THE EFFECT OF FERRULE ON THE FRACTURE RESISTANCE OF TEETH RESTORED WITH CAST DOWEL SYSTEM

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ABSTRACT
Cast post and cores have been advocated by some clinicians as preferable restorations for endodontically treated abutment teeth. Preference for this post and core system derives, in part, from the incorporation of an encircling collar of metal (ferrule), which is hypothesized to protect the tooth from wedging stresses. This study determined the effectiveness of a metal collar in reducing stress concentrations when cast post and cores were loaded. Twenty freshly extracted canines free of cracks, caries, fractures, and restorations were selected for the study. The anatomic crowns of all teeth were removed perpendicular to the long axis of the tooth, from the most incisal point of the approximal cementoenamel junction. The teeth were assigned randomly to 2 groups 10 teeth each. The specimens were then endodontically treated. Core were modelled with sticky wax. Post and cores were cast in Ni-Cr alloy. Cast post and core restoration were then cemented in place with zinc polycarboxilate cement. The specimens were then embedded to an acrylic resin block (42x42x26 mm). The compressive-shear stress was applied 152 degrees to the long axis of the teeth in a lingual dimple on the cores with a vertical loading apparatus on the Instron Testing Machine. Among the specimens groups, significantly higher fracture loads were observed in teeth restored with 2.0-mm ferrule compared with without ferrule (p<0.0003).

Introduction
Cast post and cores have been advocated by some clinicians as preferable restorations for endodontically treated abutment teeth (1). Preference for this post and core system derives, in part, from the incorporation of an encircling collar of metal (ferrule), which is hypothesized to protect the tooth from wedging stresses (2-5). The few studies that have tested this hypothesis have provided conflicting results. As dentin is removed during preparation of the dowel space, reduction in fracture resistance may outweigh any likely gains associated with the dowel. Nevertheless, horizontal loss of the clinical crown of an endodontically treated tooth occurs, commonly, with minimal ferrule in the remaining tooth structure (6, 7). Trope et al. (8) noted that a dowel and core in an endodontically treated tooth could transfer occlusal forces intraradicularly with resultant predisposition to vertical fracture of the root. Sorensen and Engelman (6) proposed that the preparation design of endodontically treated teeth was a critical consideration, but this topic has received limited attention.

A 2 mm band of metal unattached to a post and core can produce a ferrule effect that increases resistance to fracture from expansive forces (9). One study demonstrated a tenfold increase in strength when a collar was incorporated into cast posts and cores (10). Other studies reported no significant differences in failure loads between incisors restored with cast post and cores with or without 1 mm collars (11).

This study determined the effectiveness
of a metal collar in reducing stress concentrations when cast post and cores were loaded.

**Materials and Methods**

Twenty freshly extracted canines free of cracks, caries, fractures, and restorations were selected for the study. All external debris was removed with an ultrasonic scaler (mini Piezon, EMS Piezon Systems, Nyon, Switzerland), and the teeth were stored in saline solution until testing. The anatomic crowns of all teeth were removed perpendicular to the long axis of the tooth, from the most incisel point of the approximal cementoenamel junction (CEJ), with the use of a water cooled diamond store (Diatech, 801-016 MLA Istätten, Switzerland) and an air turbine (NSK, Nakamichi Inc., C4608085, Tochigi, Japan) at 300 000 rpm. The roots length were measured from the CEJ on the facial surfaces, and the widest faciolingual and mesiodistal dimensions of each specimen were determined with a digital caliper accurate to 1 µm (Digimatic Calipers Model 500-196; Mitutoyo Corp, Aurora, Ill).

The teeth were assigned randomly to 2 groups 10 teeth each. Group 1 consisted of 10 teeth with ferrule lengths of 2 mm and 1.2 mm shoulder finish lines, Group 2 consisted of 10 teeth with no ferrule preparation (Fig. 1). The root dimensions were assessed with Two-way analysis of variance (ANOVA), and no significant differences among the measurements for the various groups were found (p=.05). The specimens were then endodontically prepared with a step-back procedure with a size 55 file (Flex R File; Union Broach, York, Pa). After intermittent rinsing with 2.5 % sodium hypochlorite, the endodontic treatment was completed with lateral condensation of gutta-percha (Gutta Percha Points; United Dental Manufacturers, West Palm Beach, Fla) and eugenol-free sealer (AH 26; Dentsply De Tray, Konstanz, Germany).

Gutta-percha was removed from the root canals with a reamer (Peso Reamer; Dentsply-Maillefer, Ballaigues, Switzerland). Post holes were prepared to a depth of 14 mm with a No. 5 Para-post drill (Whaledent International, New York, N.Y.) The specimen teeth in Group 1 then prepared to ferrule lengths of 2 mm and 1.2 mm shoulder finish lines. Silicone impression material (Elite H-D+ Light Body, Zhermack®, Germany) were injected to the post holes of the teeth. All were removed after the silicone had polymerized, and autopolimerizing acrylic resin (Pattern Resin; GC Corp, Tokyo, Japan) was injected into the impression cavities to produce acrylic resin patterns. Core were modelled with sticky wax. Post and cores were cast in Ni-Cr alloy (Wiron 99; Bego, Germany). Cast post and core restoration were then cemented in place with zinc polycarboxilate cement (Poly-F Plus, Dentsply De Trey, England) mixed according to the manufacturer’s instructions. The specimens were then embedded to acrylic resin block (42x42x26 mm).

The compressive-shear stress was applied 152 degrees to the long axis of the teeth in a palatal dimple on the cores with a vertical loading apparatus (Fig. 2) on the Instron Testing Machine (Fig. 3). This angle corresponded to the average interincisal angle between the maxillary and mandibular canines (12). A compressive force was applied at a crosshead speed of 1 mm/min until fracture occurred (Figs. 4, 5). The fracture loads (kg) were determined and the obtained data were analyzed by Student’s t Test (SPSS/PC, Version 9.0;SPSS, Chicago;III). The mode of fracture also was
recorded, and the fractures were classified whether located below or above the incisal third of the roots. A Fisher exact test was performed to detect within-and between-group differences in fracture modes. No adjustment to the alpha level was made when performing the multiple A Fisher exact tests. A significance level of p=.05 was used for all comparisons.

Results and Discussion
Mean failure loads were calculated for all groups. Student’s t Test was performed to test the effect of ferrule (p<0.0003). The results of the analysis revealed a significant difference in the effect of ferrule (p<0.0003) (Table 1). The group with no ferrule effect received 55.65±1.14 kg loads. The group with 2 mm ferrule received significantly higher loads 89.90±4.04 kg loads (p<0.0003) (Fig. 6).

Differences regarding the mode of failure among the different groups were observed and analyzed. Fracture patterns were classified according to location, as incisal third of the root or below (Fig. 7) (Table 2). A Fisher exact test detected no significant differences in fracture patterns within and between groups (p=.05).

Dentists are presented with a multifaceted restorative challenge when confronted with an endodontically treated tooth
TABLE 1
Main failure loads (kg) of experimental groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Minimum load (kg)</th>
<th>Maximum load (kg)</th>
<th>X kg ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (with ferrule)</td>
<td>56.20</td>
<td>89.90</td>
<td>72.15±4.04</td>
</tr>
<tr>
<td>Group 2 (without ferrule)</td>
<td>49.20</td>
<td>60.70</td>
<td>55.65±1.14</td>
</tr>
</tbody>
</table>

Fig. 6. Main failure loads of experimental groups.

TABLE 2
Number of root fractures according to localization for each group

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (with ferrule)</th>
<th>Group 2 (without ferrule)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above incisal third¹</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Below incisal third²</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

¹Fractures located in incisal third of root.
²Fractures located below incisal third of root.

The maxillary canine teeth was selected because it is one of the more commonly used abutments (20, 21). However, the use of the canine presented a unique situation in that its length allowed for longer posts than those reported in other studies. The post was left 7 mm short of the root apex so the post length would not be unreasonably long. This distance corresponds to the optimal intact apical seal as recommended by Mattison (22).

The large bulk of remaining tooth structure could have minimized the influence of ferrule effect, because an increase in remaining tooth bulk has been cited as a factor that can reduce stress (23-28).
Morgano and Brackett (28) reported that when the ferrule is absent or extremely small, occlusal loads may cause the dowel to flex with eventual micromovement of the core, and the cement seal at the margin of the crown may fracture in a short time with resultant leakage and caries (28).

Under the conditions of this in vitro study, 2.0-mm ferrule preparation increased the fracture resistance of endodontically treated teeth regardless of the cast dowel system tested (p<0.0003). Fracture patterns were classified as failures above or below the incisal third of the roots. Differences between the groups in the present study were not significant; perhaps because of the limited sample size.

In the present study, Student’s t Test was used to test the effect of ferrule on the fracture resistance of teeth restored with cast dowel system. Significant within-group differences were observed for all groups (p<0.0003).

Because there was a limited number of specimens in this study, it is impossible to draw definite conclusions on the failure modes. It must also be noted that this study did not address the biologic effects of failure of the cement seal of the artificial crown.

Conclusions
1. There was a significant difference in the mean fracture loads of endodontically treated teeth prepared to 2.0-mm ferrule compared with without ferrule of the cast dowel system tested (p<0.0003).

2. Among the specimens groups, significantly higher fracture loads were observed in teeth restored with 2.0-mm ferrule compared with without ferrule (p<0.0003).

REFERENCES