeth.

The restoration system used in this study (i.e., tooth-GFP-metal coping) could be considered as both a limitation and strength of the present study. It was a limitation because the GFP no longer accounted for the fracture resistance of ETT alone, but that the metal coping should be taken into account too. It was a strength because since the metal coping influenced the fracture load values of the restoration system, it could be leveraged to reinforce ETT and improve their fracture resistance under occlusal loading\cite{29}. Therefore, higher fracture load values were obtained in this study compared to reports on teeth restored with GFPS but not crowned. Unlike previous studies\cite{22}, there were no differences in fracture pattern among the four groups of specimens. This might be due to high fracture load values and limited number of specimens.

CONCLUSION

Within the limitations of this study, it was concluded that bone level and post length did not affect the fracture resistance of ETT and the fracture mode. Further experimental studies and clinical trials are needed to validate the results of this in vitro study.

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REFERENCES


