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Fracture resistance of structurally compromised and normal endodontically treated teeth restored with different post systems: An *in vitro* study

Vajihesadat Mortazavi,[1] Mohammadhossein Fathi,[2] Najmeh Katiraei,[1] Shirin Shahnaseri,[3] Hamid Badrian,[4] and Navid Khalighinejad[4]

[1]Torabinejad Dental Research Center, Department of Operative Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
[2]Department of Materials Engineering, Biomaterials Research Group, Isfahan University of Technology, 8415683111, Isfahan, Iran
[3]Torabinejad Dental Research Center, Department of Oral and Maxillofacial Surgery, Isfahan University of Medical Sciences, Isfahan, Iran
[4]Dental Student, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

Address for correspondence: Prof. Vajihesadat Mortazavi, Dental Research Center and Department of Operative Dentistry, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, 8174673461, Iran. E-mail: v_mortazavi@dnt.mui.ac.ir

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Abstract

Background:

With the aim of developing methods that could increase the fracture resistance of structurally compromised endodontically treated teeth, this study was conducted to compare the effect of three esthetic post systems on the fracture resistance and failure modes of structurally compromised and normal roots.

Materials and Methods:

Forty five extracted and endodontically treated maxillary central teeth were assigned to 5 experimental groups (n=9). In two groups, the post spaces were prepared with the corresponding drills of the post systems to be restored with double taper light posts (DT.Light-Post) (group DT.N) and zirconia posts (Cosmopost) (group Zr.N). In other 3 groups thin wall canals were simulated to be restored with Double taper Light posts (DT.W), double taper Light posts and Ribbond fibers (DT+R.W) and Zirconia posts (Zr.W). After access cavity restoration and thermocycling, compressive load was applied and the fracture strength values and failure modes were evaluated. Data were analyzed using two-way ANOVA, Tukey and Fisher exact tests (P<0.05).

Results:

The mean failure loads (N) were 678.56, 638.22, 732.44, 603.44 and 573.67 for groups DT.N, Zr.N, DT.W, DT+R.W and Zr.w respectively. Group DT+R.W exhibited significantly higher resistance to fracture compared to groups Zr.N, DT.W and Zr.w (P<0.05). A significant difference was detected between groups DT.N and Zr.W (*P*=0.027). Zirconia posts showed significantly higher root fracture compared to fiber posts (*P*=0.004).

Conclusion:

The structurally compromised teeth restored with double taper light posts and Ribbond fibers showed the most fracture resistance and their strengths were comparable to those of normal roots restored with double taper light posts. More desirable fracture patterns were observed in teeth restored with fiber posts.

Keywords: Endodontically-treated teeth, fracture resistance, post, Rebbond

INTRODUCTION

Restoration of root canal treated teeth with a durable permanent restoration play an important role in the success rate of endodontically treated teeth.[1] An optimal permanent restoration should provide esthetic; function and protection for endodontically weakened teeth.[2]

As a rule, endodontically treated teeth are weaker than intact teeth due to loss of tooth structure, reduction in tooth flexural strength,[3] changing the collagen cross-links and moisture content reduction and tooth dehydration.[4] Canal enlargement and cavity preparation can reduce the stiffness of the teeth[5] and brittleness could be a final result of a root canal treatment.[6]

When most of the coronal structure of an endodonticaly treated teeth has been lost due to caries or root canal treatments, the use of post and core systems seems mandatory.[7] The decision regarding the treatment plan and post insertion should be based on three aspects:

Position of tooth in the arch,[8] Amount of remaining tooth structure[9] and Esthetic requirements.[10,11]

The main goal of the post insertion is to provide an optimum retention for the core which eventually supports the crown.[12–14]

A post is a rigid structure, that can be inserted in the root canal after appropriate root canal treatment.[3,15] Recent studies suggest that the rigidity of the post in the best situation should be similar to the root. In addition, they should show an elastic modulus similar to dentin, which can efficiently transmit the stress from the post to the root structure.[3]

There are a wide range of endodontic posts from metallic to nonmetallic, rigid to flexible and esthetic to non-esthetic.[7] Until 1980, the use of cast metal post and cores was a cutting edge in the field of endodontic posts.[15] But these traditionally used prefabricated and cast metal posts, were so rigid that they impose a high rate of stress to the root and dramatically increase the fracture rate.[16,17] Considering this fact, researchers tried to find post with an elastic modulus closer to dentin that can distribute the stress in the root canals.[18] Moreover, the increasing demand for more esthetically appealing and biocompatible restorations has led to the development of tooth-colored, translucent, metal-free post-core systems.[19]

Today, numerous types of non-metallic posts are available like carbon fiber post, zirconium coated carbon fiber post, all zirconium, cerapost, fiber reinforced light post and glass fiber post and each of them has its own advantages and disadvantages.[7,20] Full ceramic posts are aesthetically acceptable and bio-compatible.[11] Zirconia ceramics have higher stiffness compared to other ceramics. Zirconia posts are very stiff and show high modulus of elasticity that cause lesser bending than other ceramic posts.[8,21] The main drawback of these posts is their stiffness that can increase the root fracture rate.[22–24] An appropriate post should have the elastic modulus similar to dentin and carbon fiber posts fulfill this goal.[25,26] Double taper light posts are quartz fiber posts. These posts are translucent and provide the maximum aesthetic. The manufacturer has claimed that these posts are the most compatible with root canal and prevent the root fracture.[14,23] Fiber composite laminate (FCL) posts also have been suggested to prevent additional removal of tooth structure following canal preparation for post insertion. These posts also minimize the rate of root fracture and provide the maximum aesthetic for anterior teeth.[27]

The important role of anterior teeth in esthetic and function makes these teeth a significant component in dentition. Traumatic accidents are so common in maxillary anterior teeth especially in 8 to 12-year-old children. These traumas often lead tooth to a degenerative cycle which eventually causes necrosis. Root canal therapy (RCT) is often successfully done after apexification but compromised dentinal walls especially in cervical area, makes these teeth susceptible to fracture.[28] The fracture resistance of endontically treated teeth is highly dependent on the remaining dentine thickness around post and core systems.[29] Thin-walled root canals always present a challenge to dentists to select a restorative treatment that does not further weaken the tooth structure.

The present study was conducted to compare the fracture resistance and fracture pattern of endodontically treated teeth with structurally compromised or normal root walls, restored with three esthetic post-core systems with different modulus of elasticity values: Double Taper Light Posts (DT Light Post), double taper light posts with leno wave ultra-high modulus (LWUHM) polyethylene fiber (Ribbond) and Zirconia posts.

MATERIALS AND METHODS

Tooth selection and preparation

Forty five maxillary central teeth with the same mesiodistal and buccolingual dimensions and the same root length were selected from a pool of recently extracted maxillary central teeth without caries, previous restorations, internal or external resorption and history of trauma. The teeth were examined by use of fiber optic unit (3M, S. Paul, Minn) to ensure the absence of cracks, microcracks or caries lesions. Tooth lengths were measured from cemento-enamel junction on the facial surfaces and the mean length was reported 23±1 mm. Teeth with less than 10 mm root length were excluded from the study.[30] The mesiodistal widths were also measured in the cemento-enamel junction area with Vernier-caliper with 0.1 mm accuracy and the mean diameter was reported as 6±0.1 mm. The teeth were stored in normal saline in the room temperature.

For each tooth the access cavity for endodontic therapy was prepared in a conventional manner and the cervical margin was located 2 mm above the cementoenamel junction. The root canal treatment was carried out by size 2 and 3 Gates Glidden (Maileffer, Ballaigues, Switzerland) to obtain straight line access in the middle and the coronel third of root. The canals then were stepback prepared to a size 40 file as Master Apical File. After being intermittently rinsed with normal saline and dried with paper points (Union Broach), the root was obturated with laterally condensed gutta-percha (Aryadent, Tehran, Iran) and AH 26 eugenol-free sealer (De Trey, Konstanz, Germany).

The teeth then were randomly divided in to 5 groups each containing 9 samples. In three groups the weakening procedure was done based on the following protocol:

The length of the weakened region from the cemento-enamel junction (CEJ) was 6 mm and the thickness of remained walls at the CEJ and 2.5 mm above and below this area was 1.5 mm. This situation resemble the anterior teeth condition in the mixed dentition in the third stage of Cvek classification.[21] In two others groups (not-weakened) to assimilate the crowns' conditions, the weakening procedure was just done above the CEJ. As the mean diameter of mesiodistal width in the cementoenamel junction was 6 mm, in order to provide 3 mm space for post placement, 1.5 mm dentin thickness was left in the mesial, distal, buccal and lingual walls of roots. To preserve adequate length of gutta percha for appropriate apical seal, post spaces with 8 mm length were considered.

Procedure for group DT.N specimens (not-weakened teeth restored with double taper light post)

Post space preparation with 8mm length was carried out with special preparation drills up to number 3. Double taper light post 13 (DT.Light-Post, Recherches Technique Dentaires, RTD, St. Egreve, France) with 11 mm length was used. The root canal was prepared for 30 s with self-etch primer (ED-Primer, Kuraray Co., Osaka, Japan) and the post was luted with dual cure resin cement (Panavia F, Kuraray, Japan). The resin cement was mixed for 10 s and applied in the canal walls by endodontic file. A thin layer of cement was placed on the post surface, and the post was gently placed in the canal. Then the post and access cavity were cleaned and etched for 10 s with 40% acid phosphoric (K –etchant, Kuraray Medical Inc. Tokyo, Japan) and primed for 20 s with primer (Clearfill SE Bond, Kuraray Medical Inc., Tokyo, Japan). Bonding resin (Clearfill SE Bond, Kuraray, Medical Inc., Tokyo, Japan) was applied and cured for 20 s and then the tooth was filled with hybrid composite (Clearfill AP-X, Kuraray Co. Osaka, Japan) with incremental technique. Three increments were used and each Increment was cured for 40 s.

Procedure for group DT.W specimens (weakened teeth restored with D.T light post)

As the first 6 mm of the root canal was weakened, the preparation with drill as accordance to size-3 D.T. Light-Post was done in the last 2 mm of post space. Other procedures were similar to the DT.N group.

Procedure for group DT+R.W specimens (weakened teeth treated with DT light post and ribbond)

Apart from the first 6 mm of the post space, the last 2 mm was prepared with Peeso Reamer 16 (Dentsply Maillefer Ballaigues, Switzerland) for the placement of post and a LWUHM polyethylene fiber (Ribbond, Ribbond, Inc; Seattle, USA). Double taper post was cut in 11 mm length and a 2 mm width and Ribbond fiber was cut in 22 mm length. The dual cure resin cement was inserted in the prepared canal. The Ribbond fiber then immersed in ED-primer for 30 s and the excess solvent was evaporated by air syringe. The D.T. light-post was coated by cement resin and the middle of the Ribbond fiber then placed at the end point of post and the post-ribbond fiber complex was carried in to the prepared root canal. The inserted post and Ribbond fiber complex was then cured for 40 s. The restoration of the teeth was done like group DT.N.

Procedure for group Zr.N specimens (not-weakened teeth restored with zirconia post)

In this group zirconia post (Cosmopost, Ivoclar, Schaan, Liechtenstein) with 1.4 mm diameter was used. The post was cut to a length of 11 mm and air-abraded with 50 µm aluminum oxide for 10 s and then cleaned with alcohol. Post space with 8 mm length was prepared with special drill. Other procedures were similar to group DT.N.

Procedure for group Zr.W specimens (weakened teeth treated with zirconia post)

All procedures were similar to group Zr.N except that the canal preparation was limited to the last 2 mm of the post space because of the wakening procedure of the first 6 mm.

Testing fracture resistance and pattern

After specimens' preparation, all samples were kept in normal saline in room temperature. Samples were mounted on the 45° ramp as their long axis was perpendicular and along with the ramp right angle bisector. In this manner the pattern of applied forces was similar to class I occlusion as the angle between applied force by lower incisors to upper incisors is 135°.[20] So the force magnitude and direction were similar in all samples.

In order to assimilate the surfaces in which forces are applied, a composite block with 5 mm mesiodistal width and 3 mm incisocervical height was made 3 mm away from incisor edge in the palatal surface.

Then all samples underwent 1500 thermal cycles intermittently between 5 and 55°C for 30 s with 12 s intervals.

A Universal testing device (Dartec. Series TLCLO, England) was used to apply a constant compressive load on the composite blocks at a crosshead speed of 0.5 mm/min until fracture occurred.[31] At this point the amount of force was recorded. Also the failure mode for each group was evaluated.

Data was analyzed by SPSS software version 15.0 to compare the mean fracture resistance of all groups, and two way analysis of variance (ANOVA) was used. Paired comparisons between groups were made by Tukey test. Also the failure mode between groups was analyzed by Fisher exact test ($P<0.05$).

RESULTS

Fracture resistance

The mean amount of fracture resistance and the comparison of means are presented in Tables 1 and 2. Group DT+R.W and group Zr.W showed the highest and lowest fracture resistance with 732.444 and 573.666 N respectively.

The fractured resistance values of studied groups are compared in Table 2.

Fracture pattern

The fracture patterns were divided into two groups: 1) coronal fracture (desirable fracture) 2) root fracture (not desirable fracture).

The fracture pattern frequencies in different groups are presented in Table 3.

The fisher exact test revealed that the fiber post restored groups show significantly more desirable fractures than Zirconia restored groups do ($P=0.004$).

DISCUSSION

Tooth restoration is the final step after appropriate root canal treatment. Root canal treatment is done just to save the root and to restore back the fracture resistance of weakened tooth, other methods should be applied.[7] Numerous studies have shown that RCT can decrease teeth fracture resistance; therefore, restoring these teeth has been a challenge to maintain function, aesthetic and serviceability of teeth.

Traditionally, root canal treated teeth have been restored with cast metal post and cores.[32] So many shortcomings have been reported for cast metal post and cores: Post retention lost, post corrosion, esthetic problems and vertical root fractures.[22,25,26] As the use of supra-gingival margins are growing with ceramic restoration crowns, the importance of metallic or carbon fiber post "shine through" effect has been highlighted, so many researches have been carried out to introduce new tooth-colored posts.[10]

The present *in vitro* study was conducted to compare the fracture resistance and failure modes of endodontically treated teeth restored with three different post systems. As the maxillary anterior teeth are more prone to trauma and fracture, these teeth were selected to simulate an *in vivo* condition.

From the present study it is concluded that DT+R.W group (weakened teeth treated with double taper light post and Ribbond) and Zr.W group (weakened teeth treated with Zirconia post) showed the highest and lowest fracture resistance respectively. In fiber treated groups there was a significant difference in fracture resistance between group DT+R.W and group DT.W. Ribbond is a memory free cold gas plasma-treated woven fiber that its use can increase the strength of the root canal.[31] Widening the post-space, which may in a better way simulate severely compromised roots, will allow the placement of the high strength fiber ribbons in the canal and also increase the bonding surface area. By this definition the high mean fracture resistance of the weakened teeth treated with double tapered light post and Ribbond seems rational.

In the present study, the narrow canals restored with double taper light posts showed greater but not significant different bond strengths compared to the same canals restored with zirconia posts. This insignificant difference also was seen between the wide canals restored with these two post systems. The post core systems with lower modulus of elasticity and higher degree of elasticity showed lower fracture resistance.[10] In comparison between Fiber posts and zirconia posts, the fiber posts are more elastic, so it is rational that the fracture resistance of fiber treated groups be lower than Zirconia treated ones. This theory is contrary to the results of present study as the mean fracture resistance of fiber treated groups was higher than zirconia groups. This can explain that there are some other factors which affect the fracture resistance. It has been theorized that tooth bonded posts can significantly increase the tooth strength.[10,33] As fiber posts show good adhesion to resin cement and by considering that zirconia does not show homogenous adhesion[22] we can define the results of the present study.

Both wide and narrow canals restored with zirconia posts showed the least fracture resistance and these findings are consistent with Butz *et al*. study that declared low survival rates and fracture strengths for zirconia posts with composite cores.[34] Although for both zirconia and DT light post systems, the not-weakened teeth showed higher fracture resistance compared to the weakened ones, these differences were not significant and this finding can be explained by the fact that appropriate use and selection of post systems and adhesive agents can efficiently compensate the effect of weakening procedures.[35,36]

When the fracture occurs, the pattern of fracture is important as it acts as guidance for the restorability of fractured teeth. In the present study the fiber post treated teeth showed significantly more desirable fracture patterns compared to those restored with zircon posts. These results were described by Brandal theory in 1987, that in a system, destructive stress can be transmitted from the stiffest part to the dentin. As double taper light posts have lower modulus of elasticity which is more similar to dentin, the pattern of fracture is more desirable.[23] These findings are consistent with Mannocci et al. and Akkayan and Gülmez studies which showed fiber quartz posts can minimize the probability of root (undesirable) fractures and can significantly increase the teeth fracture resistance.[13,23]

It should be considered that the present study was an *in vitro* performance and the situation can not completely simulate *in vivo* conditions. Also the more realistic approach of endodontically treated teeth requires fabrication of cast crowns that it was not applied in this study. So the need for further *in vivo* and *in vitro* studies with more similar conditions seems rational.

CONCLUSIONS

Within limitations of the study it can be concluded that:

1. The structurally compromised teeth restored with double taper light posts combined with Ribbond fibers showed the most fracture resistance and their strengths were comparable to those of normal roots restored with double taper light posts.
2. More desirable fracture patterns were observed in teeth restored with fiber posts.

Footnotes

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Figures and Tables

Table 1

Groups	Mean±SD
DT.N	678.56±90.87
DT.W	638.22±93.71
DT+R.W	732.44±81.79
Zr.N	603.44±68.68
Zr.W	573.67±91.34
Total	645.27±99.43

DT.N: Not-weakened teeth restored with double taper light post, DT.W: Weakened teeth restored with D.T light post, DT+R.W: Weakened teeth treated with DT light post and ribbond, Zr.N: Not-weakened teeth restored with Zirconia post, Zr.W: Weakened teeth treated with Zirconia post

Means of fracture resistance (*N*) for different groups

Table 2

Groups	DT.W	DT+R.W	Zr.N	Zr.W
DT.N	0.368	0.205	0.065	0.027×
DT.W		0.037×	0.382	0.158
DT+R.W			0.002×	0.001×
Zr.N				0.446

(×indicates that the difference is significant). DT.N: Not-weakened teeth restored with double taper light post, DT.W: Weakened teeth restored with D.T light post, DT+R.W: Weakened teeth treated with DT light post and ribbond, Zr.N: Not-weakened teeth restored with zirconia post, Zr.W: Weakened teeth treated with zirconia post

Comparison of mean fracture resistance by *P* value

Table 3

Groups	Total coronal fracture	Total root fracture
DT.N	9	
	100%	
DT.W	8	1
	88.9%	11.1%
DT+R.W	9	
	100%	
Zr.N	5	4
	55.6%	44.4%
Zr.W	6	3
	66.6%	33.3%
Total	37	8
	82.2%	17.8%

DT.N: Not-weakened teeth restored with double taper light post, DT.W: Weakened teeth restored with D.T light post, DT+R.W: Weakened teeth treated with DT light post and ribbond, Zr.N: Not-weakened teeth restored with zirconia post, Zr.W: Weakened teeth treated with Zirconia post

Fracture pattern frequencies in different groups