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ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Effect of composite thickness over the fiber post on fracture resistance of endodontically treated teeth

Influenza dello spessore del composito sul perno in fibra sulla resistenza alla frattura di denti trattati endodonticamente

KEYWORDS
Composite Resin, Conservative Dentistry, Endodontically Treated Teeth, Fiber Post, Fracture Resistance, Restorative Dentistry

PAROLE CHIAVE
Composito, Odontoiatria conservativa, Denti trattati endodonticamente, Perno in fibra, Resistenza alla frattura, Odontoiatria restaurativa

Kasra Rahimipour[1]
Narges Panahandeh[1]
Seyedeh Mahsa Sheikh-Al-Eslamian[1*]
Reza Mousavi[1]
Hassan Torabzadeh[1]

[1]Dental Research Center, Research Institute of Dental Sciences, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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Abstract

Aim: *This study aimed to assess the effect of composite thickness over the fiber post on fracture resistance of endodontically treated teeth.*
Materials and Methods: *This in vitro experimental study was performed on 50 sound human premolars, which were randomly divided into 5 groups (n=10). Teeth in Group 1 remained intact while other specimens underwent root canal treatment with a Mesio-occluso-distal (MOD) cavity preparation, restored with fiber posts with a distance of 1.5 mm to the occlusal surface in groups 2 and 4 and 0.5 mm in groups 3 and 5.24 hours of incubation was applied for groups 1-3 and 1 year of incubation for groups 4 and 5. Thereafter fracture strength measured using a Universal Testing Machine at a crosshead speed of 1 mm/minute. Data were analyzed using Shapiro-Wilk, Two-Way ANOVA and Tukey HSD.*
Results: *The results showed a significant difference in terms of fracture resistance (P<0.05). The difference in fracture resistance between Group 1 and other groups was not statistically significant at 24h (P>0.05). Also, Tukey HSD revealed no statistically significant differences between Group 1 and 4 at one year. However, Group 1 (1255.25±280.61N) exhibited significantly higher fracture resistance than that of Group 5 (855.72±300.20N) at one year (P=0.027). The difference between other groups was not significant at any time point (P>0.05).*
Conclusions: *By covering the fiber post with 1.5 mm thickness of composite resin and cuspal reduction of 2 mm, the fracture resistance of endodontically treated teeth can be increased to the level of sound teeth.*

Obiettivo: *lo scopo di questo studio è di valutare l'influenza dello spessore del composito, posizionato sopra il perno in fibra, sulla resistenza alla frattura dei denti trattati endodonticamente.*
Materiali e Metodi: *questo studio in vitro è stato effettuato utilizzando 50 premolari umani che sono stati suddivisi in 5 gruppi (n=10). I denti del Gruppo 1 non sono stati trattati mentre negli altri campioni è stata preparata una cavità mesio-occluso-distale (MOD) ed è stata effettuata una terapia canalare. I campioni sono stati poi ricostruiti tramite posizionamento di perni in fibra, posti ad una distanza dalla superficie occlusale di 1.5 mm (Gruppo 2 e 4) e di 0.5 mm (Gruppo 3 e 5). I denti dei Gruppi 1, 2 e 3 sono stati incubati per 24 ore, quelli dei Gruppi 4 e 5 per un anno. Successivamente, utilizzando una Universal Testing Machine ad una velocità di 1 mm/min, è stata valutata la resistenza alla frattura dei campioni. I dati sono stati analizzati con i test statistici Shapiro-Wilk, Two-Way ANOVA e Tukey HSD.*
Risultati: *i risultati hanno mostrato una differenza significativa nella resistenza alla frattura (p<0.05). La resistenza alla frattura tra il Gruppo 1 e gli altri gruppi non è risultata statisticamente significativa a 24 ore (p>0.05). L'utilizzo del Tukey HSD non ha mostrato una differenza statisticamente significativa tra il Gruppo 1 e il Gruppo 4 a un anno di distanza. Il Gruppo 1 (1255.25±280.61N) ha mostrato una resistenza alla frattura statisticamente più alta del Gruppo 5 a un anno di distanza (855.72±300.20N) (P=0.027). Non c'è stata differenza statisticamente significativa fra gli altri gruppi (P>0.05).*
Conclusioni: *la resistenza alla frattura di un dente trattato endodonticamente risulta la stessa di un dente integro, effettuando una riduzione cuspidale di 2 mm e coprendo il perno in fibra con 1.5 mm di composito.*

Corresponding author
Seyedeh Mahsa Sheikh-Al-Eslamian | Research Institute of Dental Sciences, Shahid Beheshti University of Medical Science, Evin, Tehran | Iran
Tel. +98 21 22413897 | mahsa.sheikh@gmail.com

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Introduction

The main goal of dentistry is to preserve the teeth and minimize tooth loss as much as possible (1, 2). Many techniques have been suggested for restoration of severely damaged teeth after endodontic treatment. Evidence shows that the success of endodontic treatment not only depends on the successful completion of all procedural steps of endodontic treatment such as providing an apical seal and removing the necrotic tissue but also depends on the successful restoration of teeth (3). It should be noted that a root canal treatment should not be considered complete until the tooth crown is well restored (4).
Endodontically treated teeth are susceptible to fracture and researchers have long been in search of restorative materials and technique to reinforce the remaining tooth structure.
Considering the recent advances in formulations of composite resins and their affordability, direct composite restorations are suitable for endodontically treated teeth. Panahandeh et al (5) evaluated the effect of composite thickness on stress distribution in a restored endodontically treated premolar with cusp reduction. The results demonstrated that more stress is observed in the tooth without cusp reduction compared to the other models, and cusp reduction resulted in more suitable stress distribution.
Considering the poor retention of restorative materials in endodontically treated teeth that have lost a great portion of their coronal structure, intra-radicular posts are often used in such cases to provide retention for the coronal restoration (6). Fiber posts are increasingly used in dental clinical settings due to their higher flexibility compared to metal posts and having a modulus of elasticity close to that of dentin. They allow relatively uniform stress distribution and decrease the incidence of Catastrophic tooth fracture (7). Torabzadeh et al (8) evaluated the efficacy of using fiber in direct composite restorations and showed that cusp coverage of 1.5 and 2.5 mm in MOD access cavities with or without insertion of resin impregnated fiber had similar fracture rates in the endodontically treated teeth. Further evidence confirmed that cuspal coverage in directly bonded restorations enhanced the fracture resistance of teeth and protected the cusps against fracture (9).
In this regard, the thickness of the core material can significantly affect the fracture resistance of endodontically treated teeth with intra-radicular posts (10). Composite resins are commonly used for reconstruction of the core in endodontically treated teeth and the thickness of composite covering the post can significantly affect load distribution and fracture resistance of teeth (11, 12). However, data are scarce regarding the effect of the composite thickness over fiber posts on fracture resistance of teeth. Therefore, this study was undertaken to assess the effect of composite thickness (0.5 and 1.5 mm) over the fiber post on the fracture resistance of endodontically treated teeth after 24 hours and one year.

Materials and Methods

This in vitro study was performed on 50 sound single-canal human premolars extracted for orthodontic or periodontal reasons during the past six months. The soft tissue residues and calculus were removed from the coronal and radicular surfaces of the teeth using a hand scaler (Gracy Curette SG 17/18; Hu Friedy; Chicago, IL, USA). The teeth were inspected under a stereomicroscope (SZ61; Olympus, Tokyo, Japan) at x10 magnification to ensure the absence of cracks and caries. The teeth were anatomically examined to ensure that they all had normal anatomy and had no anomaly. The teeth were stored in distilled water in a screw-top container at 4 °C until the preparation. The water was refreshed weekly.
Tooth preparation

Figure 1
Silicone impression as an index for the restoration of the crown.

The buccal and lingual height from the cusp tip to the cementoenamel junction (CEJ) and the buccolingual width of teeth at the height of contour were measured by a digital caliper (Mitutoyo, Tokyo, Japan) to select teeth with relatively equal dimensions (for the purpose of standardization of samples). The size of the tooth was calculated by dividing tooth height by tooth width. The teeth (n=50) were randomly divided into 5 Groups of 10. Impressions were made of teeth in Groups 2 to 5 using putty silicone impression material (Speedex putty type I; Coltene, Altstätten, Switzerland) (8).
After polymerization of impression material, it was sectioned occlusoapically by a scalpel to obtain two half-impressions to serve as molds. The teeth were then removed from the impressions. These impressions were used as an index for the restoration of the crown (figure 1).
Teeth in Group 1 remained intact. In Groups 2 to 5, the access cavity was prepared in teeth using diamond fissure burs. A #15 K-file (Mani Inc., Tochigi, Japan). The root canals were cleaned, filed and flared to file #60 using the step-back technique. Saline was used for irrigation. The master file was #35, and the root canals were filled using lateral compaction technique. A #25 spreader, #15 lateral gutta-percha cones and #35 gutta-percha master cone (Aridanet, Tehran, Iran) along with AH26 sealer (Dentsply/DeTrey, Konstanz, Germany) were used for this purpose.
At this stage for post space preparation, gutta-percha in the canal was removed to 5 mm above the apex using #1 and #2 Gates-Glidden drills (Gates Glidden; Dentsply Maillefer, York, PA) and #1 and #2 peeso reamers(Peeso Burs; Dentsply Maillefer, York, PA).
The mesio-occluso-distal (MOD) cavities were then prepared and cusp reduction was performed for teeth in Groups 2-5. The width of MOD cavity at the isthmus was two-thirds of the distance between the two cusp tips. The buccal and lingual walls of the cavity were parallel and the distance from the mesial and distal box floor to the cementoenamel junction was 1 mm.
After cavity preparation, a few reference grooves were created with 2 mm depth on the cusps using a fissure bur with a 1.5 mm diameter and a digital caliper (Mitutoyo, Tokyo, Japan). Using these reference grooves, buccal and palatal/lingual cusp reduction was performed.

Restorative procedures and FRC post placement
Size 1 Reforpost Glass Fiber RX posts

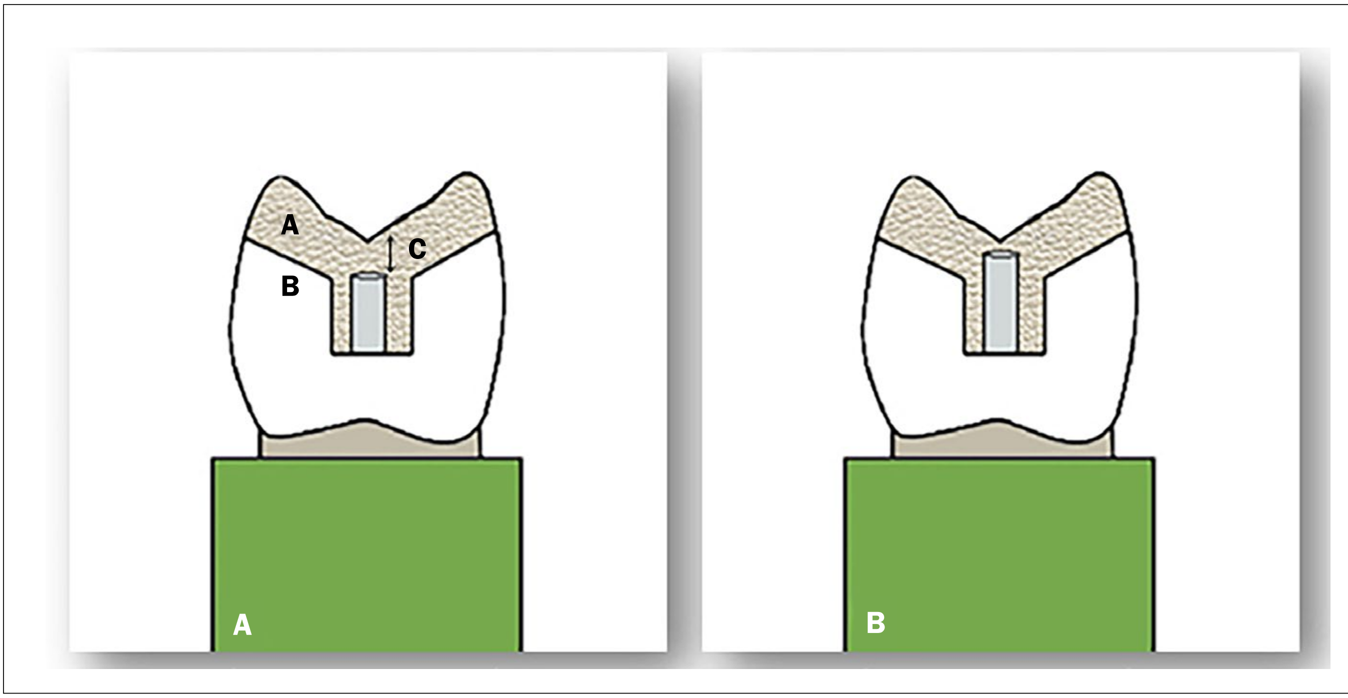

Figure 2
An overview of the relation between the posts to the occlusal surface. **(A)** Composite Build-up Restoration, **(B)** Reducted Cusps, **(C)** Distance between post tip and occlusal surface (a: 1.5 millimeters, b: 0.5 millimeters).

(RfX fiber; Ângelus, Londrina, PR, Brazil) were then used. After cavity and post space preparation, the canal and tooth crown were thoroughly rinsed and the fiber post was inserted into the canal. Next, one half of the previously made silicon impression was placed on the respective tooth. Using a digital caliper, in Groups 2 and 4 the post was marked at 1.5 mm and in Groups 3 and 5, 0.5 mm far from the occlusal surface of the tooth, respectively. Using a high-speed hand-piece, the posts were shortened to the marked points (figure 2). Using the other half of silicon impression and a digital caliper, distance of post from the occlusal surface was checked again and then it was removed from the canal. For the cementation of posts, Panavia F2 resin cement (Kuraray-PAN) was used according to the manufacturer's instructions.

The post was soaked in the cement and introduced into the canal. Light curing was performed using a quartz-tungsten-halogen light-curing unit with 705 mW/cm2 light intensity (SN.851553 Blue Point; AriaLuxe, Tehran, Iran) for 2 seconds. Excess cement was removed and light-curing was continued for another 40 seconds.

After cementation of posts, the teeth were built-up. For this purpose, the remaining tooth structure was etched with 35% phosphoric acid, rinsed and dried. Using a micro-brush, Single Bond (3M ESPE, St. Paul, MN, USA) was applied on etched surfaces, thinned with air spray for 10 seconds from 10 cm distance and light-cured for 20 seconds. Filtek Z250 (shade A2, 3M ESPE, St. Paul, MN, USA) composite was incrementally applied into the cavity using the layering technique until the tooth was completely restored. Each increment had 1 mm thickness and light-cured for 20 seconds. The final increment of composite was applied to the previously made silicon mold and the tooth was then placed in the mold. After removing the excess composite, final curing was performed for 40 seconds.

Compressive test
All teeth were then mounted in acrylic resin to 2 mm below their CEJ (simulating the alveolar crest). The teeth were immersed in distilled water and incubated at 37 °C for 24 hours and 1 year. Next, they were transferred to a universal testing machine (Zwick Roell, Ulm, Germany) and subjected to compressive

stress. The load was gradually increased with a crosshead speed of 1 mm/minute until fracture occurred. The maximum load at fracture was recorded in Newtons (N) and indicated the fracture resistance of tooth.
After the fracture, all samples were evaluated by the naked eye and divided into two groups in terms of the location of the fracture line above or below the CEJ. The percentage of each mode of failure was calculated.
Data were statistically analyzed using SPSS version 22 (SPSS Inc., IL, USA). The mean and standard deviation (SD) of fracture resistance in each group were calculated. The Shapiro-Wilk test showed that the data were normally distributed, therefore, data analyzed by Two Way ANOVA and Tukey HSD test. Statistically significant was defined as $P<0.05$.

Results

Table 1 shows the mean and SD of fracture resistance in the five groups. The highest fracture resistance was noted in Group 1 and the lowest in Group 5. The Shapiro-Wilk test showed that the data were normally distributed in any of the five groups. The Two Way ANOVA test was applied to compare the groups and showed that the groups were significantly different in terms of fracture resistance ($P<0.05$) but no interaction between factors. Thus, the Tukey HSD test was applied for pairwise comparisons, which showed that only the difference between the Groups 1 (control) and 5 (0.5 mm thickness) was significant ($P=0.02$). The difference between other groups was not significant at any time point.
The fracture was evaluated with naked eye and the position of fracture was considered according to the CEJ position. The fracture mode of the specimens is shown in Table 1. Fisher's exact test showed no significant difference among groups in terms of the percentage of modes of failure ($P=0.84$).

Discussion

Since premolars are greatly weakened by the process of access cavity preparation and the prevalence of fracture is high in premolar teeth, reinforcement of these teeth is often necessary. Also, premolars often play a role in a beautiful smile and thus, should be necessarily restored with tooth-colored restorative materials (13). So we used this type of teeth for our research. The teeth were standardized in terms of dimensions because these dimensions dictate the size of the access cavity and according to St-Georges et al (14) cavity depth (which is dictated by the height and size of the crown) is the most critical parameter in tooth fracture. An increase by even 1 mm in depth of cavity significantly decreases the fracture resistance

Table 1

The mean and standard deviation of fracture resistance and mode of failure in the five groups (n=10)

Groups	Time	Composite thickness (mm)	Mean (N)±SD	Mode of failure%	
				Above CEJ	Under CEJ
1	24h	Intact Teeth	1255.25±280.61	80	20
2		1.5	1146.07±301.80	70	30
3		0.5	971.07±261.34	70	30

of teeth. Cavity width is also important. According to Roberson et al (15) if the isthmus width exceeds one-third of the distance between the cusp tips, cuspal coverage should be considered to reinforce the remaining tooth structure. Cuspal coverage is necessary when the cavity width is two-thirds of the distance between the cusp tips, especially in endodontically treated teeth. According to Linn and Messer (16) loss of the two marginal ridges can weaken the tooth structure by 60%; this negative impact is greater on premolars than molars.

Load distribution in tooth structure is an important factor affecting successful restoration of endodontically treated teeth, which depends on the type of post, core material and its thickness over the post (17, 18). The use of fiber posts is increasing due to their optimal esthetics, mechanical properties, and affordability (19).

Studies on the effect of restorative material thickness over the posts are limited. Tarun et al (17) evaluated the effect of the thickness of composite covering the titanium posts on load distribution in endodontically treated teeth. They showed that increasing the thickness decreased the stress applied to the apical third of the root. However, their study was conducted on titanium posts and their results cannot be generalized to fiber posts. In this study, no significant difference was noted in fracture resistance of Groups 1 and 2 but the difference between Groups 1 and 5 was significant. Z250 composite used in our study has a modulus of elasticity close to that of dentin (20). Also, the mechanical properties of Angelus fiber post used in our study are highly similar to those of dentin (21). This may explain relatively similar results obtained in most groups. The head of fiber posts cannot be exposed to the oral environment because of the water sorption of their resin component. Microscopic signs of post surface degradation due to water uptake and a loss of structure due to occlusal wear were seen (22). Thus, 0.5 mm composite was the smallest possible thickness of composite on the post. Differences between Groups 1 and 5 can also be due to the brittleness of composite in lower thicknesses (17). The mode of failure of teeth can affect their restoration or may necessitate tooth extraction.

In all groups in our study, 70% of fractures were above the CEJ, which shows that the thickness of composite over the fiber post does not affect the mode of fracture. In a similar study, Reid et al

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(23) found no significant difference in fracture resistance of teeth restored with quartz, carbon and titanium posts but the type of fracture in teeth restored with fiber post was more favorable. Furthermore, more favorable modes of failure have been reported in teeth restored with direct composite restoration and cuspal coverage. Torabzadeh et al (8) showed that teeth that received cuspal coverage with 2.5 mm thickness had more favorable modes of failure than those restored with 1.5 mm of cuspal coverage. Thus, it may be postulated that teeth restored with direct composite restoration, fiber post placement, and cuspal coverage have modes of failure similar to sound teeth. This study had an in vitro design. Thus, a generalization of results to the clinical setting must be done with caution.
Future studies with larger sample sizes and water storage of teeth are required to assess the behavior of these restorations in the long-term.

Conclusions

The fracture resistance of endodontically treated teeth restored with a fiber post and 1.5 mm thickness of composite over it along with 2 mm of cuspal coverage after 24h and one year is comparable to that of sound teeth. 0.5 mm thickness of composite over fiber post has a significant influence on the reduction of the flexural properties after one year.
It may be concluded that 0.5 mm of composite thickness overlying fiber post seems not to be a reliable choice but 1.5 mm thickness of composite resin covering fiber posts and cuspal reduction of 2 mm, can cause the fracture resistance of endodontically treated teeth to be increased to the level of sound teeth.

Clinical Relevance

The presented article shows that despite the fact that fiber posts have a comparable modulus of elasticity to dentine and composite, minimum coverage of 1.5 mm is necessary for direct restoration of composite resins.

Conflict of Interest

The authors declare that they have no conflict of interests.

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