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Original Research

An *In Vitro* Study on the Effects of Post-Core Design and Ferrule on the Fracture Resistance of Endodontically Treated Maxillary Central Incisors

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Abstract:

Background: Endodontically treated teeth have significantly different physical and mechanical properties compared to vital teeth and are more prone to fracture. The study aims to compare the fracture resistance of endodontically treated teeth with and without post reinforcement, custom cast post-core and prefabricated post with glass ionomer core and to evaluate the ferrule effect on endodontically treated teeth restored with custom cast post-core.

Materials and Methods: A total of 40 human maxillary central incisors with similar dimensions devoid of any root caries, restorations, previous endodontic treatment or cracks were selected from a collection of stored extracted teeth. An initial silicone index of each tooth was made. They were treated endodontically and divided into four groups of ten specimens each. Their apical seal was maintained with 4 mm of gutta-percha. Root canal preparation was done and then post core fabrication was done. The prepared specimens were subjected to load testing using a computer coordinated UTM. The fracture load results were then statistically analyzed. One-way ANOVA was followed by paired t-test.

Results: 1. Reinforcement of endodontically treated maxillary central incisors with post and core, improved their fracture resistance to be at par with that of endodontically treated maxillary central incisor, with natural crown. 2. The fracture resistance of endodontically treated maxillary central incisors is significantly increased when restored with custom cast post-core and 2 mm ferrule.

Conclusion: With 2 mm ferrule, teeth restored with custom cast post-core had a significantly higher fracture resistance than teeth restored with custom cast post-core or prefabricated post and glass ionomer core without ferrule.

Key Words: cast-posts, endodontically treated teeth, ferrule, fracture resistance, prefabricated posts

Introduction

Endodontically treated teeth have significantly different physical and mechanical properties compared to vital teeth. Endodontically treated teeth are more prone to fracture because of desiccation or premature loss of moisture supplied by a vital pulp. They are also damaged by caries, previous restorations, and the endodontic access; that limited coronal tooth structure remains to be used for retaining the final restoration.

Posts have been advocated to strengthen weakened endodontically treated teeth against intraoral forces within the radicular dentin for supporting the tissue along their roots and frequently a core is fabricated to retain the final restoration. An *in vitro* study by Kantor and Pines[1] reported that an intra-radicular post doubled the fracture resistance of a root. But recent studies have showed that placement of a post can create stresses that lead to root fracture during post placement or function and that the strength of endodontically treated teeth was directly related to the remaining internal tooth structure.[2]

Preparation of the root canal weakens the root structure even before post placement. Transmission of occlusal forces has also been shown to intra radicularly predispose the root to vertical fracture. Results of stress analysis also indicated that stresses in dentin were similar whether or not a post was present. Therefore, it is questionable whether a post resolves the special needs of the endodontically treated tooth.

Post and cores may be fabricated using direct and indirect techniques. Direct techniques routinely involve the use of a prefabricated post intra radicular preparation. Indirect techniques require an impression and cast during the preparatory stages to produce a cast metal post-core build-up. Studies have demonstrated that roots restored with individual cast posts exhibited significantly higher fracture resistance than prefabricated posts. It is generally accepted that when a crown\coping extends at least 2 mm apical to the junction of the core and the remaining tooth structure, encirclement of the tooth structure with this ferrule will protect the endodontically treated tooth against fracture by counteracting and better distributing the stresses generated by the post. Libman and Nicholls, in their study on ferrule length, found, 1.5 and 2 mm ferrule lengths to be effective in improving fracture resistance of endodontically treated teeth.[3] There were also studies showing no significant difference between post and core restorations that used a ferrule and those without a ferrule.[4] Hence, the present study aimed to evaluate the effect of post reinforcement, post type and ferrule effect on fracture resistance of endodontically treated teeth. That is;

1. To compare the fracture resistance of endodontically treated teeth with and without post reinforcement
2. To compare the fracture resistance of endodontically treated teeth with custom cast post-core and prefabricated post and glass ionomer core
3. To evaluate the ferrule effect on endodontically treated teeth restored with custom cast post-core.

Four groups were studied. Each specimen was subjected to load on the lingual surface at a 135° angle to the long axis with a universal testing machine (UTM) until fracture at a crosshead speed of 0.02 cm/min. The study concludes that all of the post-core structures tested does not improve the strength of the endodontically treated teeth. Those teeth prepared with a 2 mm dentin ferrule were effective in enhancing the fracture strength of custom-cast post-core restored endodontically treated maxillary central incisors.

Materials and Methods

Materials

The materials used for the study were human maxillary central incisors. From the extracted teeth stored in a solution of neutral buffered formalin for less than 3 months at room temperature, a total of 40 human maxillary central incisors were selected for study. All selected teeth had similar dimensions (confirmed using a digital caliper), no root caries, no restorations, no previous endodontic treatment, and no cracks. An initial silicone index of each tooth was made. The 40 extracted human maxillary central incisors were treated endodontically and divided into four groups of 10 specimens each. Their apical seal was maintained with 4 mm of gutta-percha (Table 1).

Methodology

Root canal preparation

Root canals of the specimen teeth were prepared by use of reamers and files finished to number 60 files and the prepared canals were filled with zinc oxide and laterally condensed with gutta-percha points. An initial silicon index of each tooth was made. The teeth of Groups B, C, and D were sectioned horizontally with a diamond bur used in a high-speed handpiece with water spray. Teeth in Group C were sectioned 1 mm coronal to the cemento-enamel junction at a level 1 mm below the clinical gingival margin. Teeth in Groups B and D were sectioned 3 mm coronal to the cemento-enamel-junction to provide 2 mm of remaining coronal dentin. Root canals were then sealed with zinc oxide cement, and all teeth were stored in 0.9% NaCl at room temperature. Fourteen days after root canal treatment, post channels were prepared in the Groups B, C, and D with peesoreamer to a finish of 1 mm diameter with a remaining 4 mm apical seal.

Post and core fabrication

For teeth in Groups B and C, the post-core patterns were fabricated in inlay wax with a plastic burnout post. The patterns were invested and cast in Co-Cr alloy. The post-core was then cemented to their corresponding teeth using glass ionomer cement. For teeth in Group D, prefabricated posts were cut to fit each root canal, leaving 2 mm of the post head extended above the preparation. These posts were cemented with the same glass ionomer cement and techniques as used in Groups B and C. The coronal core portion was built up with glass ionomer core building material.

The teeth then were embedded in an auto polymerizing acrylic resin block to a depth 2 mm apical to their cementoenamel junction to relate it to the clinical situation. Each tooth was embedded at an angle of 45° to the vertical plane of the acrylic block with the help of a sine bar, so that finally when the load is applied, the total angle of load application will be 135° to the long axis of the tooth (Figure 1).

Table 1: Classification of 40 extracted human maxillary central incisors were treated endodontically and divided into four groups of ten specimen each.

Group A (control group)	Group B	Group C	Group D
Endodontically treated teeth restored with metal crowns\copings	Endodontically treated teeth with 2 mm ferrule restored with custom cast post-core and metal crowns\copings	Endodontically treated teeth with no ferrule restored with custom cast post-core and metal crowns\copings	Endodontically treated teeth with 2 mm ferrule restored with prefabricated post and glass ionomer core and metal crowns\copings

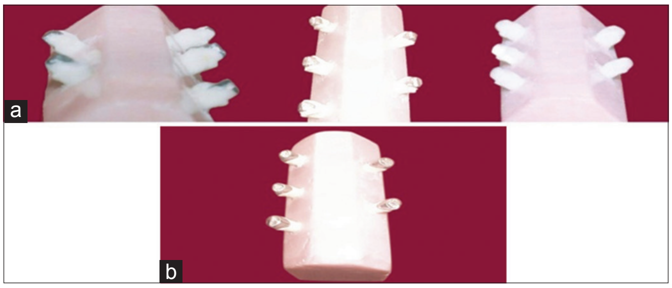


Figure 1: (a) Specimens after cementation of posts; (b) Specimens after cementation of crowns\copings.

Each tooth was prepared using diamond instruments under water spray to receive a metal crown\coping. A flat end tapered fissure diamond was used to prepare the labial, lingual, and proximal surfaces with a uniform 1 mm reduction after placing depth cuts measuring 1 mm. The reduction was confirmed by use of the initial silicon index. A chamfer finish line of 0.5 mm was prepared 1 mm coronal to the cementoenamel junction. This was done to mimic the natural embedding of tooth within the gingiva. The inciso-gingival dimension was 4 mm for all preparations measured from the labial aspect. Preparations were finished with superfine diamond burs. The dimensions of the prepared cores were confirmed with a digital caliper.

Impressions of the prepared specimens were made with vinyl polysiloxane impression material (monophase) metal crowns\copings were fabricated using Co-Cr alloy by a skilled technician unaware of the group design and had an inciso-gingival dimension of 6 mm from the labial aspect. The form of the final metal crown\coping was confirmed with the initial silicon index. Glass ionomer cement was used to cement these metal crowns\copings. The prepared specimens were then stored, to simulate the humidity *in vivo* until they were tested, in 100% humidity for 1 month at room temperature.

Testing of the specimens

The prepared specimens were subjected to load testing using a computer coordinated UTM (Schimadzu Inc.) (Figure 2). The test specimens were placed in the lower jaw of the load testing machine and a vertical rod mounted on the upper jaw of the UTM was aligned to apply load on the palatal aspects of the specimen teeth 2 mm apical to the incisal edge of the metal crown\coping.

The positioning of the specimen teeth at an angle of 45° in the acrylic block ensured that the net force applied on the teeth was at an angle of 135°. A crosshead speed of 0.2 cm/min was used for testing the fracture strength. The fracture load results were then statistically analyzed. One-way analysis of variance (ANOVA) was followed by paired *t*-test for significance between groups.

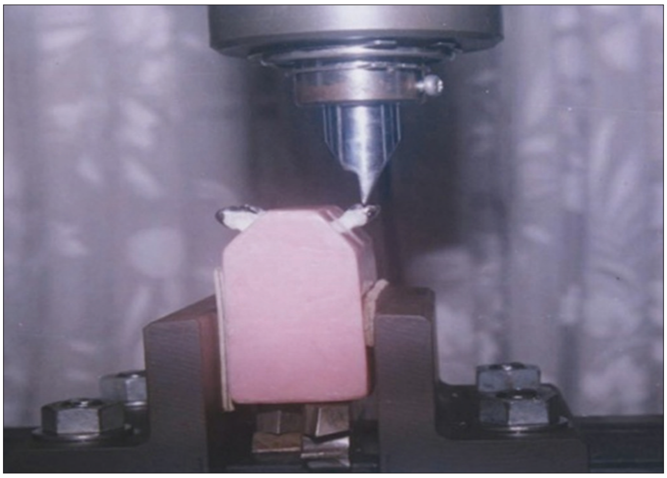


Figure 2: Specimens loaded in the universal testing machine for testing fracture strength.

Testing of the specimens

Table 2 shows the mean loads at which the teeth fractured. The highest mean fracture strength of 1124.6 N was noted for Group B (custom made cast post with 2 mm ferrule) , followed by Group C (custom made cast post with no ferrule) with a mean of 689.476 N and Group D (prefabricated post and glass ionomer core with 2 mm ferrule) with a mean of 681.397 N. The control group i.e., Group A (no post) showed the lowest mean fracture strength of 665.42 N.

Table 3 shows the result of one-way ANOVA for testing. The $P < 0.5$. This indicates that the mean values of all the groups have a significant difference statistically.

Table 2: Mean fracture strength of specimens (in Newtons).

Sample Number	Group A	Group B	Group C	Group D
Sample 1	715.22	813.292	719.81	727.97
Sample 2	707.47	914.123	783.06	502.47
Sample 3	774.5	859.832	792.69	483.41
Sample 4	807.84	993.981	812.46	479.13
Sample 5	574.13	958.493	589.97	683.47
Sample 6	718.34	1392.51	764.63	644.77
Sample 7	592.46	1013.21	582.47	798.49
Sample 8	802.12	1453.32	803.28	819.98
Sample 9	463.46	1553.27	439.18	864.66
Sample 10	498.66	1294.98	607.21	809.63
Mean	665.42	1124.7	689.48	681.4

Table 3: ANOVA - Single factor.

Groups	Count	Sum	Average	Variance
Group A	10	6654.198	665.4198	15575
Group B	10	11246.01	1124.601	73473.4
Group C	10	6894.758	689.4758	16091.5
Group D	10	6813.966	681.3966	22065.3

ANOVA: One-way analysis of variance

Source of variation	SS	Df	MS	F	*P* value	F crit
Between groups	1493779.4	3	497926.5	15.7	0.000001	2.87
Within groups	1144847.7	36	31801.32			
Total	2638627.1	39				

Table 4: Comparison of different groups.

Groups	Mean value	Difference	Critical difference
a. A versus other groups			
A	6654.198	4591.816	
B	11246.014	240.56	156.3124
C	6894.758	159.768	
D	6813.966		
b. B versus C and D			
B	11246.014		
C	6894.758	4351.252	156.3124
D	6813.966	4432.05	

Table 4a shows Group A (no post) has only moderate difference from Group C (custom made cast posts with no ferrule) and Group D (prefabricated post and glass ionomer core with 2 mm ferrule) , but has statistically significant difference with Group B (custom made cast post with 2 mm ferrule). A custom made cast post with 2 mm ferrule increases the fracture resistance of an endodontically treated tooth significantly.

Table 4b shows that Group B (custom made cast post with 2 mm ferrule) is significantly different from Group C (custom made cast post with no ferrule) and Group D (prefabricated post and glass ionomer core with 2 mm ferrule).

Table 4 shows the values of paired *t*-test for significance. Only Group B (custom made cast post with 2 mm ferrule) is significantly different from rest of the groups which further emphasizes the fact that only a custom-made cast post with 2 mm ferrule significantly increases the fracture resistance of an endodontically treated tooth.

Table 5 shows the fracture mode of each group. The 5 typical fractures, vertical root fracture, mid-root fracture, cervical root fracture and the apical root fracture and crown fracture.

Results and Discussion

The present study was conducted to evaluate the effect of post reinforcement, post type and ferrule on the fracture resistance of endodontically treated maxillary central incisors. The highest mean fracture strength of 1124.6 N was noted for Group B (custom made cast post with 2 mm ferrule), followed by Group C (custom made cast post with no ferrule) with a mean of 689.476 N and group d (prefabricated post and glass ionomer core with 2 mm ferrule) with a mean of 681.397N. The control group, i.e., Group A (no post) showed the lowest mean fracture strength of 665.42 N (Tables 2-5). Results of this study indicate that the fracture resistance of endodontically treated maxillary central incisors increased significantly when restored with custom cast post- core and 2 mm ferrule (Group B). This result is in agreement with the results of studies conducted by Lu *et al*. (2002)and Zhi-Yue and Yu-Xing (2003).[5,6] The increased fracture resistance may be attributed to two reasons: A custom cast post-core can be prepared to fit the shape of the post-space. The 2 mm ferrule reduces the potential for stress concentration at the junction of the post and core. It was found by this study that the fracture resistance of endodontically treated maxillary central incisors restored without any post (Group A) performed similar to post reinforced teeth (Group C and D) except for teeth with a 2 mm ferrule, then restored with custom cast post-core (Group B). So by reinforcing an endodontically treated tooth having less crown structure, with a post and core; its fracture resistance can be made at par with that of an endodontically treated tooth with natural crown.

Teeth restored with custom cast post-core without a ferrule (Group C) fractured at poorer loads. This was because, ferrule was absent, occlusal forces must be resisted exclusively by a post that may eventually fracture; otherwise root fracture may occur. This result is in agreement with the results of Assif and Gorfil, Libman and Nicholls, Mezzomo *et al.* and Milot and Stein.[3,7-10] When a 2 mm ferrule is preserved, the fracture resistance of endodontically treated teeth restored with prefabricated post and glass ionomer core (Group D) was significantly lower than for those restored with custom cast post-core (Group B). This finding is similar to studies by Fraga *et al*., and Sirimai *et al*.[11,12] Endodontically treated teeth restored with prefabricated post and glass ionomer Core (Group D)fractured at significantly lower loads in spite of having 2 mm ferrule.

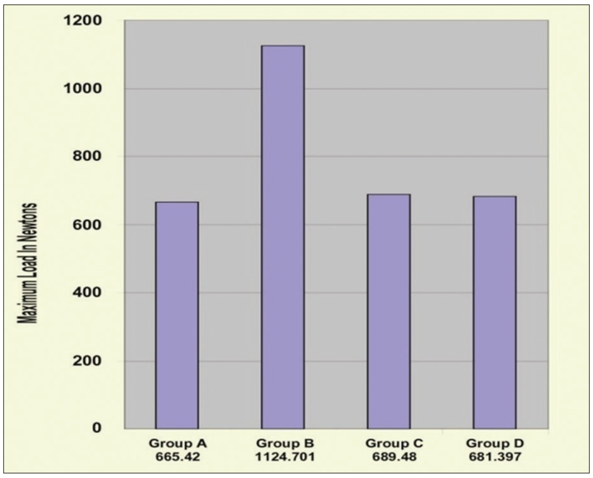
This may be due to the lack of an accurate fit of the prefabricated post to the post space that hindered the transmission of occlusal stresses and led to root fracture at lower loads. When analyzing the fracture mode of each group, it can be noted that cervical and mid-root fracture occurred only in Group A (Table 6). In all other groups that were restored using posts, fracture occurred either at the coronal part of the endodontically treated

Table 5: Paired *t*-test for significance between groups.

Groups	*P* value
A versus B	0.001895
A versus C	0.0969
A versus D	0.8426
B versus C	0.0027
B versus D	0.000103
C versus D	0.921837

Table 6: Fracture mode of each group.

Fracture mode	Group A	Group B	Group C	Group D
Crown fracture	0	5	5	4
Root vertical fracture	0	0	3	0
Cervical root fracture	7	0	0	0
Mid root fracture	1	0	0	0
Apical root fracture	2	5	2	6



Graph 1: Average fracture strength of specimens.

teeth or at their apical third. This could be due to the lack of post reinforcement in the cervical and mid-root region in Group A. Placement of posts in all other groups, reinforced the tooth in the cervical and mid-root region and hence prevented root fracture in these regions. Vertical root fracture occurred only in Group C, that was restored with custom cast post-core without a ferrule. When a ferrule is absent, occlusal forces must be resisted exclusively by a post that may eventually fracture; otherwise root fracture may occur (Graph 1). Therefore, a conservative preparation design must be considered, and only the unsupported tooth structure should be removed to enhance the transmission of tensile and shear stresses to the coronal tooth structure and thereby reduce the possibility of root fracture.

Limitations in the design of this study may be that a single static load was used to test the fracture resistance of endodontically treated teeth. For more meaningful results, further studies should incorporate thermocycling and fatigue loading. Furthermore, the simulation of the periodontal ligament and the alveolar bone was not attempted in this study that slightly deviates the study from the actual *in vivo* situation.

Conclusion

From the study the following conclusions were drawn:

Reinforcement of endodontically treated maxillary central incisors with post and core improved their fracture resistance to be at par with that of maxillary central incisor with natural crown which is endodontically treated. The fracture resistance of endodontically treated maxillary central incisors is significantly increased when restored with custom cast post-core and 2 mm ferrule. The fracture resistance of endodontically treated maxillary central incisors is much higher when restored with custom cast post-core and 2 mm ferrule compared to custom cast post-core without a ferrule. When endodontically treated maxillary central incisors with 2 mm ferrule were tested, teeth restored with custom cast post-core had a higher fracture resistance than teeth restored with prefabricated post and glass ionomer core.

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