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Comparison of Push-Out Bond Strengths of Different Fiber Post Systems Bonded with Resin Cement

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ABSTRACT

Aim: This study compares the push-out bond strengths of 3 different fiber post systems bonded with resin cement to root canal dentin.
Material and Methods: The study used 15 extracted single-rooted mandibular canine teeth. After the endodontic treatment of the teeth, they were randomly divided into three groups to apply different post-systems (n=5). Reforpost glass-fiber, Polydentia glass-fiber, and AAA Transparent fiber post systems were used in this study. The posts have adhered to the root canal with Panavia F2.0. A total of 6 slices of 1 mm thickness in the transversal direction were obtained, two from each of the coronal, middle, and apical sections of the prepared samples. The push-out test was performed from apical to coronal at a 0.5 mm/min speed. ANOVA and Tukey HSD tests were used for statistical analysis ($p<0.05$).
Results: The highest push-out binding values were observed in Polydentia (5.04±0.54); the lowest was seen in Reforpost (1.5±1.03). There was no statistical difference between the push-out binding values of the samples' apical, middle, and coronal regions for Reforpost and Transparent groups. In Polydentia group, the push-out binding values of the coronal region samples were significantly higher than those in the middle region. When the post groups were compared, the difference between the push-out binding values of all groups was statistically significant.
Conclusion: The surface properties of the posts can affect the push-out bonding values. Polydentia showed the highest push-out binding values. In addition, the push-out attachment values of the posts may vary in different root canal regions.

Rezin Simanla Yapıştırılan Farklı Fiber Post Sistemlerin Push-out Bağlanma Dayanımlarının Karşılaştırılması

Makale Bilgisi

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ÖZET

Amaç: Bu çalışmanın amacı, rezin simanla kök kanal dentinine bağlanan üç farklı fiber post sisteminin push-out bağlanma dayanımları karşılaştırmaktır.
Gereç ve Yöntemler: Çalışmada 15 adet çekilmiş tek köklü kanin diş kullanıldı. Dişlere endodontik tedavi yapıldıktan sonra farklı post sistemi kullanılmak üzere rastgele 3 gruba ayrıldı (n=5). Çalışmada, Reforpost cam fiber post, Polydentia cam fiber post ve AAA Transparent fiber post sistemleri kullanıldı. Postlar kanal içine Panavia F2.0 ile üretici firmanın talimatları doğrultusunda yapıştırıldı. Hazırlanan örnekler %100 nemde 24 saat 37 °C'de 1 gün bekletildikten sonra her bir diş kökünün postu içeren kısmının koronal, orta ve apikal bölümlerinin her birinden 2'şer adet olmak üzere, 1 mm kalınlıkta transversal yönde toplam 6 kesit elde edildi. Push-out testi, 0,5 mm/dk hızla apikalden koronale doğru yapıldı. Verilerin istatistiksel analizi için ANOVA ve Tukey HSD testleri uygulandı ($p<0,05$).
Bulgular: En yüksek push-out bağlanma değerleri Polydentia grubunda (5,04±0,54) görülürken; en düşük değerler reforpost grubununda (1,5±1,03) görüldü. Reforpost ve AAA Tranparent gruplarının apikal orta ve koronal bölge örneklerinin push-out bağlanma değerleri arasında istatistiksel olarak farklılık görülmedi ($p>0,05$). Polydentia grubunda ise; koronal bölge örneklerinin push-out bağlanma değerleri orta bölgedeki örneklerden anlamlı olarak daha yüksek bulundu ($p=0.006$). Post grupları birbirleriyle karşılaştırıldığında; tüm grupların push-out bağlanma değerleri arasındaki fark istatistiksel olarak anlamlı bulundu ($p<0,05$).
Sonuç: Postların yüzey özellikleri push-out bağlanma değerlerini etkilemektedir. Polydentia en yüksek push-out bağlanma değerlerini göstermiştir. Ayrıca postların push-out bağlanma değerleri kökün farklı bölgelerinde değişkenlik gösterebilmektedir.

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INTRODUCTION

Post systems are used in the rehabilitation of endodontic-treated teeth whose dental crown has been partially or entirely destroyed.[1] The clinical success of post-supported restorations is related to factors such as the effectiveness and durability of the post, dentin, and adhesive combination.[2] With adequate bonding between these components, the forces occurring along the root are distributed evenly, and the tooth structure is protected. Failure in one of these components prevents the homogeneous distribution of incoming chewing forces and can create stress areas in the tooth structure.[3]

The fact that metallic posts' elasticity modulus is more remarkable than root dentin causes stress areas at the dentin/post interface. This situation is one factor that predisposes to root fractures.[4,5] Moreover, the natural color and opacity properties of metal or metal alloy posts negatively affect the aesthetic appearance of the final restoration. Additionally, some alloys can oxidize, producing dark pigments that cover and darken the roots and gum edges of teeth.[4–6]

In order to eliminate these problems, new types of materials have been produced for root canal posts. Among the existing post systems, fiber post systems, which show high success rates in clinical practice and their advanced aesthetic features, are widely preferred today.[7] Important advantages of fiber posts are that their elastic modules are close to dentin and that they reduce stress transmission to the root canal walls and the risk of vertical fractures.[7,8] Studies have reported that the combined use of fiber post systems with adhesive resin cement is efficacious in improving the bonding of these systems with root dentin.[9,10]

There are various fiber post systems available to clinicians today. From an ideal post system, it is expected to have easy applicability, high aesthetic properties, an elastic modulus close to dentin, minimal stress on the tooth, and good sealing properties. Among fiber post systems, glass fiber posts (GFP) have a modulus of elasticity similar to dentin and significantly reduce the risk of root fracture.[5,11–13] In addition, the color and opacity of GFPs are close to dentin, and they do not undergo oxidation.[6] The attachment of GFPs to the root canal is based on adhesive cementation. The retention of these posts in the canal depends on the bond strength between the post/cement/root dentin.[14] As it progresses to the apical region of the root, the decrease in light transmittance limits its polymerization process.[15] Efforts are being made to strengthen polymerization and adhesion in this region by using translucent post systems and dual-cure resin cement. Additionally, different morphological options are available in fiber post systems. Parallel and conical-shaped fiber posts are widely preferred. Retention is tried to be increased with parallel-shaped fiber posts. Since conical fiber posts have a form closer to the root-canal anatomy, canal-post compatibility is expected to increase and less stress will be transmitted to the tooth by using these post systems.

This study compares the push-out bond strength of 3 different fiber post systems bonded with adhesive resin cement to root canal dentin. The null hypothesis of the study: 1) There will be no difference between the push-out bond strengths of different post systems. 2) There is no difference between push-out binding values in different root canal regions.

MATERIAL AND METHODS

This in vitro study was approved by the Faculty of Dentistry Ethics Committee, Selçuk University (approval no: 2023/44). The study used 15 single-rooted mandibular canine teeth with completely closed roots, no cracks or fractures, similar root diameters and lengths, and straight root canals. Teeth were stored in distilled water until samples were prepared. The crowns of the teeth were removed by cutting in the horizontal direction under water cooling below the cementoenamel junction using a diamond bur to leave a root length of 15 mm for each tooth. After accessing the root canals, the number 10 K-file (Mani Inc., Tochigi, Japan) was advanced enough to be visible from the root tip, and working lengths were determined to be 1 mm shorter than the determined length.

Endodontic Treatment Procedure

Endodontic access cavities of the teeth were prepared with the help of a round bur. A number 10 K-type file (Mani Inc., Tochigi, Japan) was advanced until it was visible from the root tip, and the working length was determined to be 1 mm shorter than the determined length.

Root canals were prepared using the F3 size Protaper Ni-Ti rotary instrument series (Dentsply, Maillefer, Ballaigues, Switzerland). During root canal shaping, the canals were washed with 2 mL of 5.25% NaOCl after each file. After shaping, the canals were washed with 10 ml of distilled water and dried using paper points.

Root canal fillings were performed with AH-plus sealant (Dentsply, Konstanz, Germany) and F3 numbered Protaper gutta-percha cones (Diadent Group Int., Chungcheongbuk-do, Korea). The canal accesses were temporarily closed with zinc phosphate cement (Imibond-F, Imicryl Dental, Turkey), and the roots were stored in the incubator at 37 °C and 100% humidity for seven days.

Preparation of Post Cavities

The temporary filling material on the access cavities was removed. 11 mm post slots were prepared with size #3 Gates-Glidden drill (Mani Inc., Tochigi, Japan). At least 4 mm of canal-filling material was left in the apical third. Post slots were washed with 2 mL of 5.25% NaOCl, followed by 10 mL of distilled water, and dried using paper points.

Groups of Study

The samples were randomly divided into three groups using three different post systems (n=5). Each group was divided into 3 subgroups: coronal, middle, and apical regions (n = 10). G*Power version 3.1.9.4 (Erdfelder, Faul and Buchner) was used to determine the sample size and the effect size was determined as 0.5. In the study, Reforpost Refill glass fiber post (Angelus, Londrina, PR, Brazil), Polydentia glass fiber post (Polydentia SA, CH-6805 Mezzovico, Switzerland), and AAA Transparent fiber post (StarDent, China) systems were used. The surfaces of the fiber posts to be used were cleaned with alcohol and air-dried. The post systems have adhered to the canal with Panavia F2.0.

Panavia F2.0 Rezin Cement Application Procedure

After mixing, equal amounts of ED PRIMER liquids A and B were applied to the coronal part and the tooth structure around the post. After waiting for 60 seconds, it was dried with light air. Afterward, resin-containing pastes A and B were mixed equally and placed in the post cavity. After placing the posts in the cavity, they were polymerized with an LED light device (1000 mW /cm2, Valo, Ultradent, UT, USA) for 40 seconds.

Push-out Test

The prepared samples were kept at 100% humidity for 24 hours at 37 °C for one day. A total of 6 slices of 1 mm thickness in the transversal direction were obtained, two from each of the samples' coronal, middle, and apical sections. Sections were prepared using a slow-speed water-cooled diamond saw (Isomet, Buehler Ltd., Lake Bluff, IL, USA). The thickness of each section was checked with a digital caliper (Mitutoyo Corp 500 series, Kanagawa, Japan) with an accuracy of 0.01 mm.

The push-out test was performed using a universal testing machine (Elista, Istanbul, Turkey) by applying a 0.5 mm/min load from the apical to the coronal direction. Pushing force was applied until the post separated from the root surface. The maximum load at failure was recorded in Newtons (N). The push-out bond strength of each slice was calculated and expressed in (MPa).

To determine the exact bonding surface, the post diameters were measured before the push-out test on each surface of the post/dentin sections using the digital caliper.

The bonding area was calculated using the formula:[16]

(R1 represents the larger post radius, R2 the smaller post radius, and h is the thickness of each part.)

Failure Modes

After the push-out testing, all slices were analyzed under a stereomicroscope at 20 × magnification to determine the failure mode.

The patterns were classified as:

- Adhesive failure 1 (cement/dentin): Resin cement had wholly separated from the dentin surface.
- Adhesive failure 2 (cement/post): Resin cement completely separated from the post surface.
- Mixed failure: Resin cement is on the dentin and post surface.

Statistical Analysis

One-way analysis of variance (ANOVA) test was used to compare the data. Multiple comparisons were evaluated with the Tukey HSD test method (p<0.05).

Table 1: Materials used in the study.

Material	Manufacturer	Composition
Reforpost Refill (Parallel) glass fiber post	Angelus, Londrin, PR, Brazil	80% fiberglass, 20% epoxy resin; fiber structure extending longitudinally into the resin matrix (radiopaque post)
Polydentia (Conical) glass fiber post	Polydentia SA, CH-6805 Mezzovico, Switzerland	80% fiberglass, fiber structure extended longitudinally into polyester resin matrix (radiopaque post)
AAA Transparent (Conical) fiber post	StarDent, China	65% quartz fiber (radiolucent post)
Panavia F2.0	Kuraray/ Noritake, Japan	ED Primer A: HEMA, 10-MDP, 5-NMASA, water, accelerator ED Primer B: 5-NMASA, water, accelerator, sodium benzene sulfinate Paste A: Silanated silica, microfillers, 10-MDP, methacrylates, photochemical initiator Paste B: Silanated barium glass, surface treated NaF, dimethacrylates, chemical initiator

RESULTS

The mean push-out binding and standard deviation values of the groups in MPa are shown in Table 2.

The highest push-out binding values were observed in the Polydentia group (5.04 ± 0.54); the lowest was seen in the Reforpost group (1.5 ± 1.03). There was no statistical difference between the push-out binding values of the apical, middle, and coronal region samples of the Reforpost and AAA Transparent groups (p>0.05). In the Polydentia group, the push-out binding values of the coronal region samples were significantly higher than those in the middle region (p= 0.006). When the post groups were compared, the difference between the push-out binding values of all groups was statistically significant (p<0.05).

Failure Mode Analysis

The predominant failure modes of Reforpost, Polydentia, and AAA Transparent groups were adhesive failure 1 (dentin/cement) and mixed (dentin/cement and post/cement) failure modes. Adhesive failure 2 (post/cement) mode was less common in all groups (Table 3).

Table 2: The mean push-out binding and standard deviation values of the groups in Mpa.

Groups	Root Canal Regions		
	Apical	***Middle***	***Coronal***
Reforpost	2.21 ± 0.72aA	1.5 ± 1.03aA	2.82 ± 1.52aA
Polydentia	4.4 ± 0.53abB	4.07 ± 0.61aB	5.04 ± 0.54bB
AAA Transparent	2.62 ± 0.45aC	2.66 ± 0.58aC	3.27 ± 0.58aC

* Different lowercase letters in the same row and different uppercase letters in the same column indicate statistical significance (p<0.05).

Table 3: Distribution of failure modes.

Groups	Adhesive Failure 1	Adhesive Failure 2	Mix Failure	Total
Reforpost				30
coronal	6	1	3	10
middle	6	1	3	10
apical	4	0	6	10
Polydentia				30
coronal	4	3	3	10
middle	6	1	3	10
apical	5	1	4	10
AAA Transparent				30
coronal	1	0	9	10
middle	3	1	6	10
apical	5	2	3	10

DISCUSSION

This study compared the push-out bond strength values of three different fiber post systems bonded with dual-cure resin cement in different root regions. According to the results of the study, it was seen that the null hypotheses were rejected. There was a statistically significant difference between the binding values of the post systems. In addition, the difference between the binding values in different root regions was statistically significant.

The most common problem in traditional post-supported restorations is the stress centers formed in the tooth due to irregularities in stress distribution. This stress can enlarge microcracks in the tooth and post-core structure, leading to dentin fractures overtime.[3,17] This problem is being tried to be solved with fiber post systems that are easy to apply, have an elastic modulus similar to dentin, have high aesthetic properties, and do not show corrosive properties.[18–20]

The fact that fiber posts have a high flexure strength and elasticity modulus similar to dentin reduces the possibility of tooth fracture by ensuring a homogeneous distribution of the forces on the restoration.[21,22] Fiber posts have passive retention in the root canal, so resin cements are needed to increase post retention. Additionally, the need for a perfect fit of the fiber post into the root canal space is another critical limitation in using these systems.[23]

Adhesion with root dentin is a very complex process. In addition to the limiting anatomical structure of the dentin tissue, many factors such as the presence of the smear layer, bacterial contamination, operator experience, root canal irrigant used, adhesive system, and root canal sealer affect the adhesion between root dentin-post. In our study, post spaces were washed with 2 mL of 5.25% NaOCl, followed by 10 mL of distilled water. NaOCl is a strong organic tissue solvent. It also has a high antibacterial effect. An attempt was made to increase the infiltration of the adhesive resin into the dentin by removing the smear layer with 5.25% NaOCL irrigation. Additionally, the dual-curing polymerization mechanism of the resin cement used in the present study is expected to provide a more homogeneous conversion rate along all root canals.[24] Moreover, the researchers try to increase the bond strength between root dentin and fiber posts by using fiber post systems with different surface properties or translucent.[25–27] In our study, a translucent fiber post system (conical-shaped) was used alongside two opaque fiber post systems (conical/parallel-shaped).

The number and distribution of dentinal tubules vary anatomically in different regions of the tooth root. Since these differences affect adhesion to dentin tissue, they are essential for the success of restorations bonded to dentin. It has been reported that the number of tubules in root dentin decreases from the coronal to the apical direction.[28] The studies report that the highest bond strength is in the coronal region, and the lowest is in the apical region, regardless of the post system applied. Higher bond strength values measured in the coronal region were associated with more dentinal tubules in this region. As the number of tubules increases, the areas where adhesive resins can penetrate increases.[10,29–31] Similarly, in our study, the highest binding values in the Polydentia group were seen in the sections in the coronal region of the root. Besides, there was no statistical difference between the push-out binding values of the apical, middle, and coronal region samples of ReforPost and AAA Transparent post systems.

In our study, it was observed that the push-out bond strength values of all post systems were statistically different ($p<0.05$). The highest values were Polydentia (coronal: 5.04 ± 0.54); the lowest values were seen in the Reforpost glass-fiber post system (middle: 1.5 ± 1.03). The compositions of Polydentia and Reforpost glass-fiber post systems are similar. They contain the same amount of glass fiber (80%). The most significant difference between these systems is the post geometry. The Polydentia post system is in conical form; Reforpost is in parallel form. The conical form is more suitable for the anatomy of the tooth root. Additionally, the thickness of the resin cement used to bond conical posts can be more uniform throughout the root canal. This situation may contribute to the balanced distribution of the forces on the post-supported restoration and increase the push-out bond resistance of the post. These factors may influence the Polydentia post system, showing higher bond strength values than Reforpost.

The difficulty of photoactivation and polymerization in the apical region is a significant limitation in the cementation of post restorations.[15,32] For this reason, manufacturers have developed transparent post systems. Studies have shown that transparent posts increase photoactivation in intraradicular dentin.[33] However, other studies have shown that achieving the same performance with opaque posts is possible even in the apical third.[34] Our study's AAA Transparent fiber post system showed the second-highest push-out bond strength values. Compared to Reforpost, the conical shape and translucent feature of the AAA Transparent fiber post system increased the bond strength values. However, this post system showed significantly lower values than Polydentia, which has a conical form and opaque structureThe AAA Transparent post system differs from the other post systems in the study with its 65% quartz-fiber content. The composition of the post materials may also be effective in failures that may occur at the interfaces of the tooth-cement-post trio.

Different studies in the literature evaluate the push-out bond strength of fiber posts.[35–37] Comparative studies have used different adhesive and fiber post systems with different content and structures. When the results of these studies are examined, it is seen that the researchers did not reach a common conclusion.[38–40]

When the failure modes of post systems were evaluated in our study, adhesive failure 1 (dentin/cement) and mixed failure (dentin/cement, post/cement) were commonly observed. However, reaching a clear conclusion about the failure mode in the post systems adhesion is impossible. Additionally, different failure modes were observed predominantly in different root-canal regions of the same post system. For this reason, the number of samples should be increased and supported by clinical studies to analyze the bond strength of fiber post systems in more detail.

CONCLUSION

The push-out bond strength of conical-shaped fiber post systems was more successful than the parallel-shaped post systems. The use of transparent post systems can strengthen adhesion, but in our study, the highest bonding values were seen in the opaque Polydentia fiber post system. Push-out bonding values of post systems may vary in different root regions. In all fiber post systems in our study, the highest push-out bonding values were detected in the coronal region of the root.

Ethical Approval

The necessary ethical approval for this study has been obtained from the Selcuk University Non-Drug and Medical Device Ethics Committee (2023/44).

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Conflict of Interest

There is no conflict of interest in this study.

Author Contributions

Design: MG, ARC, Data collection or data entry: MG, ARC, OKT, AKO Analysis and interpretation: MG, ARC, OKT, AKO Literature review: MG, ARC, OKT, AKO Writing: MG, ARC

REFERENCES

1. Lemos Martins Sicuro S, Gabardo MCL, Castiglia Gonzaga C, Dias Morais N, Baratto-Filho F, Correr Nolasco GM et al. Bond strength of self-adhesive resin cement to different root perforation materials. J Endod. 2016;42:1819-21.
2. Bonfante EA, Pegoraro LF, de Góes MF, Carvalho RM. SEM observation of the bond integrity of fiber-reinforced composite posts cemented into root canals. Dent Mater. 2008;24:483-91.
3. Coelho CS de M, Biffi JCG, Silva GR da, Abrahão A, Campos RE, Soares CJ. Finite element analysis of weakened roots restored with composite resin and posts. Dent Mater J. 2009;28:671-8.
4. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, Part II (Evaluation of fatigue behavior, interfaces, and in vivo studies). Quintessence Int. 2008;39:117-29.
5. Amarnath GS, Swetha MU, Muddugangadhar BC, Sonika R, Garg A, Rao TRP. Effect of post material and length on fracture resistance of endodontically treated premolars: an in-vitro study. J Int Oral Health. 2015;7:22-8.
6. Gallo JR 3rd, Miller T, Xu X, Burgess JO. In vitro evaluation of the retention of composite fiber and stainless steel posts. J Prosthodont. 2002;11:25-9.
7. Uzun I, Keskin C, Özsu D, Güler B, Aydemir H. Push-out bond strength of oval versus circular fiber posts irradiated by erbium-doped yttrium aluminum garnet laser. J Prosthet Dent. 2016;116:425-30.
8. Asmussen E, Peutzfeldt A, Heitmann T. Stiffness, elastic limit, and strength of newer types of endodontic posts. J Dent. 1999;27:275-8.
9. Bitter K, Priehn K, Martus P, Kielbassa AM. In vitro evaluation of push-out bond strengths of various luting agents to tooth-colored posts. J Prosthet Dent. 2006; 5:302-10.

10. 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.

11. Lamichhane A, Xu C, Zhang F-Q. Dental fiber-post resin base material: a review. J Adv Prosthodont. 2014;6:60-5.

12. Novais VR, Rodrigues RB, Simamoto Júnior PC, Lourenço C-S, Soares CJ. Correlation between the mechanical properties and structural characteristics of different fiber posts systems. Braz Dent J. 2016;27:46-51.

13. Bosso K, Gonini Júnior A, Guiraldo RD, Berger SB, Lopes MB. Stress generated by customized glass fiber posts and other types by photoelastic analysis. Braz Dent J. 2015;26:222-7.

14. Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, Pereira-Cenci T. The role of resin cement on bond strength of glass-fiber posts luted into root canals: a systematic review and meta-analysis of in vitro studies. Oper Dent. 2014;39:31-44.

15. Kim YK, Kim SK, Kim KH, Kwon TY. Degree of conversion of dual-cured resin cement light-cured through three fibre posts within human root canals: an ex vivo study. Int Endod J. 2009;42:667-74.

16. Bitter K, Meyer-Lueckel H, Priehn K, Kanjuparambil JP, Neumann K, Kielbassa AM. Effects of luting agent and thermocycling on bond strengths to root canal dentine. Int Endod J. 2006;39:809-18.

17. da Silva NR, Raposo LHA, Versluis A, Fernandes-Neto AJ, Soares CJ. The effect of post, core, crown type, and ferrule presence on the biomechanical behavior of endodontically treated bovine anterior teeth. J Prosthet Dent. 2010;104:-306-17.

18. Ferrari M, Vichi A, García-Godoy F. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. Am J Dent. 2000;13:15B-8B.

19. Novais VR, Quagliatto PS, Bona AD, Correr-Sobrinho L, Soares CJ. Flexural modulus, flexural strength, and stiffness of fiber-reinforced posts. Indian J Dent Res. 2009;20:277-81.

20. Tsintsadze N, Margvelashvili-Malament M, Natto ZS, Ferrari M. Comparing survival rates of endodontically treated teeth restored either with glass-fiber-reinforced or metal posts: A systematic review and meta-analyses. J Prosthet Dent. 2022;S0022-3913:00047-6.

21. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J. 2011;56:77-83.

22. Lassila LVJ, Tanner J, Le Bell A-M, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canal posts. Dent Mater. 2004;20:29-36.

23. Coniglio I, Magni E, Cantoro A, Goracci C, Ferrari M. Push-out bond strength of circular and oval-shaped fiber posts. Clin Oral Investig. 2011;15:667-72.

24. Carek A, Dukaric K, Miler H, Marovic D, Tarle Z, Par M. Post-Cure Development of the Degree of Conversion and Mechanical Properties of Dual-Curing Resin Cements. Polymers. 2022;14:364-9.

25. Balbosh A, Kern M. Effect of surface treatment on retention of glass-fiber endodontic posts. J Prosthet Dent. 2006;95:218-23.

26. Torbjörner A, Karlsson S, Syverud M, Hensten-Pettersen A. Carbon fiber reinforced root canal posts. Mechanical and cytotoxic properties. Eur J Oral Sci. 1996;104:605-11.

27. 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.

28. Vichi A, Grandini S, Davidson CL, Ferrari M. An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. Dent Mater. 2002;18:495-502.

29. Erdemir U, Mumcu E, Topcu FT, Yildiz E, Yamanel K, Akyol M. Micro push-out bond strengths of 2 fiber post types luted using different adhesive strategies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;110:534-44.

30. Montanari M, Prati C, Piana G. Differential hydrolytic degradation of dentin bonds when luting carbon fiber posts to the root canal. Med Oral Patol Oral Cir Bucal. 2011;16:e411-7.

31. Lopes GC, Ballarin A, Baratieri LN. Bond strength and fracture analysis between resin cements and root canal dentin. Aust Endod J. 2012;38:14-20.

32. Pereira JR, Pamato S, Santini MF, Porto VC, Ricci WA, Só MVR. Push-out bond strength of fiberglass posts cemented with adhesive and self-adhesive resin cements according to the root canal surface. Saudi Dent J. 2021;33:22-6.

33. Reginato CF, Oliveira AS, Kaizer MR, Jardim PS, Moraes RR. Polymerization efficiency through translucent and opaque fiber posts and

bonding to root dentin. J Prosthodont Res. 2013;57:20-3.

34. De Munck J, Vargas M, Van Landuyt K, Hikita K, Lambrechts P, Van Meerbeek B. Bonding of an auto-adhesive luting material to enamel and dentin. Dent Mater. 2004;20:963-71.

35. Bazzo JF, Pedriali MBBP, Guiraldo RD, Berger SB, Moura SK, de de Carvalho RV. Push-out bond strength of different translucent fiber posts cemented with self-adhesive resin cement. J Conserv Dent. 2016;19:583-6.

36. Calixto LR, Bandéca MC, Clavijo V, Andrade MF, Vaz LG, Campos EA. Effect of resin cement system and root region on the push-out bond strength of a translucent fiber post. Oper Dent. 2012;37:80-6.

37. Rocha AT, Gonçalves LM, Vasconcelos AJ de C, Matos Maia Filho E, Nunes Carvalho C, De Jesus Tavarez RR. Effect of Anatomical Customization of the Fiber Post on the Bond Strength of a Self-Adhesive Resin Cement. Int J Dent. 2017;2017:5010712.

38. Zorba YO, Erdemir A, Turkyilmaz A, Eldeniz AU. Effects of different curing units and luting agents on push-out bond strength of translucent posts. J Endod. 2010;36:1521-5.

39. Giachetti L, Grandini S, Calamai P, Fantini G, Scaminaci Russo D. Translucent fiber post cementation using light- and dual-curing adhesive techniques and a self-adhesive material: push-out test. J Dent. 2009;37:638-42.

40. Kececi AD, Ureyen Kaya B, Adanir N. Micro push-out bond strengths of four fiber-reinforced composite post systems and 2 luting materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;105:121-8.