

Microleakage of Different Post Systems and a Custom Adapted Fiber Post

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Abstract

Objective: The effects of closely adapting a prefabricated fiber to the post space remain unknown. The purpose of this study was to quantify the microleakages of a custom adapted fiber-reinforced post, a prefabricated quartz fiber post and a cast post using nondestructive methods.

Materials and Methods: Sixty-five extracted human premolars were endodontically treated and randomly divided into three groups (n=15), which were restored using a cast post-and-core, a custom adapted fiber post (Refropost) with a microhybrid microfiller resin composite (Gradia), or a prefabricated quartz fiber post (DT light post) and two groups of control (n=10). All groups were cemented using a dual polymerizing resin cement (Panavia F_{2.0}). A composite core (Z100) was used for the fiber posts. The microleakage was calculated for the experimental and control groups before and after thermal cycling and cycling loading using a radio-tracer solution (thallium 201 chloride) and a gamma counter device. Data were subjected to statistical analysis of ANOVA and Tukey HSD at significant level of P< 0.05.

Results: Significantly lower microleakage values were found for the cast post-and-core (mean value = 16.04×10^4) and custom adapted fiber post groups (mean value= 14.36×10^4). Thermal cycling and cyclic loading had no significant effect on the microleakage value of any tested group.

Conclusion: Post systems with improved adaptation showed similar microleakage to casting posts.

Key Words: Microleakage, Thallium, Fiber post
Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2013; Vol. 10, No.1)

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Received: 17 September 2012
Accepted: 5 December 2012

INTRODUCTION

In teeth with extensive coronal tissue loss, a post-and-core foundation is usually needed to

retain a definitive restoration[1]. In the past decades, a commonly employed system included a prefabricated fiber post and adhesive

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cement followed by core build-up [2]. Advantages of using prefabricated adhesive posts include improved aesthetics and retrievability, as well as the need for only one treatment/visit [3,4]. Due to the lower elastic modulus of fiber posts which are closer to that of dentin, better stress distribution is expected [3]. Clinical studies; however, show that failure can occur with all restorative systems, including post-and-core systems [5]. Debonding and retention loss are common failure modes with fiber posts [6,7]. The retention properties of posts depend on their design, length, surface treatment, fitting accuracy and the resistance of luting agents to dislodging forces generated during function [8,9].

Of the prefabricated posts, the retentive value of parallel posts is higher than that of tapered posts [10]. However, since the root canal anatomy may be neither circular in cross section nor cylindrical in length, shaping the canal using the drill supplied with the post kit frequently sacrifices the remaining dentin, especially in the apical third [1]. Therefore, tapered posts are preferred to avoid weakening the teeth that already have lost a part of their hard tissues due to caries or root canal therapy.¹¹ However, passive tapered posts are less retentive than other prefabricated post types [3]. To improve the retentive ability of passive tapered posts, it is important to maintain both close adaptation of the post to the post space and a homogeneous thin cement layer [12]. However, due to the individual curvature and cross-sectional shape of root canals, differences between post space preparation and the root canal wall have been reported even when the corresponding preparation burs of a post system was used [13]. With sub-optimally adapted posts, cement can fill the excess space between the post and root dentin, allowing excessive and hazardous stress to concentrate within the cement layer during functional loading [14]. The mechanical properties of the luting agent must therefore be considered when determining the localized stress. Voids and imperfec-

tions along the bonded interface can result in gap formation and enhance microleakage, leading to coronal and/or apical failure [15].

A few studies have investigated the influence of post adaptation on fracture resistance [16,17]. These have revealed that shrinkage stress in the resin cement layer and external loading can cause irregularities, crack formation and post debonding [18-20], which are related to increased microleakage. However, few studies have directly addressed the microleakage. Less microleakage was found in over-flared canals restored by individually shaped posts using a polyethylene woven fiber ribbon (Ribbond) compared to those restored by a preshaped glass fiber or quartz fiber post [21]. However, another study revealed similar microleakage values when a custom Ribbond post or glass fiber post was used [22]. To our knowledge, it remains unknown how the close adaptation of a fiber post may affect the microleakage of such systems under fatigue loading. Therefore, the aim of the present study was to compare the microleakage of teeth restored with a custom adapted fiber post and those restored with an indirect resin composite, both with and without cyclic loading. The null hypothesis was that there was no difference between the microleakages of a prefabricated fiber post, a custom adapted fiber post with a highly-filled resin composite and a custom casting post.

MATERIALS AND METHODS

Sixty-five extracted single-rooted human teeth were used, none of which displayed cervical lesions, cracks, craze lines or resorption of the immature apices. The teeth were almost straight in the 10-mm coronal portion of the root length. To ensure similarity in teeth dimensions, the buccolingual and mesiodistal dimensions and the root length were measured using a digital caliper (Series 500 Caliper, Mitutoyo, Tokyo, Japan) with an accuracy of 0.01 mm. Teeth within 0.5 mm of an average 7-mm buccolingual dimension and 5-mm mesiodistal

dimension and within 1 mm of a 15-mm ro-length were selected [23]. Experimental group teeth were decoronated from the most coronal portion of the cemento-enamel junction (CEJ) using a diamond bur in a high-speed hand piece under water spray.

Root canal preparation

Each tooth was endodontically treated with a working length 1-mm shorter than the length at which a # 10 K file tip (MANI Inc., Kiohara Industrial Park, Tochigi, Japan) passed the apical foramen, using the flat surface of a coronal section as a reference point. Canals were prepared to a master file size of 40 using the step-back technique and were flared up at the middle third and coronal third using Gate Glidden # 2 and #3 (Maillefer, Dentsply, Ballaigues, Switzerland), respectively. Files were replaced after use in four canals.

The access cavity was filled with a non-eugenole provisional material (Cavit-G, 3M ESPE, St Paul, MN).

The apical fourth was sealed externally with a glass ionomer cement (Ionofill, Lot 002033, VOCO, 3M ESPE) and stored in normal saline for 72 h before post space preparation. Gutta-percha was removed with #2 specified reamers of a DT light post (RTD, St. Egreve, France) to create a 9-mm-long post space. Drills were discarded after five tooth preparations.

Post and core fabrication

Specimens were randomly allocated into three experimental groups; namely, cast post (CP), custom adapted fiber post (CF) and prefabricated post (PF) groups.

Cast post group

A groove (1 mm deep, 2 mm long) was prepared as an antirotation using a diamond bur (#856-010, D-Z Co., Bern, Switzerland) to prevent post rotation during cementation. Passively fitting polycarbonate posts (Pin-jet, Angelus Dental Solution, Lonrina, Brazil) were

adapted to the post space with auto-polymerizing acrylic resin (Pattern Resin, Lot 0505061, GC America Inc., Alsip, IL). The occlusal surface was formed with two cusps of 15°.

A silicone index (Putty, Speedex, Coltene/Whaledent Inc., Apadana Tak, Tehran, Iran) was used to standardize the preparations. Patterns were cast in a base metal alloy (Vera-Bond, Fairfield, CA).

Canals were cleaned with water and dried. A self-etching primer (ED Primer, Lot 51169, Kuraray Co. Ltd., Osaka, Japan) was applied to each canal with a microbrush tip (Microbrush International, Waterford, Ireland) and was air-thinned after 60 s. Margins were light-polymerized (Coltolux 75, Coltene/Whaledent) for 60 s at 500 mW/cm² and a distance of 1.0 mm.

Custom adapted fiber post group

An antirotation was prepared as described for the CP group. A #2 glass fiber post (Reforpost, Angelus Dental Solution) was placed in the canals and cut 3 mm above the tooth surface with a diamond disk (Edenta AG Dentalprodukte, Hauptstrasse, Switzerland). Post spaces were coated with a thin layer of a separating agent (GC Gradia Separator, GC Corp., Tokyo, Japan).

Airborne abrasion was used on the post surface with 50-µm aluminum oxide particles (Shenzen Co, Shanghai, China) under 3 kg/cm² of pressure for 10 s at a distance of 5 cm.

Post surfaces were conditioned with two layers of a saline solution (Monobond S, Viva-dent, Schaan, Liechtenstein).

One layer of a self-etching light-polymerizing bonding agent (G Bond, lot 1002051, GC Corp.) was applied to the post surfaces, gently air dried and exposed to 500 mW/cm² light (Coltolux 75) for 20 s at a distance of 1.0 mm. A microhybrid microfilled resin (MFR) composite (Shade DA2, lot 0909102 Gradia Indi-

rect, GC Corp.) was applied to the post surfaces and in the canals using a microbrush (Microbrush International). Any voids or defects on the post surfaces were corrected by adding composite and light polymerizing for 60 s. The core was fabricated by indirect composite (DA2 GC Gradia, GC Corp.) to a height of 5 mm. Each layer was initially light polymerized in the Gradia Step Light unit for 10 s.

Prefabricated post group

A quartz fiber post (DT light post, RTD) was inserted in the prepared post space cut 12 mm from the apical end using a diamond disk (Edenta AG Dentalprodukte).

Control groups

The negative control group included 10 untreated teeth that were sectioned 4 mm above the most coronal portion of the CEJ. The teeth were sealed on both ends with cyanoacrylate (Super Glue, Razi Chemicals, Terhan, Iran). In the positive control group (n= 10), the canals were obturated with gutta percha, but no sealer was used and the access cavity was not temporized.

Microleakage test

For the experimental groups, a double layer of nail varnish (My, Kahl & Co, Ghazvin, Iran)

was painted on the root surfaces at 1-mm apical to the core interface. For the control groups, all surfaces except (positive control) or including (negative control) the access cavity were coated.

All specimens were immersed for 24 h in 50 cc of a thallium 201 chloride solution (MDS Nordion, Fleurus, Belgium) with the specific activity of 1 mCi.

The specimens were washed with a liquid detergent material (Prill, Henkel, Saveh, Iran) on a swab tip for 60 s.

Specimens were inserted in a specific tube, with care being taken to position them identically and were placed in a gamma counter device (Kontron Gammamatic, Neufahrn, Germany).

The radiation was counted with a thallium 201 photon pick of 77 Kev and an energy window of 15% for 60 s.

To eliminate the radioactive physical contamination, the specimens were then kept in a lead shield container for 12 day.

To simulate the oral condition, all specimens were subjected to thermal cycling (TC) between 5° and 55° for 60 s each and a dwelling time of 12 s.

The periodontal ligament was simulated on the roots of teeth in the cyclic loading (CL) test groups using a silicone index.

Table1. Mean gamma counts of experimental groups

	groups	N	Mean	Std ^a	Minimum	Maximum
Before	CP	15	16.04 ×10 ⁴	4.20×10 ⁴	7.98×10 ⁴	24.33×10 ⁴
	CF	15	14.36×10 ⁴	7.86×10 ⁴	4.35×10 ⁴	33.81×10 ⁴
TC/CL	PF	15	25.54×10 ⁴	7.09×10 ⁴	4.35×10 ⁴	36.93×10 ⁴
	Positive control	15	29.92×10 ⁴	8.39×10 ⁴	14.4×10 ⁴	43.74×10 ⁴
After	CP	15	14.8×10 ⁴	3.58×10 ⁴	7.99×10 ⁴	20.26×10 ⁴
	CF	15	13.6×10 ⁴	5.28×10 ⁴	7.68×10 ⁴	25.71×10 ⁴
TC/CL	PF	15	22.58×10 ⁴	7.33×10 ⁴	11.58×10 ⁴	39.11×10 ⁴
	Positive control	15	26.51×10 ⁴	2.62×10 ⁴	13.82×10 ⁴	47.50×10 ⁴

^a = standard deviation

Specimens were subjected to 100,000 cycles of 50 N load at a frequency of 1.5 Hz to simulate 6 months of service [17]. After loading, specimens were removed from the acrylic block and carefully cleaned. Nail varnish was applied as described above. The microleakage was measured after immersing the specimens in thallium 201 solution, as described above. The net microleakage in experimental groups was calculated by subtracting the mean microleakage value of negative controls" known as surface contamination" from the measured value of each specimen. One-way ANOVA, Tukey HSD post-hoc and Dunnett T3 tests were used to reveal any difference between the mean microleakage values of the tested groups, either before or after TC/CL. To compare the microleakage values of each group before and after TC/CL, the paired *t*-test was used. The significance level was set to $\alpha = 0.05$ and the statistical software SPSS ver. 11 (SPSS Inc, Chicago, IL) was used.

RESULT

None of the specimens failed during the loading period. Dislodgements that caused loss of contact with the loading head or fracture were considered failures. Greatest microleakage occurred in the positive control and PF groups before and after TC/CL. Except for the negative control, the lowest microleakage was found in the CP and CF groups before and after TC/CL (Table 1). Before TC/CL, ANOVA revealed significant differences in the mean microleakage values among post systems.

Multiple comparison tests indicated that CP and CF had significantly lower microleakage values than PF and the positive control, but PF and the positive control were not significantly different (Table 2).

The same microleakage ranking was found in the test groups after TC/CL. No difference was found between the microleakage values of each test group before and after TC/CL.

DISCUSSION

The null hypothesis of the present study was rejected, because the custom adapted fiber post and the cast post had significantly lower microleakage values than the prefabricated fiber post.

However, TC/CL did not affect the microleakage values in the tested groups.

Due to the use of different combinations of post systems, luting materials and methodologies, it is not possible to directly compare the results of previous studies to the present results.

However, previous studies have generally shown that a lower microleakage value corresponds to improved fiber post fitness. Using systems without cores, Usumez et al. [22] found significantly less microleakage using a direct custom fiber post with a polyethylene woven fiber post ribbon (Ribbond) compared to systems using a prefabricated stainless steel (Para Post) or zirconia post.

No difference was seen compared to a prefabricated fiber post in contrast to the results of the present study.

Table 2. The results of multiple comparisons test before TC/CL

Groups	CP	CF	PF	Positive controls
CP	NA	P=.915	P=.01	P=.001
CF	P=.915	NA	P=.02	P=.001
PF	P=.01	P=.02	NA	P=.43
Positive Controls	P=.001	P=.001	P=.43	NA

The level of significance was set at $\alpha=0.05$

Our custom adaptation procedure improved post accuracy through a process of removing the post from the canal and directly repairing any voids with composite resin.

A third generation indirect composite (Gradia) was used to closely adapt the custom FRC post. The MFR composite incorporates ceramic fillers with a mean particle size of less than 1 μm , which is twice the content of organic matrix (~ 66% inorganic fillers and 33% resin matrix). The increased filler content improves fracture toughness (resistance to crack propagation) and decreases polymerization shrinkage. Surfaces bonded to Gradia are more compliant (i.e., can relieve shrinkage strain) [24] than those directly bonded to the post surface (such as in the PF group). Furthermore, the elastic modulus of Gradia (50 MPa) [25] is 400 times lower than that of the DT light post (20 GPa), permitting the composite resin layer to undergo more plastic deformation and to compensate for the negative effect of stress production under loading and during polymerization [26,27].

Another explanation for the different results is the use of different microleakage measurement methods. The poor correlation among different microleakage evaluation methods is related to differences in the mechanisms of action. The fluid filtration method assesses the liquid forced through the voids and gaps between dentin, cement, post and/or sealer and the filtration law is applied to any liquid movement. Tracer penetration depends on passive capillary movement [28]. Despite methodological differences, the results of the present study were consistent with those of a study conducted by Erkut et al. [21], in which individually formed fiber posts performed better than pre-shaped glass or quartz fiber posts in term of microleakage measured by dye penetration. A dual polymerizing adhesive cement (Rely X Arc) was used to compensate for the remaining space in the coronal portion of the overflared canals, which appear to be weaker. This finding may have contributed to the high-

er microleakage values of the two prefabricated post types in their study.

Thermal cycling and mechanical loading did not influence the microleakage values of posts in the present study. Repeatedly applying a low magnitude force to restorative materials in the oral environment can introduce failure over time, by propagating flaws and microcracks along the interface between the post-and-core and tooth structure [1,9,14]. It is recommended to simulate the masticatory cyclic loading when investigating the clinical application of a restorative material [29]. Application of an insufficient number of loading cycles may help explain our obtained results, because sufficient time is required for the cracks to become macroscopically detectable [9]. Mechanical loading protocols that simulate years of clinical service may be considered as "accelerated aging" protocols [20]. In reality, it takes years for a cement to disintegrate due to microleakage subsequent to a gap. In addition, simultaneous TC/CL was not possible because of the design limitations of the machine used. More cycles and simultaneous TC are recommended for future investigations [30]. Several attempts were made to standardize the specimens in the present study. The dimensions of included teeth were measured to be similar and standardized rotary instruments were used to finish the root canals and prepare post spaces. However, no crown or ferrule (a minimum residual 1.5-2 mm vertical length of coronal dentin) was considered. The reinforcement effect of these factors could obscure the effect of the post and cement types. In vitro microleakage investigations are increasingly criticized for their limited clinical application. Nevertheless, quantified methods (e.g., fluid filtration) are preferred over non-quantified methods (e.g., dye penetration) [31]. The method adopted in the present study, namely gamma counting, may be considered a quantified method. Radioisotopes are routinely used in visualizing physiologic body images [32], and thallium 201 is a cyclotron-generated radionuclide that

degrades to mercury (emitting x-rays) and thallium (emitting gamma rays). A specific gamma counter or high resolution camera can produce the gamma profile absorbed by a specimen immersed in the appropriate solution for several hours [32]. The solution concentration used in the present study was determined by trial and error, since similar studies were unavailable from the literature. Similar to fluid filtration, the gamma counting method is repeatable and non-destructive to the specimens, allowing other tests to be performed simultaneously. The size of the hydrated thallium 201 ion is similar to that of the hydrated potassium ion, which can enter any gap along in a water molecule [32]. Hydrodegradation of the fiber post is one possible source of increased flexibility and deboning [4]. Thallium tracing may reveal the amount of water contaminating a test specimen and is therefore relevant to the physiological oral condition. In the future, a specified camera could be used to obtain more information on the pattern of microleakage.

CONCLUSION

Within the limitations of the present study, we conclude that the microleakages of the custom-adapted fiber post-and-core and cast post-and-core systems were significantly less than that of the prefabricated fiber post system. The microleakage values of the test groups showed no significant difference after short-term TC/CL.

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