Fracture resistance of endodontically treated teeth restored by different FRC posts: An *in vitro* study

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ABSTRACT

Background: Posts and cores are often required for restoration of pulpless teeth and to provide retention and resistance for a complete crown, but conventional posts may increase the root fracture.

Objective: This study was performed to compare the root fracture resistance of extracted teeth treated with different fibers reinforced with composite posts and treated teeth with conventional post and core systems.

Materials and Methods: Root canal therapy was performed for 50 mandibular first premolars. The coronal portion of each tooth was amputated, and five post and core systems (cast, polyethylene woven, glass, carbon, and quartz fiber posts) were compared. Acrylic resin blocks were used for mounting, using a layer of elastomeric impression material covering the roots. The load was applied axially and measured with a universal testing machine.

Results and Conclusion: Significantly, cast posts and cores had a higher failure threshold including teeth fracture; whereas, fiber posts failure was due to core fracture, with or without fractures in coronal portion of posts. Difference in FRC posts did not provide any significant difference in the load failure and the mode of fracture.

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Endodontically treated teeth, often resulted into the loss of a significant part of the tooth structure, weakness due to the endodontic treatment.[1] Posts are often required to restore these teeth and to provide retention and resistance for a core material and to provide a coronoradicular stabilization.[2-4]

Posts were used in restoration of endodontically treated teeth for more than one hundred years,[2-5] and are used when more than half of the coronal tooth structure is lost.[6] Their physical properties should be similar to the tooth structure, and in order to have identical bonding ability and biocompatibility.[7] The bonding ability provides more retention, which improves the stress distribution and reinforces the tooth.[2] The post should also be removed easily from the canal if required,[5] and in cases of failure, to protect the teeth from a catastrophic root fracture.[8,9] Cast post and core does not have any bonding ability, and is prone to corrosion. Its elasticity is different from the tooth structure producing stress and the potential for a root fracture.[3,10] FRC posts were introduced in dentistry around 15 years ago,[11] and are composed of carbon, glass, or quartz fibers embedded in epoxy resin.[12] They have bonding ability to dentin and the core material.[3,13] They can reinforce the tooth,[13,14] and as their elasticity is compatible with dentin,[11,15] they can absorb stresses and protect the root from fracture.[13] Saupe *et al.*, reported that FRC posts treated teeth had more resistance to masticatory forces.[16] FRC posts have a lower fracture strength compared to cast posts and cores, but in cases of failure, the post or core will fracture, instead of the roots in cast post and core restored teeth.[16] There are several reports which show that FRC posts minimize the root fracture;[17-31] and if required, removal of FRC posts from the canal is easier than other post systems.[23] Two groups of FRC posts are available, including chairside fabricated FRC post composed of polyethylene woven fiber tapes[13] and prefabricated FRC post comprising of three types. Carbon fiber post composed of pyramidal carbon fibers embedded in an epoxy resin matrix[24,25] which is biocompatible, corrosion, and fatigue resistant, and has physical properties similar to dentin,[3,26] whereas its dark color is considered as its main disadvantage.[26] The fiber post comprises of unidirectional glass fiber in an epoxy resin matrix, and the quartz fiber post, which was recently introduced, provides the most esthetic results, and transmits the light.[27] Both groups have similar properties to carbon fiber post.[12,28] Several studies revealed that failure load of FRC post groups are lower than the cast posts and cores.[2,4,10-13,29-31]

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This study was undertaken to compare different FRS posts in relation to failure loads and their modes.

MATERIALS AND METHODS

A total of 50 recently extracted mandibular first premolars with similar root sizes, were selected and stored in 2% formalin solution. Their roots were examined for any cracks or caries. With the use of a diamond bur in a high speed hand piece, the teeth were decoronated, while all resulting roots had the length of 14 mm. Endodontic treatment was performed and attempts were made to calibrate all roots uniformly. The roots were obturated with laterally condensed gutta-percha and a resin sealer (AH26, Dentsply DeTrey Gmblt 78467 Kon Stanz, Germany). Root canal filled roots were stored in normal saline till the end of this study. The root surfaces were dipped into a melted wax to a depth of 2 mm, below the cervical line to produce a 0.2 to 0.3 mm layer using a carver to provide this thickness to be approximately equal to the average thickness of the periodontal ligament. The control group teeth were then mounted in acrylic resin blocks (Pekatray, Bayer, Leverkuser, Germany) and positioned using custom-made positioner such that 2 mm of the cervical part of root was out of acrylic resin (to duplicate the biologic width). Wax spacer was removed from the root surface and from the alveolus of the acrylic resin block. Light bodies of condensate silicone impression material (Speedex, Colten, AG, Feldwiesenstrasse 20, CH-9450 Altstattea, Switzerland) were mixed and applied into the acrylic resin alveolus. The teeth were then reinserted into the test blocks with the same positioner, and the impression material was allowed to set. The thin layer of silicon material simulated the periodontal ligament. Roots were randomly divided into five groups of ten specimens.

In group 1, the canal of each tooth was restored with a cast post and core using a direct technique, in which a 9 mm depth was prepared with a size 1 RTD drill. Acrylic patterns were made with duralay acrylic resin (Duralay, Rellance Dental MFG Co., Worth III, US) and base metal alloy (4all, Ivoclar Vivadent, Schaan, Licchtenstein), was used to cast the posts and cores. The cast posts and cores were refined, finished, and air abraded with 50 μm aluminium oxide. After etching and irrigation, Varolink II cement (Ivoclar vivadent AG, FL-9494 Schaan, Lichtenstein), dual cure resin cement was mixed according to the manufacturer's instructions and then was introduced into each root canal by using a lentulo spiral drill. Cement was placed on the post, and the post was gently reseated and polymerized from buccal, lingual, mesial and distal surfaces with a light gun for 20 seconds each.

For group 2, root canal was prepared just similar to the group 1 and the teeth were treated with a polyethylene woven fiber. A preimpregnated fiber tape (Interlig, Angelus Rua Goias, Londrina, PR, Brazil) 2 mm wide, was used and the inner wall of canals were etched. Voriolink II cement was mixed and introduced into the canals. A double-folded fiber tape was introduced into the canals by the use of a file as a carrier to a 9 mm depth and were polymerized identical to group 1. In group 3, canals were restored with a size one prefabricated glass fiber post (Dentorama, Svenska Solna/stock holm, sweden), which has the same size similar to the size one of RTD drill. Posts were silaned, bonded (Excite, Ivoclar vivadent, AG, FL- 9494 Schaan/Lichtentein), light polymerized, and were cemented in the same manner as in group 1.

In group 4, carbon fiber post (RTD, Paris, France) size one was used for restoration of the roots. Special RTD drill was used to prepare the canal to a 9 mm depth. Preparation of the root canal, post surface, and cementation process were just like group 3. In group 5, the canal of each tooth was restored with a quartz fiber post (RTD, Paris, France) size one, while all procedures were the same as the previous groups.

Core formation

A brilliant (Colten AG, Feldwiesenstrasse 20, CH-9450 Altstattea, Switzerland) composite was used to build up the cores of groups 2 to 5. The cores were prepared and finished. For preparation of occlusal surface, a special bur [Figure 1] was used to uniform the occlusal angles of all the specimens which were perpendicular to the tooth long axis during the occlusal surface preparation. All specimens were loaded in a universal testing machine (1026, Instrum Corp, Canton, Mass) at a crosshead speed of 0.5 mm/min until fracture. Load was applied to a small sphere which was placed on the occlusal surface of the prepared teeth at the long axis of the root. Fracture loads and modes were recorded. Tooth fractures were classified as reparable and catastrophic failures [Figures 2-8]. Statistical tests (One Way ANOVA, Fisher's Exact and Tomhan's tests) were used for statistical analysis and a P value less than 0.05 was considered significant.

RESULTS

The mean and standard deviation of failure loads are listed in Table 1. Failure modes are demonstrated in Table 2. In group 1, all the ten teeth revealed catastrophic root fracture, while the mean failure load for this group was 2675 ± 228.4 N. Also, 60% of the teeth in group 2 experienced core fracture with or without coronal portion of the post and four samples

Table 1: Mean and standard deviation of failure loads (N)

Group	Mean	Standard deviation
1	2675.1	228.40
2	891.2	105.13
3	1015.2	71.06
4	1029.6	89.9
5	820.4	419

1 = cast post and core, 2 = polyethylene woven fiber post, 3 = glass fiber post, 4 = carbon fiber post, 5 = quartz fiber post

had fracture irreparably. The mean failure load of this group was 891.27 ± 105.13 N. In group 3, six teeth had repairable core fracture and four exhibited catastrophic root fracture. The mean failure load was 1101.52 ± 71.06 N. In group 4, five teeth experienced repairable and five irreparable root fractures, with a mean failure load of 1029.62 ± 89.99 N. Out of the ten teeth in group 5, six showed a repairable core fracture and four irreparable ones. The mean failure load was 820.48 ± 419.3 N. Group 1 had significantly a higher incidence of catastrophic root fracture than group 2 ($P < 0.005$), group 3 ($P < 0.004$), and group 5 ($P < 0.003$), but the difference with group 4 was not significant. Also, group 2 to group 5 had no significant difference in relation to the failure modes. Group 1 had significantly higher failure load than the other groups and none of FRC postrestored groups demonstrated a significant difference.

DISCUSSION

In the present study, teeth were carefully selected for

Table 2: Distribution of failure modes in 5 groups

Failure mode group	Repairable (%)				Irreparable (%)		
	Core dettachment [Figure 2]	Core and post fracture [Figure 3]	Cervical root fracture [Figure 4]	Middle root fracture [Figure 5]	Apical root fracture [Figure 6]	Vertical root crack [Figure 7]	Horizontal root fracture [Figure 8]
1				40	10	40	10
2	30	30		30		10	
3	30		30	10		20	10
4	20	30		10	10	30	
5	40	10	20	10		20	
Total	24	14	10	20	4	24	4

1 = cast post and core, 2 = polyethylene woven fiber post, 3 = glass fiber post, 4 = carbon fiber post, 5 = quartz fiber post

Figure 1: Special bar for occlusal surface preparation

Figure 2: Repairable failures (core fracture)

Figure 3: Repairable failures (core and post fractures)

Figure 4: Repairable failures (cervical root fracture)

Figure 5: Irreparable failures (middle root fracture)

Figure 6: Irreparable failures (apical root fracture)

Figure 7: Irreparable failures (vertical crack)

Figure 8: Irreparable failures (horizontal root fracture)

standardized size and absence of any root caries and cracks. Attempts were made to simulate the periodontal ligament and tooth supporting structures, not by embedding the roots directly into the acrylic resin blocks, but by avoidance of an external reinforcement of the root structure by a rigid acrylic resin. Similar size roots in diameter were selected with a length of 14 mm. Attempts were made to simulate the force of the mouth on the roots on mandibular first premolars, while the teeth were oriented vertically in the alveolar bone. Functional and parafunctional forces were applied vertically and at the buccal cusp tip. Buccal cusp tip was oriented at the vertical long axis of the teeth and at the midway buccolingualy and mesiodistaly. So, occlusal surfaces of cores were prepared uniformly and similar to the occlusal surface of maxillary premolars to apply the forces at the long axis and at the middle of the teeth. In similar studies comparing the different post systems, Cormier *et al.*[17] and Elisabeth *et al.*,[11] used mandibular premolars and loaded them at 90 degrees at the long axis of the teeth. In this study cast post and core group exhibited the highest failure load, but failure modes in this group was a catastrophic root fracture. Similar results were reported from previous studies.[2,4,10,11,13,29,31]

In woven fiber restored group, failure load was significantly lower than the control group, but failure modes were significantly more repairable. In a study of similar restorations by Simirai *et al.*, similar results were observed on polyethylene woven fiber posts.[4] In glass fiber restored group, failure load was higher than the woven fiber restored group and lower than group 1. In this group, failure load and mode was significantly different from the control group, but the difference compared to the woven fiber restored group was not statistically significant. In a study on fracture resistance of teeth restored with glass fiber post, all the teeth revealed a core fracture.[20] In a similar study by Toksovel, these teeth showed the most catastrophic forms of fracture.[31] In this study, 60% of teeth presented a core fracture and 40% demonstrated a root fracture. These results seem to be more logical as bonding ability of FRC posts enables them to reinforce the teeth, although this reinforcement is not enough to support the root from a fracture. Carbon fiber restored teeth exhibited significantly a lower failure load than the control group, but the failure load was not statistically different from group 2 and 3. In a study on fracture resistance of teeth restored with carbon fiber post, the tooth fractures were uncommon and the most frequent site of failure was the post and core interface. On the other hand, in teeth restored with a cast post and core, fracture of the teeth was observed in 91% of the specimens.[24] In this study, 50% of the teeth restored with carbon fiber post, resulted into detachment of core from the post and 50% exhibited irreparable root fracture. Failure mode in this group had no statistical difference from all other groups. Akkayan *et al.,* reported that teeth restoration by quartz fiber post would exhibit significantly a higher failure load than those restored by glass fiber post.[32] In the present study, failure load in quartz fiber restored group was the lowest and this difference was statistically significant from the control group. Akkayan *et al.,* revealed that quartz fiber post protects the root from fracture more than the glass fiber post.[33] Results of the present study confirmed these reports; however, the difference was not statistically significant. Perhaps higher incidence of detachment of core from post is the result of a high cross-linkage of resin matrix in these posts making a difficult chemical bonding with the composite core. In the present study, brilliant composite was used for core formation. Use of this core material resulted into present findings. Also, using stronger and newer core materials may result into a different finding. So, it is not true to extend our results for other core materials.

In fracture load testing of dental materials, cyclic (fatigue) loading would be the best method of load application while the single load to fracture is not considered as an ideal method. So, cyclic loading is recommended in further studies.

In most studies compared to our results, the load application and its angulation was different. In some studies, full crown was used on posts and cores, but their results in relation to different post and core systems were still comparable to the present study.

We noticed that cast post and core had the highest failure load of all FRC posts, failure modes in FRC posts were more repairable than the cast post and core, failure mode of carbon fiber posts was not significantly different from the cast post and core, and different systems of FRC posts had no significant difference in failure loads and modes.

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