Fracture resistance after simulated crown lengthening and forced tooth eruption of endodontically-treated teeth restored with a fiber post-and-core system

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ABSTRACT: Purpose: To evaluate the effect of ferrule preparation length on the fracture resistance after simulated surgical crown lengthening and after forced tooth eruption of endodontically-treated teeth restored with a carbon fiber-reinforced post-and-core system. Methods: 40 extracted endodontically-treated mandibular first premolars were decoronated 1.0 mm coronal to the buccal cemento-enamel junction. The teeth were divided randomly into five equal groups. The control group had no ferrule preparation (Group A). Simulated crown lengthening provided ferrule preparations of 1.0 mm (Group B) and 2.0 mm (Group C). Simulated forced tooth eruption provided ferrule preparations of 1.0 mm (Group D) and 2.0 mm (Group E). After restoration with a carbon fiber post-and-core system, each root was embedded in an acrylic resin block from 2.0 mm apical to the margins of a cast Ni-Cr alloy crown, and loaded at 150° from the long axis in a universal testing machine at a crosshead speed of 1.0 mm/minute until fracture. Data were analyzed using ANOVA with Tukey HSD tests, and Fisher’s exact test, with α= 0.05. Results: Mean failure loads (kN) for Groups A, B, C, D and E were: 1.13 (SD= 0.15), 1.27 (0.18), 1.02 (0.11), 1.63 (0.14) and 1.92 (0.19), respectively. Significant differences were shown for the effects of treatment method and ferrule length, with significant interaction between these two sources of variation (P< 0.0001). Increased apical ferrule preparation lengths resulted in significantly increased fracture resistance for simulated forced tooth eruption (P< 0.0001), but not for simulated crown lengthening (P≥ 0.24). (Am J Dent 2009;22:147-150).

CLINICAL SIGNIFICANCE: Simulated crown lengthening with 2.0 mm apical extended ferrule preparations resulted in significantly reduced fracture resistance for endodontically-treated roots restored with a carbon fiber post-and-core system. However, the combination of simulated forced tooth eruption and apical crown margin ferrule placement resulted in significantly increased fracture resistance.

Introduction

Placement of post-cores or dowel-cores is a conventional method for restoring endodontically-treated teeth when inadequate tooth structure remains. The main function of the post in the root canal is to provide retention for the core, not to improve the fracture resistance of the endodontically-treated tooth.1-3 However, many factors affect root fracture resistance, such as canal configuration and post adaptability,4 post width,5 post material,6 and ferrule design.7-10 When compared to metal alloy posts, carbon fiber-reinforced posts have mechanical properties that more closely match those of dentin,11,12 and are also significantly better in preventing catastrophic root fracture.13,14 Ferrules effectively improve the fracture resistance of endodontically-treated teeth when adequate coronal tooth structure remains. At least 1.5 mm ferrule preparation lengths for cast alloy post-cores,15 and 2.0 mm ferrule preparation lengths for prefabricated non-metallic post-and-cores9 have been recommended.

Broken down teeth with extensive tissue loss in the cervical third of the root are a challenge for clinicians to provide an adequate post-core retained artificial crown. Few studies have evaluated ferrule preparations for this situation.16 The apical extended ferrule preparations must maintain the ‘biological width’ of the periodontal tissues. Surgical crown lengthening aims to increase the length of coronal tooth structure by removing the supporting periodontal structures to expose subgingival root surfaces.17,18 A normal biological width can be re-established by this procedure.19 If the tooth has reduced bone support or the osseous surgical procedure would create either a poor crown-to-root ratio, or an esthetic problem, then crown lengthening is contraindicated.19,20

An alternative method used to increase the length of coronal tooth structure is by orthodontic forced tooth eruption,21,22 which employs slow passive or active extruding forces to achieve approximately 2.0 mm of extrusion per month.23 This method preserves the supporting alveolar bone and provides a better crown-to-root ratio when compared to surgical crown lengthening.16,19,22 Which of these two methods is best for increasing the fracture strength of endodontically-treated roots restored with fiber-reinforced post-and-core restorations, and the optimal length required for the ferrule preparations, remains unresolved.

The present in vitro study evaluated the effect of ferrule preparation length on the fracture resistance of endodontically-treated teeth restored with a prefabricated carbon fiber-reinforced post-and-core system and cast metal alloy crowns, using either simulated surgical crown lengthening or simulated orthodontic forced tooth eruption. The null hypothesis proposed was that the root fracture resistance was independent of the ferrule preparation length and of the simulated treatment method.
Table 1. Mean dimensions (mm) of randomly assigned mandibular first premolar roots in each group.

<table>
<thead>
<tr>
<th>Group (N=40)</th>
<th>Root length*</th>
<th>Mesial</th>
<th>Buccal</th>
<th>Distal</th>
<th>Lingual</th>
<th>M-D</th>
<th>B-L</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.11 (0.55)</td>
<td>1.94 (0.09)</td>
<td>2.24 (0.19)</td>
<td>1.84 (0.13)</td>
<td>2.27 (0.30)</td>
<td>5.05 (0.33)</td>
<td>7.42 (0.39)</td>
</tr>
<tr>
<td>B</td>
<td>14.48 (0.77)</td>
<td>1.96 (0.15)</td>
<td>2.37 (0.15)</td>
<td>1.97 (0.15)</td>
<td>2.28 (0.18)</td>
<td>5.22 (0.23)</td>
<td>7.71 (0.35)</td>
</tr>
<tr>
<td>C</td>
<td>14.24 (0.46)</td>
<td>1.94 (0.13)</td>
<td>2.23 (0.18)</td>
<td>1.89 (0.15)</td>
<td>2.37 (0.26)</td>
<td>5.04 (0.28)</td>
<td>5.71 (0.36)</td>
</tr>
<tr>
<td>D</td>
<td>14.26 (0.30)</td>
<td>1.95 (0.16)</td>
<td>2.32 (0.14)</td>
<td>1.93 (0.11)</td>
<td>2.31 (0.18)</td>
<td>5.19 (0.34)</td>
<td>7.49 (0.65)</td>
</tr>
<tr>
<td>E</td>
<td>14.39 (0.50)</td>
<td>2.07 (0.20)</td>
<td>2.29 (0.11)</td>
<td>1.94 (0.11)</td>
<td>2.35 (0.14)</td>
<td>5.21 (0.22)</td>
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1-way ANOVA F=0.563 P=0.69 F=1.002 P=0.42 F=1.150 P=0.35 F=1.289 P=0.29 F=0.790 P=0.54 F=0.768 P=0.55 F=0.595 P=0.67

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Materials and Methods

Specimen preparation - Forty sound mandibular first premolars extracted for orthodontic reasons were obtained with the consent of healthy Chinese adults aged 20-30 years. The study was approved by the Medical Ethics Organization of Jiangsu province, PR China. After cleaning and the removal of attached soft tissues, the teeth were examined stereoscopically at x10 magnification to verify the absence of cracks, before being stored in 0.9% saline solution at 4°C. The teeth were used within 4 weeks after extraction. The teeth were used within 4 weeks after extraction. The study was approved by the Medical Ethics Organization of Jiangsu province, PR China. After cleaning and the removal of attached soft tissues, the teeth were examined stereoscopically at x10 magnification to verify the absence of cracks, before being stored in 0.9% saline solution at 4°C. After 24 hours in the isotonic saline storage medium, a standardized nickel-chromium (Ni-Cr) alloy crown fabricated in the dental laboratory for each of the prepared teeth was cemented with glass-ionomer cement (Glasionomer®). The teeth were kept in the storage medium at all times except during the experimental testing.

Fracture resistance testing - Each root was coated with a 0.1-0.2 mm thin layer of a vinyl polysiloxane silicone (modulus of elasticity 0.3 MPa) (Aquasil®), to simulate the periodontal ligament before being embedded, from 2.0 mm apical to the crown preparation margins, in a block of self-cured acrylic resin® (modulus of elasticity ~2.5 GPa).

A unidirectional static load was then applied to the buccal cusp of the Ni-Cr alloy crown, at an angle of 150° from the long axis of the root, using a cylindrical Ni-Cr alloy rod (3.0 cm long x 0.8 cm diameter) in a universal load-testing machine (Model CSS-2202®) at a crosshead speed of 1.0 mm/minute (Fig. 2). The 150° angle simulated the application of an oblique occlusal force. The force (kN) for initial root fracture was recorded and the failure site pattern noted.

Statistical analysis - All analyses employed a commercial software package (SPSS v11.0®). One- and two-way ANOVAs with Tukey HSD tests, and Fisher’s exact test were used to detect any significant differences between the groups. The probability level for statistical significance was set at α = 0.05.
**Fracture resistance of teeth**

<table>
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<th>Table 2. Mean force (kN) required to fracture the tooth roots, and the fracture sites, in each group.</th>
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2-way ANOVA:
- Treatment method effect: F=81.81, P<0.0001**
- Ferrule effect: F=21.95, P<0.0001**
- Interaction effect: F=31.81, P<0.0001**

The mean force (kN) required to fracture the restored teeth, and the root fracture sites, in each group are shown in Table 2. For fracture resistance, 2-way ANOVA revealed statistically significant differences in the effects of both the treatment method and the ferrule length, with significant interaction also between these two sources of variation (P<0.0001).

For the simulated surgical crown lengthening method, Group B (1.0 mm ferrule) demonstrated significantly higher fracture resistance loads than Group C (2.0 mm ferrule), (P=0.008), but both of these groups showed no significant differences when compared to the control Group A (no ferrule), (P=0.24, 0.39). However, for the simulated forced tooth eruption method, there were significant differences among all three groups (P≤0.005), with increased ferrule preparation length being associated with higher fracture resistance loads. The findings are shown in Table 3 and illustrated in Fig. 3.

Almost all of the fractures were found at or above the cervical one-third of the roots (Table 2). No statistically significant differences among the three groups were found (P=1.00).

**Discussion**

Specimen preparation and fracture resistance testing - Mandibular first premolars were selected for this study because these teeth are vulnerable to vertical root fracture following endodontic treatment. The teeth were extracted from young adults who lived in the same locality, and had very similar root forms and dimensions (Table 1). Gross destruction of coronal tooth structure was simulated by using standardized flat root-face preparations. All the cores and ferrule preparations were machined by the same person (Q-FM) using the same milling device.

The roots of the restored teeth were coated with silicone rubber and embedded in acrylic resin. The moduli of elasticity of these materials approximated those of the viscoelastic periodontal ligament and the alveolar bone, respectively. An oblique force, applied at 150° from the long axis of the mandibular premolar tooth, was employed to simulate functional working-side buccal cusp loading.

Fracture resistance of restored premolars - The effective clinical crown length (Ce) to embedded root length (Rb) ratio (Ce/Rb) is defined as "the physical relationship between the portion of the tooth within the alveolar bone compared with the portion not within the alveolar bone, as determined radiographically." An oblique force, applied at 150° from the long axis of the mandibular premolar tooth, was employed to simulate functional working-side buccal cusp loading.

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Fig. 4. Effective clinical crown length (Ce) to embedded root length (Rb) ratios (Ce/Rb) for the restored teeth: Group codes are defined in Fig. 1.

A minimum 1:1 crown-to-root ratio has been suggested for a prospective abutment tooth under normal circumstances. The diameter and dentin bulk of the root also decreases towards the root apex because of root taper. Therefore, clinical attention should be paid to the potential reduction in root fracture resistance when preparing a long ferrule in the cervical portion of an extensively broken-down endodontically-treated single-rooted tooth. For Groups D and E, which simulated forced tooth eruption, the Ce/Rb ratios were both less than the minimum suggested. The combination of forced tooth eruption and a ferrule preparation increased significantly the fracture resistance of the endodontically-treated teeth (Table 2, Fig. 3).

In this in vitro study, the null hypothesis was not accepted for either the apical extended ferrule preparation length or the simulated treatment method employed.

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References


