Microleakage of endodontically treated tooth with post and core restoration materials using exposed and non-exposed intracanal post techniques

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Objectives: This *in vitro* study aimed to investigate coronal microleakage of endodontically treated tooth restored with prefabricated fiber post and resin core materials using two different techniques at different water-exposing time periods.

Materials and methods: Eighty extracted human premolars were endodontically treated and randomly divided into eight groups of ten specimens each. The specimens of groups 1-4 were restored with prefabricated fiber post and core using exposed intracanal post technique, while the specimens of groups 5-8 were restored using non-exposed intracanal post technique. All specimens were thermocycled at different number of cycles representing water-exposing time periods of 1, 2, 4 weeks, and 6 months. After immersion in 2% Methylene blue for 48 hours, the specimens were subsequently cut into two halves longitudinally. The longitudinal sections were used for the measurement of dye infiltration along the interface using image analysis software. Mann-Whitney U-test and Kruskal Wallis test were performed to determine significant differences among microleakage of each group at a significant level of 0.05.

Results: Microleakage was measured with significant difference at the water-exposing time period of 6 months comparing two types of the post-core restoration technique ($p = 0.02$). Using exposed intracanal post technique, the specimens showed significant difference of microleakage between the water-exposing time periods of 1 week and 6 months ($p = 0.01$); whereas, no significant difference of coronal microleakage was found among all groups using non-exposed intracanal post technique at different water-exposing time periods.

Keywords: endodontically treated tooth, intracanal post, microleakage, prefabricated fiber post, water-exposing time

Introduction

The success of endodontically treated tooth depends not only on the efficient root canal treatment, but also on an appropriate coronal seal from dental restorations. Since improper restoration is the most important factor related to the failure of the endodontic treatment, the type of coronal restorations should be of interest. [1,2] Several types of coronal restoration could be selected for endodontically treated tooth, however, quantity and quality of the remaining tooth structure is one of the key factors for choosing any type of the restoration. Most of the endodontically treated teeth are severely destructed which results in the

need for post and core restorations prior to the definitive restoration. The posts may be casted in metal or prefabricated, which does not affect the success of the restoration of the endodontically treated tooth. [3] Prefabricated fiber posts are preferred to be used in endodontically treated tooth in order to increase the retention of the core material as a foundation for coronal restoration because their modulus of elasticity resembles that of dentin, which can better distribute the chewing force throughout the root surface. On the contrary, casting posts produce higher stress at the post-dentin interface resulting in the increase of the incidence of root fractures. [4] Other advantages of fiber posts include esthetics especially in the anterior teeth, ease of removal, and preservation of the remaining tooth structure. [5,6] One of the most common failures of the endodontically treated teeth restored with prefabricated fiber post and crown has been reported to be the dislodgement of fiber post. [3,7] The factors that may affect fiber posts dislodgement are adaptation of the post within the canal, types of cement, technique of cementation, occurrence of secondary caries, and microleakage.

The fiber post surface should be completely covered coronally by a layer of core material of a few millimeters in thickness to protect the post from microfractures which might occur to the abutment. [8] This technique of post and core restoration is called non-exposed intracanal post technique. Nevertheless, visibility of the exposed post on a direct restoration is a common finding in clinical situation as a result from another technique of post and core restoration, which is called exposed intracanal post technique. [9] Previous study reported that the exposed post may have structural alteration due to wear and water degradation, which negatively affects its mechanical properties. [10] However, it has not been clear yet whether the exposure of the post

to the environment have an effect on the coronal microleakage of the restoration. Furthermore, duration of the time of water exposure might also influence the coronal microleakage, in case the restorations with post exposure have to be left uncovered in the oral environment for a period of time.

The aim of this in vitro study was to compare coronal microleakage of endodontically treated teeth restored with prefabricated fiber post and resin core materials using two different techniques—exposed intracanal post and non-exposed intracanal post techniques at different water-exposing time periods.

Materials and methods

Materials used are shown in Table 1. Eighty extracted mandibular premolar teeth were used in this study with Ethics Committee approval (MU-DT/PY-IRB 2016/012.2906). These teeth were stored in 0.1% Thymol solution (M dent®) at room temperature. The inclusion criteria were teeth that had characteristics as follows: (1) one root canal, (2) root length of 13-14 mm, (3) straight root, and (4) curvature of root canals not more than 10 degrees at 10 mm of the coronal part of the root length. [7] Teeth with open apex, dental caries, crack, resorption, and restoration were excluded from the study. The teeth were cleaned with ultrasonic scaler and rinsed with 2.5% sodium hypochlorite (M dent®). The crowns were cut perpendicular to the long axis of the tooth at 2 mm coronally to the cementoenamel junction (CEJ) with a high-speed cylindrical diamond bur, leaving the total tooth length of 16 mm. The root canals were cleaned and shaped to the size of endodontic file No. 35 and 6% taper at the working length of 15 mm with crown down technique, using serial rotary nickel titanium files (K3®, SybronEndo)

with 2.5% sodium hypochlorite irrigation (M dent®). The files were used for root canal preparation to the maximum of 10 canals, and then the new set of files was picked up. Matched gutta-percha points (SybronEndo®) were fit for tug-back in each canal at the working length. Final irrigation with 17% EDTA (M dent®) and 2.5% sodium hypochlorite (M dent®) was performed. The canals were dried with paper points and obturated with continuous wave condensation of gutta-percha and eugenol-free sealer (AH plus®, Dentsply®), leaving approximately 4 mm of gutta-percha at the apical one third of the root length. Radiograph was taken to evaluate the quality of the root canal filling. After that, the teeth were kept moist at 37°C for at least 24 hours. The post space preparation was created with the universal drill and DT drill corresponding to the selected post size in order to passively place the post size 2 (DT light post®, X-RO®, Illusion®, RTD) to a depth of 11 mm. The posts were then cut with diamond bur to 13 mm and cleaned with 70% alcohol.

Table 1 Materials used with the manufacturer's information, composition and lot numbers

Materials	Manufacturer	Composition	Lot #
DT light-post® Illusion® X-RO®	RTD, St. Egreve, France	60 vol% Quartz fibers 40 vol% Epoxy resin matrix	309101604
Multicore® Flow	Ivoclar Vivadent, Schaan, Liechtenstein	Bis-GMA, UDMA, TEGDMA, Barium glass filler, Ba-Al-fluorosilicated glass, highly dispersed silicon dioxide, Ytterbium trifluoride, catalysts, stabilizers, pigments	U37398
AH Plus® sealer	Dentsply, Konstanz, Germany	Paste A: Bisphenol-A epoxy resin, Bisphonol-F epoxy resin, Calcium tungstate, Zirconium oxide, Silica, Iron oxide pigments Paste B: Dibenzyldiamine, Aminoademantane, Tricyclodecane-diamine, Calcium tungstate, Zirconium oxide, Silica, Silicone oil	606.20.112
Excite®F DSC	Ivoclar Vivadent, Schaan, Liechtenstein	HEMA, Dimethacrylate, Phosphonic acid acrylate, highly dispersed silicone dioxide, initiators, stabilizers, Potassium fluoride in an alcohol solution	V01809
N-Etch	Ivoclar Vivadent, Schaan, Liechtenstein	Etching gel, 35% Phosphoric acid	V11384

The specimens were randomly divided into eight experimental groups of ten teeth each as follows: groups 1, 2, 3, and 4 contained ten endodontically treated teeth in each group, which were prepared to be restored with prefabricated fiber post and core using exposed intracanal post technique; whereas in groups 5, 6, 7, and 8, the specimens were planned to be restored using non-exposed intracanal post technique.

After post space preparation, the surface of the prepared root canal and the outer surface of the dentine on top were etched with 37% phosphoric acid for 15 seconds, rinsed with normal saline for 10 seconds, and dried with air blow and paper points. The bonding agent (Excite DSC®, Ivoclar Vivadent) was applied into the prepared root canal and onto the dentin on the top of the specimens, then, carefully blown dried. Excessive bonding from the root canal was removed with paper points. Multicore®Flow (Ivoclar Vivadent) was used for cementing prefabricated fiber post and building up the core foundation at the same time with the adjunct of the prepared putty silicone blocks (Silagum®, DMG). In groups 1-4, Multicore®Flow was filled to reach the level of the tip of the fiber post, whereas in groups 5-8, Multicore®Flow was added 1 mm more on top to cover the tip of the fiber post. The LED light curing unit (Bluephase G2, Ivoclar Vivadent, light intensity 1,200 mW/cm^2) was carefully used for 40 seconds afterwards. After that, the core was polished with high-speed white stone bur under water coolant (Figure 1).

Finally, the specimens of all experimental groups were prepared to complete the thermocycling process in water bath (thermocycler, TC301) for different number of cycles which represented each specific water-exposing time period. Groups 1 and 5 were set for 209 cycles (= 1 week), groups 2 and 6 were set for 417 cycles (= 2 weeks), groups 3 and 7 were set for 833 cycles (= 4 weeks), and groups 4 and 8 were set for 5,000 cycles (= 6 months). [11,12] The protocol of each cycle was 5ºC and 55ºC with a dwell time of 30 seconds and transfer time of 15 seconds.
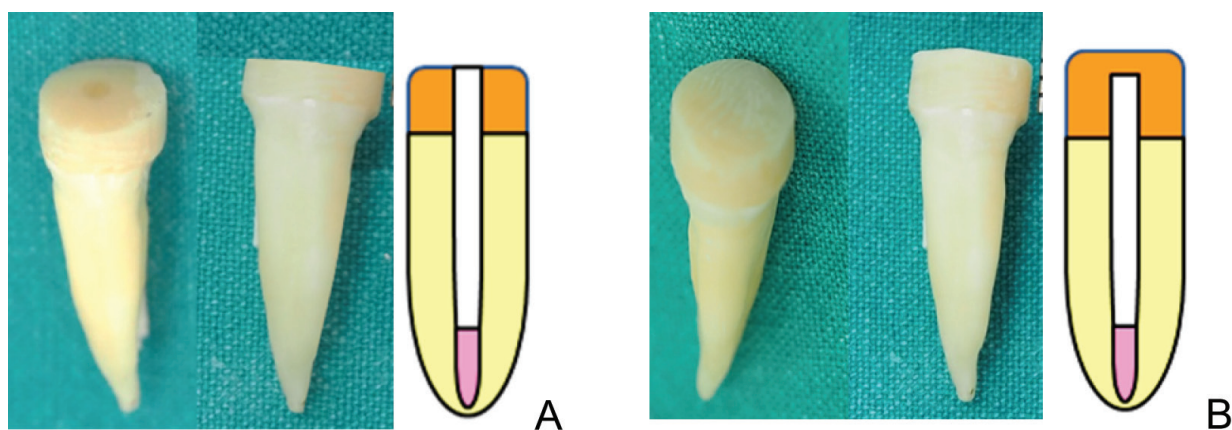
Figure 1   Finished specimens: (A) groups 1-4 restored with exposed intracanal post technique, (B) groups 5-8 restored with non-exposed intracanal post technique.
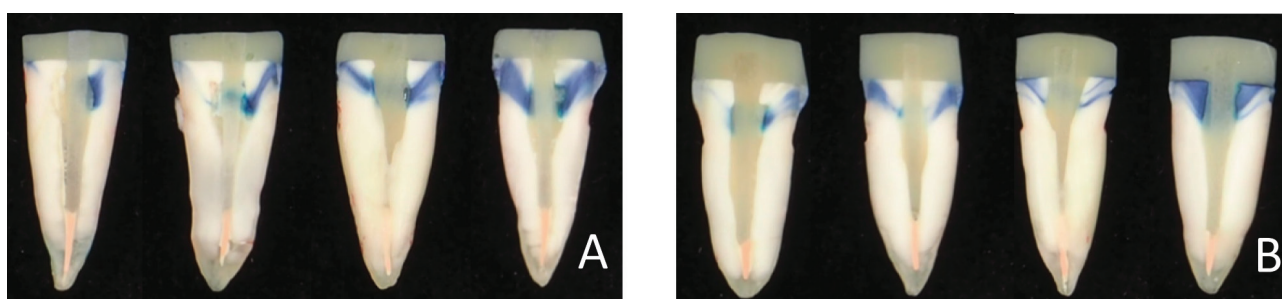
Microleakage measurement

The specimens were coated with double layers of nail varnish externally at 1 mm below the core material-tooth structure junction extending along the external root surface for preventing apical leakage and immersed in 2% Methylene blue (M dent®) for 48 hours at room temperature. The nail varnish was removed and rinsed under running water. For each experimental group, two additional specimens were used as controls: complete coverage with double layers of nail varnish acted as negative controls and roots with prepared post space without coronal restorations served as positive controls. Each specimen was then sectioned into two pieces vertically in the B-Li direction with low speed saw (Isomet™ 1000, Buehler®) at the center of the root passing through the fiber post. Photographs of each sectioned specimen were taken using digital camera (Oympus OMD E-M 10 mark II). Microleakage measurement was performed using the image analysis software (ImagePro® Plus software v.7.0). Dye-infiltration along the interface of post-dentine, post-core, and core-dentine was measured.

The highest degree of infiltration was selected as the data representing microleakage of each specimen. Mann-Whitney U-test and Kruskal Wallis test were used to determine statistical differences among microleakage of each group at a significant level of 0.05 using SPSS version 23.

Results

Coronal microleakage occurred in all experimental groups (Figure 2). All positive controls showed leakage throughout, whereas the negative controls showed no dye penetration. When comparing two techniques of prefabricated post and core fabrication at a certain water-exposing time period, microleakage has been measured with no significant difference except for the group with the longest water-exposing time (Table 2). At 6 months, the group with post and core material using exposed intracanal post technique showed significantly greater microleakage than the one using non-exposed intracanal post technique ($p = 0.02$).

Figure 2   Photographs of longitudinal section: (A) specimen from groups 1-4 restored with exposed intracanal post technique, (B) specimen from groups 5-8 restored with non-exposed intracanal post technique.

Table 2   Microleakage measurement (mean ± SD, mm) of all groups.

Techniques of fiber post cementation and core construction	Water-exposing time periods			
	1 week	2 weeks	1 month	6 months
Exposed intracanal post	6.00 ± 0.26	6.21 ± 0.21	6.65 ± 0.24	7.48 ± 0.34*
Non-exposed intracanal post	6.18 ± 0.17	6.47 ± 0.17	6.44 ± 0.28	6.34 ± 0.17*

*Indicates significant difference using Mann Whitney U-test at a significant level of 0.05.

Focusing on each technique of prefabricated post and core fabrication, the groups using exposed intracanal post technique showed significant difference of microleakage between the water-exposing time period of 1 week and 6 months ($p = 0.01$), whereas no differences were found when comparing other time periods (Table 3). On the contrary, there were no significant differences of microleakage among the groups using non-exposed intracanal post technique at any water-exposing time periods (Table 4).

Discussion

From this study, the experimental group with post and core restoration materials using exposed intracanal post technique showed significantly greater microleakage than the group using non-exposed intracanal post technique at the water-exposing time period of 6 months. Polarizing microscope evaluation showed that dye infiltration of less than 1 mm occurred at the outer interface of the fiber post and core materials in the specimens of the group using exposed intracanal post technique, while it was not found in the group using another technique (Figure 3). Additionally, SEM micrographs (400X) of the outer surface of the randomly selected specimens of the group with post and core materials using exposed intracanal post technique at the water-exposing time periods of 6 months revealed microgaps at some area of the post-core interface (Figure 4). These microgaps might be the cause of dye penetration at this interface area.

The microgaps at post-core interface of the group with post and core restoration materials using exposed intracanal post technique may be explained by the incomplete post-core integration between prefabricated post and core materials during the procedure or by the disintegration from the longtime of water exposure. The continuity of adaptation of the core material around the post plays an important role in the longevity of prosthesis of endodontically treated tooth. Incomplete post-core integration has also been reported in the study of Monticelli et al. [13] The gaps have been found at the post-core interface in every group using the combination of fiber post with different types of resin composite core materials and different core build-up techniques at each 1 mm section of the abutment. Moreover, the study of Khamverdi et al. [14] demonstrated that water storage had an effect on bond strength values of the prefabricated quartz fiber post and resin composite core material. The result showed that the longer the post-core complex was left directly exposed to the water, the weaker the bone strength of these materials, which compromised the long-term success of the post/core restoration.

Table 3   Microleakage measurement (mean ± SD, mm) of the groups using exposed intracanal post technique at 4 different water-exposing time periods.

|	Water-exposing time periods			
	1 week	2 weeks	1 month	6 months
Exposed intracanal post	6.00 ± 0.26*	6.21 ± 0.21	6.65 ± 0.24	7.48 ± 0.34*

*Indicates significant difference using Kruskal-Wallis test at a significant level of 0.05.

Table 4 Microleakage measurement (mean ± SD, mm) of the groups using non-exposed intracanal post technique at 4 different water-exposing time periods.

	Water-exposing time periods			
	1 week	2 weeks	1 month	6 months
Non-exposed intracanal post	6.18 ± 0.17	6.47 ± 0.17	6.44 ± 0.28	6.34 ± 0.17

*Indicates significant difference using Kruskal-Wallis test at a significant level of 0.05.
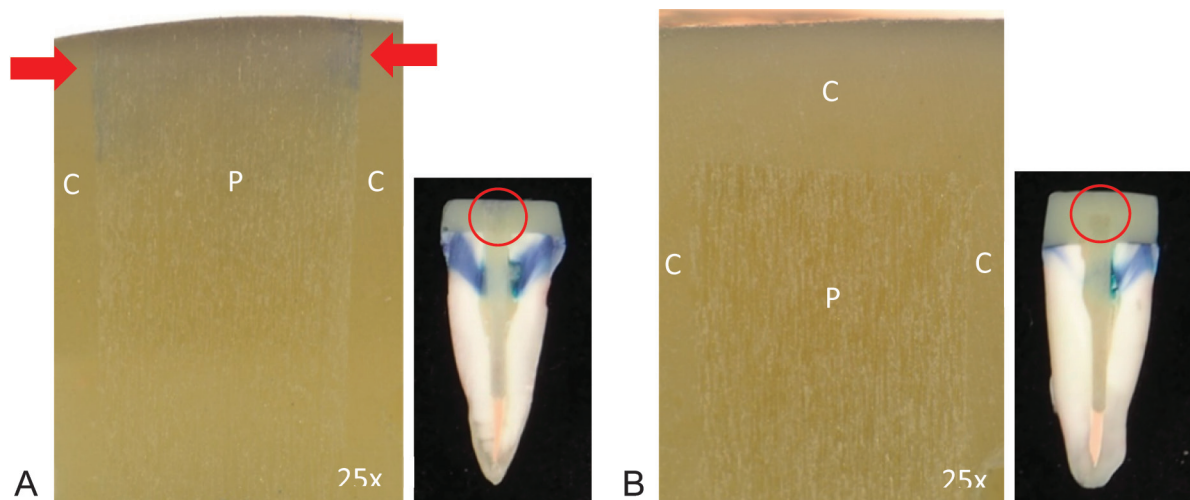
Figure 3 Dye infiltration of methylene blue at 25X magnification of polarizing microscope: (A) Sample of the group restored with exposed intracanal post technique showing dye infiltration (arrow) along the outer post(p)-core(c) interphase; (B) Sample of the group restored with non-exposed intracanal post technique showing no dye infiltration at the post-core interphase.
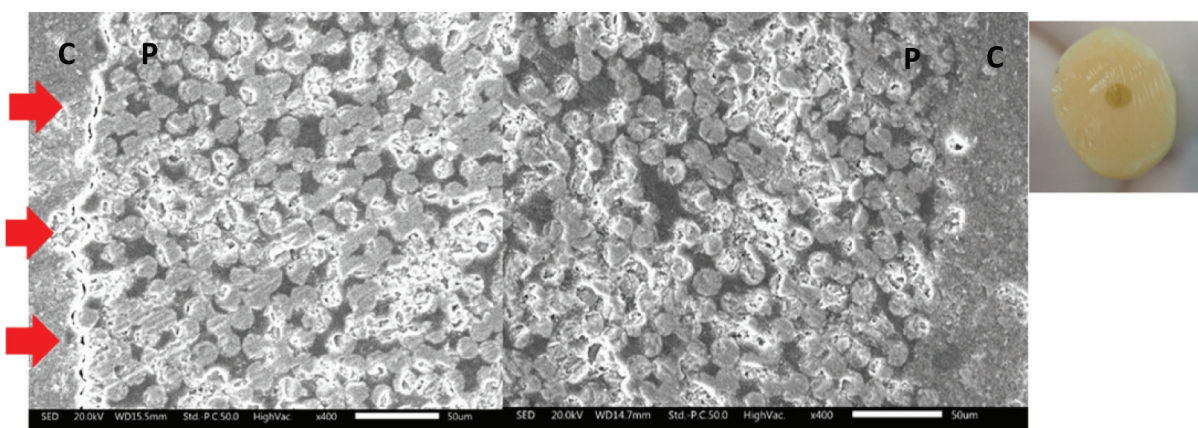
Figure 4 Representative SEM crossectional micrographs (X400; bar = 50 μm) of the outer surface of the post (p)-core (c) interface showing microgaps (arrows).

Regarding the morphological change of prefabricated fiber post, a previous study concluded that water storage had an effect on the morphological change of the fiber posts. Partial delamination of fibers from the resin matrix was found along the peripheral area of the fiber post after direct water storage up to several months. [15] However, in this study, no morphological changes of the fiber post were found within any group compared with the unused fiber post under SEM evaluation (Figure 5). This finding was also supported by the study of Veno et al. [9] This 5-year clinical study showed that no evidence of morphological change of fiber post related to water degradation was found when leaving the post head exposed to oral environment. Thus, the morphological change of fiber post did not affect the microgaps at the post-core interface in this study.

Morphologic change of resin material might occur and might be one of the causes of microgap found in this study. Martos et al. [16] evaluated the hydrolytic degradation of composite resin after 24 hours, 30 days, and 90 days of water storage and found microstructural change resulting from the loss of some inorganic particles into water, which are more electropositive and tend to react with water, especially zinc and barium. Multicore®Flow, which was used as core build-up material in this study, is also composed of barium glass. Thus, some morphological changes of Multicore®Flow might occur in the study.

The pattern of dye penetration in all experimental groups in this study appeared to be similar. For most of the groups, dye infiltration started from outer surface at the junction between core build-up material and dentin, then extended along their interface and ran along dentinal tubule of the root dentin reaching the post-dentin interface in the root canal. However, additional pattern of dye infiltration was found in the

specimens of the group using exposed intracanal post technique, namely the dye infiltration of less than 1 mm that occurred at the outer interface of the head of the exposed fiber post and core materials. Although this pattern was found in every group using exposed intracanal post technique regardless of the variation of the water-exposing time, greater numbers of specimens showing this pattern of dye infiltration were predominantly found in the group with the water-exposing time period of 6 months compared to the other groups using the same technique with lesser water-exposing time. However, the depth of this dye-penetrating distance reached only a few millimeters, which did not affect the total depth of dye penetration along the root canal. This specific pattern might merely have an effect on the long term success of the bond between fiber post and core material since the retention of core, which gives strength to the restoration, needs the effective bonding to the fiber post. [13] The microleakage that started from the junction between core build-up material and dentin, which occurred in all experimental groups, played an important role in the dye penetration into the post-dentin interface within the root canal. The maximum depth of dye penetration in every group extended mostly to the cervical third of the root length and did not reach the remaining gutta-percha at the apical area. In accordance with the study of Camilotti et al. [17], it has been found that the highest microleakage penetration did not exceed the middle third of the root, which showed that the leakage might not affect the periapical tissue. However, from the previous study of Oliveira et al. [18], the result showed that 70% of the root canals that received an intracanal post cemented with resin cement experienced microbial recontamination at the periapical area in a short period of time. Therefore, the method of measuring microleakage might affect the presented outcome.
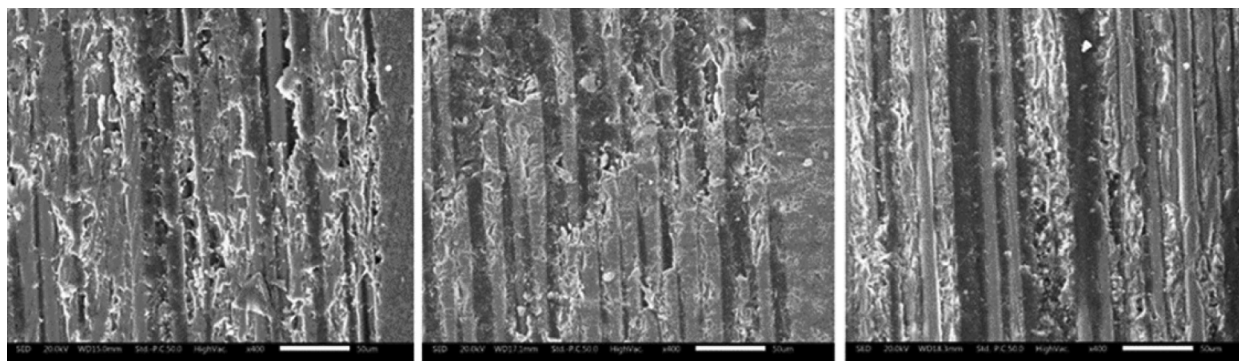
Figure 5 Representative SEM longitudinal micrographs (X400; bar = 50 μm) of fiber posts: (left) fiber post of the group restored with exposed intracanal post technique, (center) fiber post of the group restored with non-exposed intracanal post technique, (right) fresh fiber post.

Dye penetration has been the most commonly used technique in the microleakage studies. [19,20] The degree of leakage could be evaluated by three methods: longitudinal sectioning, transverse sectioning, and clearing; each method has its own benefits and shortcomings. Previous study revealed that leakage measured by any of these techniques did not show significant difference, therefore, easy and non-destructive technique should be preferred. Furthermore, microleakage has been measured as different values in previous literature, including, an ordinal score, percentage of the leakage length to the total length of observed interfaces, and linear leakage length. [19] In this study, longitudinal sectioning technique was selected for the measurement of linear leakage length, which required high standardization of the specimens, in that, the teeth with an approximate same size and length were selected and all the preparation and post length were identically performed. [19,21] Methylene blue at 2% was employed to evaluate the degree of microleakage infiltration since it is more penetrable than other tracers. [21] Although the small particle size of methylene blue may result in an overestimate of the infiltration, dye penetration in this study was found to be 6.0-7.5 mm, which was within the range of 0.5-7.6 mm reported in the literature. [19,21] Although some previous studies reviewed that

dye infiltration in microleakage test did not represent correct results related to clinical success or failure of endodontically treated tooth, the exact significance of the degree of infiltration remains unknown. [17,22] Furthermore, *in vitro* study of microleakage tests undertaken thermal cycling facilitates the simulation of the clinical situation, as it was also done in this study. [17] Concerning another point that the particle size of methylene blue is smaller than the average size of bacteria, which cannot distinguish between too narrow and sufficiently wide gaps for bacterial passage, however, enzymes and toxins metabolized by the bacteria have similar dimension to this dye solution. [17,20] Moreover, methylene blue infiltration may serve as the prediction of bonding deterioration between the core material, luting cement, and dentin surface that leads to mechanical failure of the restoration.

Despite water-exposing time variation, two techniques of fiber post cementation and core construction used in this study did not give much difference in terms of microleakage, including the degree of dye infiltration and its penetration pattern. Only when leaving the post and core materials exposed to water for a longer period of time, the technique using non-exposed intracanal post showed lesser microleakage and better post-core integration at the top of the restoration. When restoring endodontically treated tooth with

fiber post and core materials using exposed intracanal post technique, the duration of water-exposing time should be of interest. To decide which technique is more appropriate to be used in the clinical situation when fiber post and core materials have to be left uncovered for a period of time in the oral environment, further studies need to be performed regarding other aspects.

Conclusions

Under the simulated conditions of this study, the following conclusions could be drawn:

- Microleakage was presented in all groups using two different techniques of fiber post cementation and core construction at any water-exposing time periods.
- Microleakage result of the group with fiber post and core materials using exposed intracanal post technique was significantly higher than that of the group using non-exposed intracanal post technique at the water-exposing time of 6 months.
- No significant difference in microleakage was found in the groups with fiber post and core materials using non-exposed intracanal post technique resulting from water-exposing time variation.
- There is a significant difference in microleakage observed in the groups with fiber post and core materials using exposed intracanal post technique resulting from water-exposing time variation.

Acknowledgement

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