https://doi.org/10.14368/jdras.2023.39.4.187
ISSN 2384-4353 eISSN 2384-4272

Original Article

The influence of fitness and type of luting agents on bonding strength of fiber-reinforced composite resin posts

Kkot-Byeol Bae[1†], Hye-Yoon Jung[2†], Yun-Chan Hwang[1], Won-Mann Oh[1], In-Nam Hwang[1]*
[1]*Department of Conservative Dentistry, School of Dentistry, Chonnam National University, Gwangju, Republic of Korea*
[2]*Moa Dental Clinic, Seoul, Republic of Korea*

Purpose: A mismatched size in the post and post space is a common problem during post-fixation. Since this discordance affects the bonding strength of the fiber-reinforced composite resin post (FRC Post), a corresponding luting agent is required. The aim of this study was to evaluate the bonding strength of the FRC post according to the fitness of the fiber post and the type of luting agent. **Materials and Methods:** Thirty mandibular premolar were endodontic-treated and assigned to two groups according to their prepared post space: Fitting (F) and Mismatching (M). These groups were further classified into three subgroups according to their luting agent: RelyX Unicem (ReX), Luxacore dual (Lux), and Duolink (Duo). A push-out test was performed to measure the push-out bond strengths. The fractured surfaces of each cross-section were then examined, and the fracture modes were classified. **Results:** In the ReX and Duo subgroups, the F group had a higher mean bond strength; however, the Lux subgroup had no significant difference between the F and M groups. In the analysis of the failure modes, the ReX subgroup had only adhesive failures between the cement and dentin. **Conclusion:** The result of this study showed that the bond strength of an FRC post was influenced by the type of luting agent and the mismatch between the diameter of the prepared post space and that of the post. **(J Dent Rehabil Appl Sci 2023;39(4):187-94)**

Key words: fiber-reinforced composite resin post; failure modes; push-out bonding strength

Introduction

The restoration of endodontic-treated teeth is often challenging because of the loss of tooth structure by caries, fractures, restorative procedures, and endodontic access preparations. The use of posts is a universally accepted procedure for endodontic-treated teeth with insufficient coronal tooth structure. The reason for that is the use of posts maintains the core and increases the resistance form of the tooth.[1] The use of a fiber-reinforced composite resin post (FRC post) to restore an endodontic-treated teeth has become widely used in the last few years. The most important clinical feature of an FRC post is that it has a dentin-like elastic modulus and a high flexural strength.[2,3] The high flexural strength of the post causes the stress over the tooth to act onto the interfaces between the post, resin cement, and dentin, causing fractures or missing restoration rather than root fracture.[4] Since an FRC post leads to a re-restoration treatment rather than the extraction of the tooth, the overall restoration increases the success rate of endodontic-treated teeth.

One of the clinically relevant problems that den-

*Correspondence to: In-Nam Hwang
Professor, Departmentof Conservative Dentistry, School of Dentistry, Chonnam National University, Youngbong-ro 77, Buk-gu, Gwangju, 61186, Republic of Korea
Tel: +82-62-530-5819, Fax: +82-62-530-5629, E-mail: hinso@jnu.ac.kr
Received: August 28, 2023/Last Revision: September 17, 2023/Accepted: October 12, 2023
†Contributed equally to this work as first authors.

tists face when restoring endodontic-treated teeth is the mismatch between the diameter of the post and that of the post space.[5-8] With the advent of dentin adhesives and the concept of bonding, compared to the retention strength provided by conventional luting materials such as zinc phosphate cement, composite resin cement is currently used to improve the retention strength of the posts.[9]

There are few treatments in the scientific literature linking the post space and retention strength of FRC posts since the most frequent cause of bonded FRC posts failure is debonding.[10] The aim of this study was to assess the effect of the degree of mismatch between the post space and post diameters and the effect of the luting agents on the bond strength of FRC posts bonded to root canal dentin. The null hypotheses tested in this study were: 1) The accuracy of the fit between the post and post space does not influence the bond strength, and 2) there is no difference in the bond strength among the various luting agents.

Materials and Methods

This study was conducted under the approval of the exemption from the Institutional Review Board of Chonnam National University Dental Hospital (CNUDH-2023-008). Each patient consented to the study and was provided written informed consent. The mandibular premolar were obtained from patients who visited the Department of Oral and Maxillofacial Surgery at Chonnam National University Dental Hospital for tooth extraction due to periodontal reasons. Male and female patients 20 - 90 years old were selected for the extraction procedure. Thirty intact teeth were obtained, and the exclusion criteria were as follows: impaired teeth with fractures or caries, restored teeth, previous root-canal treated teeth, teeth with roots shorter than 16 mm, and teeth with defects or cracks.

The external debris was removed from the teeth using an ultrasonic scaler (Suprasson P-max; Satelec/Acteon Equipment, Merignac, France). The crown surface of each tooth was sectioned horizontally to the cement-enamel junction (CEJ) using a cylindrical diamond rotary cutting instrument. The exposed surface of the dentin was made flat and perpendicular to the longitudinal axis of the tooth using the abrasion of a grinding device.

Endodontic access was carried out with a high-speed handpiece round bur and water spray. A crown down technique was used for instrumentation using Gates Glidden (Moyco, Union Broach, York, USA) #2 to #4 drills, and then rotary files, ProTaper Universal (Dentsply-Maillefer, Ballaigues, Switzerland), were used incrementally up to F2. A solution of 5.25% NaOCl was used for a root canal irrigant during instrumentation. The enlarged canals were rinsed with distilled water and dried with paper points. The exclusion of the effect of the endodontic sealer kept the enlarged canals from being obturated. Due to the remaining root-filling material, such as gutta-percha, the bonding strength after the preparation of the post space could be influenced by the irregular form of the root canal.

The 30 teeth were randomly divided into two experimental groups according to the fitness of the FRC post. Post spaces were prepared to a depth of 12 mm from the sectioned root surface using drills with a different diameter (Table 1). Fitting group (F) used DT drill #2 (1.0 mm in tip diameter) from the DT Light-Post kit (Bisco, Schaumburg, USA) to form a 12 mm length post space. Mismatching group (M) used Peeso reamer (Komet, Schaumburg, Germany) by dividing the 12 mm length into apical 1/2 and coronal 1/2. Post spaces were formed with #5 (1.5 mm in diameter) and #6 (1.7 mm in diameter), respectively. In both F and M groups, DT Light-Post #2 (1.0 mm in tip diameter) was used as the FRC post. DT Light-Post has a double-tapered shape. DT Light-Post #2 has a tip diameter of 1.0 mm, 0.02/0.08 taper, and the widest diameter is 1.52 mm. Peeso reamer does not have a taper, so Peeso reamer #5 with a tip diameter of 1.5mm can create a mismatch space in the apical 1/2, but is narrow for use in the coronal 1/2. Therefore, in the M group, coronal 1/2 used Peeso reamer #6 with a diameter of 1.7 mm to create a post space larger than the widest diameter of DT Light-Post #2. Each group was further divided into three subgroups according to the luting agent and bonding system (Table 2). The teeth

Table 1. Experimental groups

Main groups (n = 15)	Post space	Manufacturer	FRC post
F	DT drill #2	Bisco, Schaumburg, USA	DT Light post #2
M	Apical 1/2: Peeso reamer #5 Coronal 1/2: Peeso reamer #6	Komet, Schaumburg, Germany	DT Light post #2

Table 2. Subgroups according to the luting agent

Subgroups (n = 5)	Adhesive System	Pretreatment	Pretreatment Time (s)	Primer/ Adhesive	Luting agent	Manufacturer
ReX	Self adhesive	-	-	-	RelyX Unicem	3M ESPE, Seefeld, Germany
Lux	Self etching	Self-etching primer	30	Contax	Luxacore dual	DMG, Hamburg, Germany
Duo	Total etching	Phosphoric acid 32%	15	All bond 2	Duolink	Bisco, Schaumburg, USA

were then restored with the various resin cements and bonding systems.

RelyX Unicem (ReX)

RelyX Unicem (3M ESPE, Seefeld, Germany) is a self-adhesive system that does not require any bonding agent and can adhere directly. After, the post space was rinsed with distilled water and dried using paper points. A Rex capsule was inserted in an Aplicap Actiator (3M ESPE, St. Paul, USA), and the lever was pressed for three seconds to allow time for the powder and liquid to mix. After being mixed in a Rotomix (3M ESPE) for ten seconds, the capsule was placed in an Aplicap Applier. The mixed cement was then loaded into a Uni-dose needle tip (Bisco), and the needle was placed in the canal orifice.

LuxaCore-Dual (Lux)

LuxaCore-Dual (DMG, Hamburg, Germany) group used Contax (DMG) as a pretreatment step. Each canal was conditioned with the self-etch primer from Contax for 30 seconds. After, the excess solution was removed with paper points, and then the post space was gently air-dried. Afterward, one drop each of the bonding agent and activator from Contax were mixed and applied to the post space wall with a microbrush for 30 seconds. The excess solution was removed with paper points, and then the post space was gently air-dried. The post space was light-cured using a light-curing unit (Elipar DeepCure-S, 3M ESPE, St. Paul, USA) for 20 seconds. Lux was then applied to the canal.

DuoLink (Duo)

DouLink (Bisco) group used etchant and All Bond 2 (Bisco) as a pretreatment step. The canals were etched using 32% phosphoric acid (Uni-Etch, Bisco) for 15 seconds, rinsed with distilled water for 10 seconds, and dried with paper points to leave the moist of dentin. The remaining moisture was removed by air drying. After mixing Primer A and Primer B from All Bond 2, the mixture was applied, and the excess material was removed with paper points and air dry. Pre-Bond resin from All Bond 2 was applied, and the excess material was removed with paper points and air dry. The post space was light-cured using a light-curing unit for 20 seconds. Equal amounts of Duo base and catalyst were mixed for 15 seconds until a uniform paste formed. The cement was applied using a Unit-dose needle tip and injected into the canal.

The following explanation is a commonly performed method regardless of the type of cement. The roots were restored with a DT Light post #2 and silanized with Monobond S (Ivoclar Vivadent, Schaan, Liechtenstein) before cementation. Each FRC post was prepared immediately prior to its cementation. All Cement-covered posts were then seated to the full depth in the prepared spaces using finger pressure and ensuring that the posts were extended to the same length from the orifice of the canal. The excess luting agent was immediately removed with a microbrush. Immediately after cementation, the roots were light-cured using a light-curing unit for 20 seconds. After four minutes, the roots restored with cemented posts were stored in sterile water for 24 hours at room temperature.

After embedding the teeth in self-curing resin for orthodontics (Caulk Orthodontic Resin, Dentsply Caulk, St. Paul, USA), five segments from the root apical to the CEJ were obtained by sectioning the root with a low-speed diamond saw (METSAW MSH 04-112, R&B INC., Daejeon, Korea). The sections were 1.0 ± 0.1 mm thick. Each specimen was marked on its coronal side, and the specimen thickness was measured with a digital caliper (Mitutoyo, Kanagawa, Japan). The sections were stored individually in sterile saline for 24 hours. After the slicing process, based on the coronal surface images of each specimen captured using a digital camera, the specimens that had voids and insufficient cement space were excluded. In total, 120 specimens were selected, with 20 specimens in each group.

The push-out bond strength was measured using a universal testing machine (Micro Load System; R&B inc.) at a cross-head speed of 0.5 mm/min. The coronal surface of the tooth was placed facing the jig. And the post was centered over the hole in the jig until the post was dislodged. After the surface area (mm^2, formula 1) of the filled space was calculated with the radiuses (R, r) and height (h) of each specimen, the debonding stress (MPa, formula 2) was obtained by dividing measured force (N) by the surface area (mm^2).

$$\text{Surface area } (mm^2) = \{(R + r) / 2\} \times \pi \times h \quad \text{[formula 1]}$$

$$\text{Debonding stress (MPa)} = \text{Debonding force (N)} / \text{Area } (mm^2) \quad \text{[formula 2]}$$

After the push-out tests, each sample was observed using a microscope (OPMI pico; Carl Zeiss, Oberkochen, Germany) at 23× magnification from the cervical and apical directions to determine the failure mode. The specimens were divided into four categories according to the failure mode (group 1: adhesive failures between the post and cement; group 2: adhesive failures between the dentin and cement; group 3: cohesive failures inside the cement; group 4: cohesive failures inside the dentin).

The effect of the cement and fitness inside the canal on the bond strength was analyzed using an analysis of variance (ANOVA), and then post hoc comparisons were performed using the Student-Newman-Keuls method. Furthermore, the influence of the fitness on the bond strength regarding each luting agent was investigated separately using a t-test with an adjusted *P*-value ($P < .05$). In the analysis of the failure mode, a Chi-square test was used.

Results

The mean push-out bond strengths of the six groups are listed in Table 3. The bonding strengths were significantly affected by the luting agent and fitness ($P < .05$). The post hoc analysis revealed that ReX had a significantly higher bonding strength compared with the other materials in the F and M groups ($P < .05$). Comparing the result of the F and the M subgroups showed that the bond strengths of the M subgroups were decreased compared with the same F subgroups. The bond strength of the mismatching ReX subgroup (M-ReX) was 66% of the bond strength of the fitting Rex subgroup (F-ReX). The bond strength of the mismatching Lux subgroup (M-Lux) was 83% of the bond strength of the fitting Lux subgroup (F-Lux). The bond strength of the mismatching Duo subgroup (M-Duo) was 49% of the bond strength of the fitting Duo subgroup (F-Duo) (Fig. 1). The ReX and Duo groups had a significantly higher bonding strength in the F group compared with the M group ($P < .05$). However, the Lux group showed no significant difference between the F and M groups ($P > .05$).

The analysis of the failure mode is presented in Ta-

Table 3. Mean push-out bond strength

Group	Mean (MPa) ± SD	Group	Mean (MPa) ± SD
F-ReX	11.48 ± 3.16	M-ReX	7.59 ± 3.38
F-Lux	8.43 ± 4.58	M-Lux	7.02 ± 4.09
F-Duo	9.82 ± 2.94	M-Duo	4.83 ± 1.99

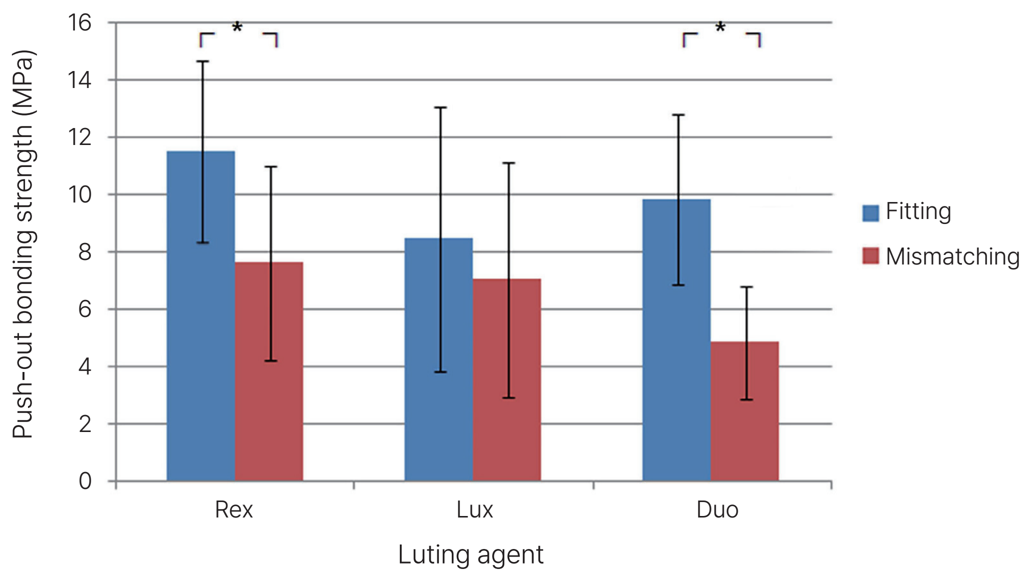

Fig. 1. Comparison of the mean bonding strength according to the fitness (*P < .05).

Table 4. Failure modes

Group	Failure mode (%)			
	Adhesive post/cement	Adhesive cement/dentin	Cohesive cement	Cohesive dentin
F-ReX	0	20 (100)	0	0
M-ReX	0	20 (100)	0	0
F-Lux	17 (85)*	3 (15)	0	0
M-Lux	9 (45)	10 (50)*	1 (5)	0
F-Duo	18 (90)	2 (10)	0	0
M-Duo	12 (60)	8 (40)	0	0

*P < .05; Chi-square test.

ble 4. The ReX group only had adhesive failure patterns between the cement and dentin. The Lux group had significantly more adhesive failures between the cement and post (85%) in the F group, and adhesive failures between the cement and dentin increased by 50% in the M group (P < .05). The Duo group had similar failure patterns to the Lux group according to the fitness; however, it had a statistical significance.

Discussion

For the metal posts luted with resin cement, increasing the post space resulted in similar or greater retention than when the posts fit the space appropriately. Despite the careful preparation of the post spaces, some canals had an elliptical shape on the cross-sections, while others had residual gutta-percha in areas that the post preparation drill could not reach. The unpredictable variations in the morphological features may also explain the relatively high standard deviations of bond strength for some of the groups.[7]

Goracci et al. reported that greater bonding potentials exist for total-etch resin-based luting systems compared with self-etched or self-adhesive systems.[11] This difference may because the acidic monomers responsible for the substrate conditioning in the self-etch resin cement were less effective in etching through the thick smear layer. Otherwise, Bouillaguat et al. reported that there was no significant difference in microtensile bonding strength of FRC posts between a total-etching system and a self-etching system.[12] Tay et al. reported that the bonding strength was higher in flat dentin but was decreased in post space at the root canal due to incomplete evaporation of the primer and moisture control.[13] The self-adhesive resin cement ReX revealed higher bond strength values compared with the other materials. ReX exhibits moisture tolerance because of water forming during the neutralization reaction of phosphoric-acid methacrylate, basic fillers, and hydroxyl apatite (data provided by the manufacturer). This could be an explanation for its superior performance in the present study since moisture content after rinsing the root canal was difficult to control because of the poor visibility.

Many studies have pointed out that the bond strength between luting agent and the post is stronger than the bond between the post and root canal dentin.[11-14] This may be related to the fact that the bond strength between the luting resin and the FRC post is greater than that between the FRC post and the root dentin. In the present study, the failure modes of the ReX group were adhesive failures between the dentin and cement.

The definition of C factor is the ratio of the bonded to the unbonded cavity surface areas. In the study by Bouillaguet et al., it was reported that in dowel restorations, the C factor exceeded 200, whereas it generally varies from 1 to 5 in intracoronal restorations.[15] In the same study, the bond strength of the root canal dentin was found to be significantly lower compared to that of the flat dentin. This was caused by the system having a high C factor and that high polymerization shrinkage stress existed, which caused the detachment of the luting resin from the dentin. In the current study, the post spaces were overflared, and a relatively larger amount of cement was evident between the dowel and root canal dentin. An increases in the amounts of luting agent can lead to high volumetric polymerization shrinkage, separation of the luting agent from the root dentin, and subsequent microleakage. In the present study, the failure mode of the Lux group showed a significant difference between the F and the M groups. A higher percentage of adhesive failures between the luting agent and dentin may caused by a high C factor and high polymerization shrinkage.

A limitation of this experiment is that the adhesion efficiency to dentin could not be controlled. Because human natural teeth were used, dentin condition may vary depending on age or level of periodontal disease. Because of this, even if the same bonding system or luting agent was used, the adhesion efficiency to dentin could not be controlled. In follow-up research, experiments should be conducted taking this into account.

The first and second null hypotheses were rejected, as the accuracy of the fit between the post and the root canal and the luting agent did influence the bond strengths. Future studies should be directed towards evaluating the effects of the new generation of self-etching adhesive bonding systems, various types of resin-based luting agents, different polymerization methods (self-polymerizing or dual polymerizing), slow polymerizing resins, which may help relieve polymerization shrinking stress, resin flow, and different light sources on the microleakage in over-flared root canals.

Conclusion

In this study, to measure the push-out bonding strength and observe the failure modes of various luting agents, three luting agents (ReX, Lux, and Duo) with different bonding systems under different FRC post fitness conditions were examined.

The results of this study showed that the bond strengths were significantly affected by the cement and the mismatch between the diameters of the prepared post space and that of the post. ReX showed significantly higher bonding strength compared with other materials. Regarding post diameter, the F group showed higher bonding strength than the M group in all groups, and this value was significant in the two groups, ReX and Duo.

ORCID

Kkot-Byeol Bae https://orcid.org/0000-0002-6061-4253
Hye-Yoon Jung https://orcid.org/0009-0006-6581-0663
Yun-Chan Hwang https://orcid.org/0000-0002-7891-9565
Won-Mann Oh https://orcid.org/0000-0001-6480-6191
In-Nam Hwang https://orcid.org/0000-0002-5388-1919

References

1. Malferrari S, Monaco C, Scotti R. Clinical evaluation of teeth restored with quartz fiber-reinforced epoxy resin posts. Int J Prosthodont 2003;16:39-44.
2. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent 1999;27:275-8.
3. Torbjörner A, Karlsson S, Odman PA. Survival rate and failure characteristics for two post designs. J Prosthet Dent 1995;73:439-44.
4. Grandini S, Goracci C, Monticelli F, Tay FR, Ferrari M. Fatigue resistance and structural characteristics of fiber posts: three-point bending test and SEM evaluation. Dent Mater 2005;21:75-82.
5. Moosavi H, Maleknejad F, Kimyai S. Fracture resistance of endodontically-treated teeth restored using three root-reinforcement methods. J Contemp Dent Pract 2008;9:30-7.
6. Erkut S, Gulsahi K, Caglar A, Imirzalioglu P, Karbhari VM, Ozmen I. Microleakage in overflared root canals restored with different fiber reinforced dowels. Oper Dent 2008;33:96-105.
7. Perdigão J, Gomes G, Augusto V. The effect of dowel space on the bond strengths of fiber posts. J Prosthodont 2007;16:154-64.
8. D’Arcangelo C, Cinelli M, De Angelis F, D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. J Prosthet Dent 2007;98:193-8.
9. Nissan J, Dmitry Y, Assif D. The use of reinforced composite resin cement as compensation for reduced post length. J Prosthet Dent 2001;86:304-8.
10. Barfeie A, Thomas MB, Watts A, Rees J. Failure Mechanisms of Fibre Posts: A Literature Review. Eur J Prosthodont Restor Dent 2015;23:115-27.
11. Goracci C, Sadek FT, Fabianelli A, Tay FR, Ferrari M. Evaluation of the adhesion of fiber posts to intraradicular dentin. Oper Dent 2005;30:627-35.
12. Bouillaguet S, Troesch S, Wataha JC, Krejci I, Meyer JM, Pashley DH. Microtensile bond strength between adhesive cements and root canal dentin. Dent Mater 2003;19:199-205.
13. Tay FR, Gwinnett AJ, Pang KM, Wei SH. Variability in microleakage observed in a total-etch wet-bonding technique under different handling conditions. J Dent Res 1995;74:1168-78.
14. Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M. The contribution of friction to the dislocation resistance of bonded fiber posts. J Endod 2005;31:608-12.
15. Hayashi M, Okamura K, Wu H, Takahashi Y, Koytchev EV, Imazato S, Ebisu S. The root canal bonding of chemical-cured total-etch resin cements. J Endod 2008;34:583-6.

섬유강화 복합레진 포스트의 결합강도에 대한 포스트 공간 적합도 및 접착 시멘트의 영향

배꽃별[1†] 전임의, **정혜윤**[2†] 개원의, **황윤찬**[1] 교수, **오원만**[1] 교수, **황인남**[1*] 교수

[1]전남대학교 치의학전문대학원 치과보존학교실

[2]서울 모아치과

목적: 포스트와 포스트 공간의 크기 불일치는 포스트 수복 중 흔히 발생하는 문제이며, 이러한 불일치는 섬유강화 복합레진 포스트의 결합강도에 영향을 미치기 때문에 이를 보상할 수 있는 적절한 접착 시멘트가 필요하다. 연구의 목적은 섬유강화 복합레진 포스트의 결합강도에 영향을 미치는 포스트 공간의 적합도와 접착 시멘트 종류에 따른 영향을 평가하는 것이다.

연구 재료 및 방법: 발거된 30개의 하악소구치를 근관 치료한 뒤, 준비된 포스트 공간에 따라 Fitting (F)과 Mismatching (M)의 두 그룹으로 분류했다. 이들 그룹은 접착 시멘트 종류에 따라 다시 RelyX Unicem (ReX), Luxacore dual (Lux) 및 Duolink (Duo)의 세 가지 하위 그룹으로 추가로 분류했다. 이후 시편을 만들어 만능 물성 시험기 상에서 결합 강도를 측정했고 각 시편의 파절 양상을 관찰하여 분류했다.

결과: 실험의 결과로 ReX 및 Duo 하위 그룹에서는 F 그룹의 평균 결합 강도가 더 높았다. 그러나 Lux 하위 그룹은 F 그룹과 M 그룹 간에 큰 차이가 없었다. 파절 양상 분석에서 ReX 하위 그룹은 시멘트와 상아질 사이의 접착 실패만 관찰되었다.

결론: 본 연구 결과, 섬유강화 복합레진 포스트의 결합강도는 접착 시멘트의 종류, 포스트 공간과 포스트 직경의 불일치에 의해 영향을 받는 것으로 나타났다. Rex는 다른 접착 시멘트와 비교 시 유의하게 높은 결합강도를 보였다. 포스트 직경은 모든 그룹에서 F그룹이 M그룹보다 높은 결합강도를 보였으며, 이 값은 ReX와 Duo 두 그룹에서 유의한 것으로 나타났다.

(구강회복응용과학지 2023;39(4):187-94)

주요어: 결합 강도; 섬유강화 복합레진 포스트; 파절 양상

*교신저자: 황인남
(61186)광주광역시 북구 용봉로 77, 전남대학교 치의학전문대학원 치과보존학교실
Tel: 062-530-5819 | Fax: 062-530-5629 | E-mail: hinso@jnu.ac.kr
접수일: 2023년 8월 28일 | 수정일: 2023년 9월 17일 | 채택일: 2023년 10월 12일
[†]이 연구의 제1저자로 동일한 기여를 하였음.