Journal of
Kerman University of Medical Sciences

https://jkmu.kmu.ac.ir
doi 10.34172/jkmu.2024.22
Vol. 31, No. 3, 2024, 135-140

Original Article

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Evaluation of Fiber Post Exposure on Coronal Microleakage of Endodontically Treated Teeth: An In Vitro Study

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Abstract

Background: Coronal leakage is a significant cause of failure in endodontically treated teeth, and studies have reported the different effects of aqueous environments and occlusal forces on fiber-reinforced composite (FRC) materials. This study aimed to evaluate the effect of fiber post exposure on coronal microleakage in endodontically treated teeth restored with fiber post and composite core.

Methods: Forty-five extracted maxillary incisors were sectioned at the CEJ, endodontically treated, and randomly divided into five groups. The specimens in the first group were restored with fiber post and core, but the post was not exposed and was covered with composite. The fiber posts were exposed in the second and fourth groups, while the fiber posts and luting cement were exposed in the third and fifth groups. The first, second, and third groups were varnished up to one millimeter below the CEJ, and the fourth and fifth groups up to the highest level of the composite core. The specimens were cut into two halves longitudinally with a diamond disc, and the depth of dye penetration was measured using a stereo microscope at the incisal and cervical interfaces. The Mann-Whitney U-test and Kruskal-Wallis test were performed to determine the significance of differences between the microleakage of different groups, with a significance level of 0.05.

Results: The microleakage values of the groups with exposed fiber posts (fiber post-cement composite) did not differ. Due to the varnish coverage, the microleakage values in the cervical interface showed no significant difference in groups 1, 2, and 3, unaffected by post exposure at the incisal region.

Conclusion: Fiber post exposure did not influence the microleakage values of endodontically treated teeth restored with fiber post-composite core buildup.

Keywords: Endodontically treated teeth, Fiber post, Microleakage

Citation: Elmamooz N, Karimi Afshar M, Eslami MA. Evaluation of fiber post exposure on coronal microleakage of endodontically treated teeth: an in vitro study. *Journal of Kerman University of Medical Sciences*. 2024;31(3):135–140. doi: 10.34172/jkmu.2024.22

Received: July 27, 2023, **Accepted**: November 26, 2023, **ePublished**: June 29, 2024

Introduction

Endodontically treated teeth are structurally more vulnerable than unrestored vital teeth and have special restorative requirements due to structural integrity loss, fracture resistance reduction, and low moisture content (1).

Using fiber posts is recommended to increase the adhesion of the core material. Given their beauty, easier use, and lower cost, fiber posts are more widely used than cast posts (2,3). One-visit treatment and the lack of corrosion potential and allergic reactions associated with metal posts are other advantages of fiber posts (2,4,5). On the other hand, fiber posts have the same modulus of elasticity as dentin and transmit forces better along the root (6,7).

Coronal leakage is the most important cause of failure in endodontically treated teeth as it can lead to secondary caries and root canal contamination (5,8). Dye penetration is the common technique to examine microleakage (9-11).

Previous studies have reported different effects of aqueous environments and occlusal forces on fiber-reinforced composite (FRC) materials (12-18).

During the finishing process of composite buildup restorations, fiber post exposure to the oral environment in clinical conditions is a common finding in direct restorations (2). In many cases, fiber post exposure to the oral environment occurs inevitably during occlusal contact adjustment because of occlusion condition and the angle of the canal in severely damaged teeth with low occlusal clearance (particularly in anterior teeth). A study by Lassila et al. reported decreased flexural properties for E-glass FRC after short-term water storage (12).

However, it is unclear whether the fiber post's exposure could endanger the coronal seal in restorations. This in-vitro study aimed to investigate the effect of fiber post exposure to water on coronal leakage. The null hypothesis was that fiber post exposure would influence the coronal seal of composite restorations with exposed fiber posts.

Materials and Methods

This experimental study was conducted on 45 maxillary incisors extracted due to periodontal problems. The teeth were single-canal and caries- and crack-free with straight roots, mature apices, and no internal or external root resorption. Teeth with open apices, caries, cracks, internal resorption, or fillings were excluded from the study. The teeth were stored in saline solution at 37 ± 1 °C, and any soft tissue and debris were removed with an ultrasonic scaler.

The crowns of teeth were cut at the CEJ using a diamond disc (roots shorter than 15 mm were excluded). Root canals were instrumented to the working length of a size #30 file (MANI Inc, Japan) with a 6% taper of size S1 to F3 rotary file (SP1 V-Taper, Shanghai Fanta Dental Materials Co. China) according to the manufacturer's instructions by the crown-down method. During preparation, a 5.25% hypochlorite solution was used for irrigation. The prepared canals were dried with paper points and obturated with gutta-percha points and eugenol-free resin sealer (AH Plus, Dentsply) using the cold lateral condensation technique. After 24 hours (completion of sealer hardening time), the post spaces were prepared using piezo reamer #3 (MANI Inc, Japan), leaving at least 5 mm of gutta-percha at the apical area. The characteristics of the materials used in this study are summarized in Table 1.

The teeth were randomly divided into five groups of nine teeth each, as shown in Figure 1:

- Group 1: The fiber post was completely covered with a composite core. The samples were covered with varnish up to one mm below the CEJ.
- Group 2: Fiber posts were exposed while surrounded only by composite (in the cementation process, the cement was removed from the surface of the coronal section of the fiber post). The samples were covered with varnish up to one mm below the CEJ.

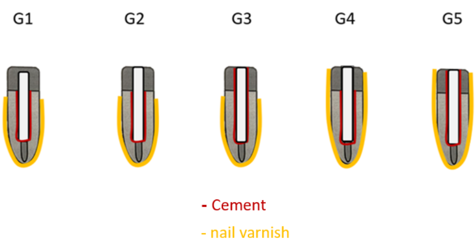

Figure 1. The schematic diagram of the five studied groups

- Group 3: Fiber posts were exposed while surrounded by cement and composite. The samples were covered with varnish up to one mm below the CEJ.
- Group 4: Fiber posts were exposed while surrounded only by composite (in the cementation process, the cement was removed from the surface of the coronal section of the fiber post). The samples were covered with varnish up to the highest level of the composite core.
- Group 5: Fiber posts were exposed while surrounded by cement and composite. The samples were covered with varnish up to the highest level of the composite core.

In each group, two teeth were considered positive and negative controls. The negative control was covered by two layers of varnish, while the positive control received no varnish coating before dye immersion (9).

Initially, fiber posts (Angelus, Brazil, No. 2) were cut (13 mm long) with a diamond bur. After this, all the posts received the same surface treatment, cleaning with alcohol, followed by the application of silane (Silano, Angelus, Brazil), and allowed to dry for one minute.

The root canals were rinsed with distilled water (60 seconds) and dried with absorbent paper cones for cementation. A dual-cured self-adhesive resin cement (TheraCem, Bisco, USA) was used for cementation. The mixed cement was applied to the canal walls using a paper point, and the fiber post was coated according to the manufacturer's instructions. The post was seated immediately in the canal. In groups 1, 2, and 4, the excess cement was removed using a micro brush so that no cement remained on the coronal surface of the fiber post. After removing the excess cement, curing was done for 40 seconds using a light-emitting diode (Demi ultra, Kerr, USA-1200 mW/cm^2 of irradiance) curing unit. The excess cement was removed from the tooth in groups 3 and 5 but kept around the post.

For composite core buildup, all tooth surfaces were etched with 37% phosphoric acid for 10 seconds, rinsed, and gently airdried (complete surface drying was avoided). Then, a universal bonding agent (G Premio, GC, Japan) was applied to the surface of the dentin using a micro brush. After 10 seconds, it was subjected to maximum air pressure for 5 seconds according to the manufacturer's instructions. Curing was done for 10 seconds.

A silicone index (Putty Material; Speedex, Coltene/Whaledent Inc., Switzerland) was used to standardize the composite core buildup. The composite core (AELITE All-Purpose Body, Bisco, USA) was formed at least one mm beyond the fiber post (the composite core covered the posts completely) using the incremental technique (each 2-mm layer was cured for 40 seconds).

The composite core was cut in groups 2 to 5 until the fiber post was exposed. Specimens were polished (Composoft, EVE, Germany) after composite core buildup.

Table 1. Characteristics of materials used in the study

Product	Material type	Composition	Manufacturer	Batch number
AH Plus sealer	Epoxide-amine resin pulp canal sealer	Epoxy resin, Calcium tungstate, Zirconium oxide, Iron oxide, silicone oil	Dentsply, USA	1201023007
Exacto	Glass Fiber post	Glass fiber, Epoxy resin	Angelus, Brazil	15218
Silano	Silane	X-R-Si(OR)3n X-organofunctional groups, R-methylene group, OR-hydrolysable group, Si-Silicon	Angelus, Brazil	10676.T
Theracem	Dual-cure, self-adhesive cement	Methacrylate-based	Bisco, USA	2000000187
G premio	Universal Adhesive	Methacryloxyethyl trimellitic anhydride, dimethacrylate monomer, Distilled water, acetone, photoinitiator, fine silica powder	GC, Japan	1518092
AELITE All-Purpose Body	Universal Micro Hybrid Composite	Glass filler, amorphous silica	Bisco, USA	1900004211

After 24 hours of water storage at 37 °C, specimens were subjected to 5000 cycles of thermocycling between 5 and 55 °C for 30 seconds each and a dwelling time of 15 seconds (4,9). The specimens were airdried and received nail varnish according to the specifications of each group described earlier (Figure 1). Then, the samples were immersed in 2% methylene blue solution (Methylene Blue, Neutron, Iran) for 72 hours (37 °C) (3,19-22). Every two specimens were immersed in each container to ensure that all surfaces were sufficiently exposed to the dye.

Then, the nail varnish was removed and rinsed under running water. The teeth in each group were sectioned longitudinally into two halves using a diamond disc (DFS Diamond, Germany) at the center of the root passing through the fiber post (2).

Using a stereomicroscope, a single operator examined the dye penetration depth of interfaces down to a tenth of a millimeter at × 10 magnification (Zeiss OPM1; Carl Zeiss, Oberkochen, Germany).

The mean difference of penetration depths was statistically analyzed using the Kruskal-Wallis and Mann-Whitney tests with SPSS 26 (SPSS Inc., Chicago, III) at a significance level of $\alpha = 0.05$.

Results

The samples' microleakage was analyzed in two areas: the cervical interface and the incisal interface.

Cervical interface

The results showed that the first group had the highest microleakage values (16 ± 0.326 mm) (Table 2).

According to the Kruskal-Wallis test, the mean rank of the groups showed significant differences at the cervical interface (Figure 2).

According to Table 3, the cervical interface of the first group was significantly different from the groups varnished up to the highest level of the composite core (4th and 5th groups). The 4th and 5th groups had no significant difference and showed no microleakage.

Incisal interface

Table 2. Descriptive statistics of microleakage at the cervical interface (composite-dentin)

Group	Mean	Standard deviation	Minimum	Maximum
1	3.16	0.326	2.70	3.70
2	2.79	0.385	2.10	3.20
3	2.86	0.416	2.20	3.30
4	0	0	0	0
5	0	0	0	0

According to the results, the highest microleakage was associated with the second group (0.06 ± 0.079 mm) at the incisal interface (Table 4).

The mean rank of the groups did not show significant differences, according to the Kruskal-Wallis test (Figure 3).

According to Table 5, none of the groups had significant differences, and in the first group, microleakage was zero or close to zero in most of the samples.

Discussion

The null hypothesis of the present study was rejected because no leakage was reported at fiber post-cement-composite interfaces in groups with fiber post exposure.

Clinical studies have indicated that debonding and retention loss are the most common cause of failure in fiber posts (4). Fiber post exposure to the oral environment in clinical conditions is a common finding in direct restorations (2).

The oral environment (occlusal forces and thermal changes) and the difference between the physical properties of teeth and restorative materials (such as polymerization shrinkage, coefficient of thermal expansion, and modulus of elasticity) can contribute to microleakage (21).

In this study, the microleakage value of the dentin-composite surface had no significant difference at cervical interfaces in groups 1–3 (2.79–3.16 mm). Overall, microleakage occurs more in the dentin than in the enamel because of dentin's properties, including its tubular structure and inherent moisture (21,23-25). Combining microleakage tests with thermal cycles helps evaluate

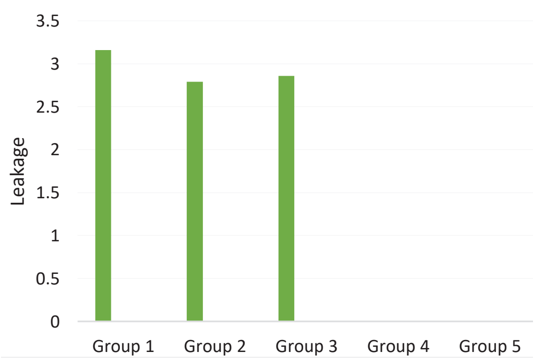

Figure 2. The mean rank of the groups according to the Kruskal-Wallis test at the cervical interface

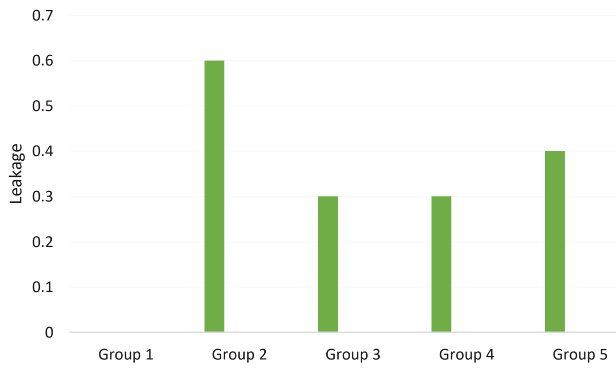

Figure 3. The mean rank of the groups according to the Kruskal-Wallis test at the incisal interface

Table 3. Pairwise comparisons between groups based on the Mann-Whitney test at the cervical interface

Group	Group	*P* value *
1	2	0.11
	3	0.24
	4	0.001
	5	0.001
2	3	0.68
	4	0.001
	5	0.001
3	4	0.001
	5	0.001
4	5	1.0

Table 4. Descriptive statistics of microleakage at the incisal interface.

Group	Mean	Standard deviation	Minimum	Maximum
1	0.00	0.000	0	0
2 F-C	0.06	0.079	0	0.2
3 F-C-C	0.03	0.076	0	0.2
4 F-C	0.03	0.049	0	0.2
5 F-C-C	0.04	0.079	0	0.2

F-C: fiber-composite; F-C-C: fiber-cement-composite.

Table 5. Pairwise comparisons between groups based on the Mann-Whitney U-test at the incisal interface.

Group	Group	*P* value
1	2 F-C	0.19
	3 F-C-C	1.0
	4 F-C	0.46
	5 F-C-C	0.46
2 F-C	3 F-C-C	0.56
	4 F-C	0.71
	5 F-C-C	0.93
3 F-C-C	4 F-C	1.0
	5 F-C-C	1.0
4 F-C	5 F-C-C	1.0

F-C: fiber-composite; F-C-C: fiber-cement-composite.

dental restorations. According to the ISO standard, 500 thermocycles at temperatures between 5 and 55 °C is a suitable test for the aging of restorative material. The samples were subjected to 5000 cycles of thermocycling between 5 and 55 °C in this study, corresponding to six months of clinical restoration service, according to Gale and Darvell (23). As the coefficient of thermal expansion of composites is higher than that of the tooth, frequent expansion-contraction stresses can affect the tooth-composite interface (19,22). The polymerization shrinkage of composites and the difference between the coefficient of thermal expansion of the composite and the tooth would increase marginal gap formation and microleakage in the tooth-restoration interface after thermocycling. The coefficient of thermal expansion in dentin and composite resin material is $11 \times 10(-6) / °C$ and in the range of $20 \times 10(-6) / °C$ to $80 \times 10(-6) / °C$, respectively (24).

In the present study, the groups in which fiber posts were exposed revealed no dye penetration at the composite-fiber and composite-cement-fiber interfaces. The null hypothesis of the study that exposure of fiber posts has no effect on ETT microleakage repaired with fiber post was confirmed, which is consistent with the result of a study by Makarewicz et al (26). Makarewicz et al found that none of the individually formed glass FRC posts showed adhesive failures between the post and the cement. They reported that FRC posts failed mostly adhesively at the cement-dentin interface. Makarewicz et al used pre-impregnated unidirectional E-glass fiber reinforcement.

One disadvantage of fiber-reinforced prefabricated posts is that the polymer matrix is highly crosslinked, which jeopardizes the bond to the resin-luting cement and the core materials because the resin composite cement monomers used for fiber post bond cannot penetrate the highly crosslinked polymer matrix. Alternative polymer matrices for fiber-reinforced posts have been developed, including a multiphase polymer matrix including linear and crosslinked polymer phases (semi-interpenetrating network, semi-IPN), to solve this problem, which has demonstrated satisfactory results. Adhesive resin monomers and cements could diffuse into the linear polymer phase and form interfusion bonding in the polymerization process, known as the secondary semi-IPN structure. Hence, besides preventing dye penetration along the composite-fiber interface, improved bonding allows a better load transfer from the crown-core system to the root (27-32).

Camilotti et al. revealed that the microleakage in exposed groups was higher after 5000 thermocycles, which is inconsistent with the present study. However, in the study by Camilotti et al, dye infiltration at the exposed fiber post interface was very low (less than 1 mm), probably due to the micro gaps in the post-core interface and incomplete integration of the post and core materials. This low value may not affect the long-term success of the bond between fiber post and composite since the core retention that provides the strength of the restoration needs an effective fiber post bond. In contrast, the microleakage that started from the core material and dentin interface at the cervical region has a crucial role in dye penetration into the root canal (2).

Dye penetration inside the root canal was limited to 1⁄3 of the cervical root in this study, which is consistent with Champirat et al and Camilotti et al. Their studies found that microleakage penetration was limited to the middle third of the root (2,33).

Conclusion

With the limitations of the present study in mind, we conclude that:

1. Microleakage was present in all study groups at the composite-tooth interface in the cervical interface that had no varnish and was not affected by the exposure of fiber post from the occlusal/incisal side.
2. Microleakage did not differ significantly between the groups with exposed fiber posts and those without fiber post exposure at the composite-fiber and composite-cement-fiber interface.

Suggestions

More studies are necessary on the effect of fiber post type, fiber post surface preparation, type of luting cement, and occlusal forces on the microleakage of the fiber-composite interface.

Authors' Contribution

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Data curation: Mohammad Amin Eslami.
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Supervision: Nafiseh Elmamooz, Mehrnaz Karimi Afshar.
Visualization: Mehrnaz Karimi Afshar.
Writing–original draft: Nafiseh Elmamooz, Mehrnaz Karimi Afshar, Mohammad Amin Eslami.
Writing–review & editing: Nafiseh Elmamooz, Mohammad Amin Eslami.

Competing Interests

The authors declare that there is no conflict of interest.

Ethical Approval

This study was approved by the ethical committee of Kerman University of Medical Sciences (ethics code: IR.KMU.REC.1400.669).

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

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