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# FRACTURE RESISTANCE OF INDIVIDUALLY FORMED AND PREFABRICATED FIBER POST IN REINFORCED STRUCTURALLY COMPROMISED TEETH

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## *ABSTRACT*

**Purpose:** The purpose of this study was to evaluate the fracture resistance of structurally compromised teeth restored with individually formed and prefabricated fiber post.

**Material and methods:** The coronal part of 60 human extracted intact upper central incisors were removed, and the remaining root received endodontic therapy. Root canal spaces were enlarged to reduce dentin wall thickness to 0.5 to 0.75 mm and post space with 8 mm length. Specimens were divided into control and experimental group (n=30) according to the reinforcement of the root canal dentin with composite resin. Each group was further subdivided according to post type used (n=15): individually formed and ready-made fiber posts. A light-transmitting plastic post was used to create root canal space and to cure the restorative composite resin. Dual-cure resin cement was used for post cementation. Standardized composite resin cores and complete cast crowns were fabricated for the specimen using conventional techniques. Each specimen was then subjected to fracture resistance test in an Instron testing machine with a cross head speed of 0.5 mm/min Data were analyzed with 2-way ANOVA and post-hoc Tukey's test ($\alpha$= 0.05) at 5% level of significance.

**Results:** ANOVA results demonstrated a statistically significant difference between root canal reinforcement and fiber post type ($P< 0.001$); however, the interaction effect was not significantly different ($P= 0.435$). Individually formed fiber posts with reinforced root canal had higher mean fracture resistance (414.50±22.09 MPa), and the lower mean fracture resistance (372.57±25.66 MPa) was found for ready-made posts in root canal without reinforcement.

**Conclusions:** Structurally compromised teeth behave significantly better when reinforced with an intermediate layer of flowable composite resin and restored with an individually formed fiber post.

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## INTRODUCTION

Restoration of teeth treated endodontically is from the greatest challenges in the field of dentistry[1], particularly for structurally compromised teeth[2]. Endodontically treated teeth are at an increased risk of biomechanical failure as a result of the tooth substance being lost during endodontic therapy. Intraradicular posts are recommended when treating these teeth to retain the core material prior to crown fabrication[3], and to aid in the stability of final restoration by distributing intraoral forces along the roots[4].

Vertical fractures may be more common in endodontically treated teeth than in normal teeth[5,6]. Two big factors may lead to this, including tooth structures weakened after root canal preparation and the weakened coronal structures following access cavity preparation. Apparently, the latter is more critical than the former[7]. As a result, the material and prosthetic treatment choices make a significant difference in the longevity of the restoration as well as the non-vital teeth[8].

Restorative dentistry has made it a priority to restore teeth treated endodontically with materials containing no metal that have physical characteristics similar to dentin[9]. Glass-fiber posts have several benefits more than other posts, including an elastic modulus similar to that of dentin, a quick simple technique, distribution of stress uniformly, and favorable corrosion resistance[10], as well as favorable optical properties for reproducing the natural appearance of restored teeth[11].

Appropriate post placement and load distribution along the roots significantly reduce the risk of root fracture[12]. Additionally, the amount of intact tooth structure, as well as the post's material, elastic modulus, diameter, and height, all contribute to the tooth resistance to fracture when restored with post and cores[12]. The remaining amount of tooth structure is the most important factor affecting endodontically treated teeth's fracture resistance[3]. However, clinicians continue to face difficulties in restoring structurally compromised teeth. Carious extension, trauma and iatrogenic misadventure can all result in structurally compromised teeth[13]. The resulting structurally compromised root canals have thin dentin walls, making them too weak to withstand normal forces of mastication and thus prone to fracture, complicating the restorative procedure[14]. Additionally, the morphology of structurally deficient canals leads to extremely wide, tapered, and non-retentive posts. If a prefabricated post is used in these situations, the excess space within the radicular canal will be filled with a large amount of cement[15]. This creates a potentially weak point in the restoration, jeopardizing the long-term prognosis[15,16]. As a result, an individually formed fiber post can be polymerized in situ within the root canal, precisely conforming to the canal's shape[17].

The aim of this study was to evaluate the influence of individually formed and prefabricated fiber post on the fracture resistance of structurally compromised teeth.

The null hypothesis was that there will be no difference in fracture resistance of individually formed versus prefabricated fiber post in structurally compromised teeth.

## MATERIAL AND METHODS

### Selection of Specimens

Sixty similar-sized (13±1 mm) intact human upper central incisors were chosen. They were scraped clean of periodontal ligament remnants then stereoscopically examined at a magnification of X10 to confirm the absence of cracks. The teeth were stored at room temperature in distilled water containing 0.1 % t thymol solution. The teeth inclusion criteria were; extracted recently, defect-free, and of the same size and shape. Cracked, carious, or fractured teeth were excluded.

### Preparation of specimens

Teeth were fixed in standardized self-curing cylindrical acrylic blocks (Shanghai Medical; Shanghai, China) with the aid of a dental surveyor (Bioart, Sao Carlos, Brazil) to maintain tooth centralization. Crowns of the chosen teeth were cut perpendicular to the long axis, 2±1 mm coronal to the cemento-enamel junction using an Isomet 1000 slow speed saw (Buehler, Lake Bluff, USA) to simulate the loss of coronal tooth structure, necessitating the use of a post and core to give root lengths of 13±1 mm. Access to the root canals was gained by diamond rotary cutting instruments (Brasseler USA, Sa-vannah, GA). Canals were instrumented endodontically and selected to have nearly identical internal dimensions, as they were all fitted with an initial apical file size of 35 (K-flex; Kerr, Romulus, MI). Root canals were manually widened by a single operator till size 50 file (K-flex; Kerr, Romulus, MI) that could be entered to the working length with little or no resistance.

K-files (Kerr) were used manually to instrument root canals to a working length of 13 mm. Between each file size change, each canal was irrigated with 5.25 % sodium hypochlorite irrigant (Sainsbury's bleach; Sainbury, London, UK). Canals were completely dried with paper points (Absorbent paper point, DiaDent, Kumgang) following the last irrigation. AH 26 root canal sealer (Dentsply DeTrey GmbH, Konstanz, Germany) was mixed and introduced into the canal by a lentullo spiral (Dentsply, Maillefer, Ballaigues, Switzerland). A sealer was applied to the apical third of a size 50 master gutta percha cone (Dentsply Maillefer; Ballaigues, Switzerland), and then the cone was fully seated to the working length. Using a lateral condensation technique, canals were obturated. The specimens were incubated for 72 hours to ensure complete set of the sealer. Gates glidden drill with a rubber stopper (Dentsply GmbH, Konstanz, Germany) was used to remove gutta percha from each canal to a point 5 mm from the apex.

To resemble sever clinical structure damage, each root canal was enlarged to reduce dentin wall thickness by rotary profile nickel titanium files (ProFile, Dentsply Maillefer), leaving specimens with an 8.0 mm posts space length and a residual dentin wall thickness of 0.5 to 0.75 mm at the cemento-enamel junction. The buccal aspect of each residual root was measured using a digital caliper (Vernier caliper, Mitutoyo, India) and x-ray film ( Skydent dental film, SKYDENT, Slovakia ) at points 2.5 and 5.0 mm apical to the coronal sectioned surface to ensure uniform thickness (0.50 to 0.75 mm) across the specimens. A dentin thickness of 0.5 mm was chosen to simulate the worst-case clinical scenario.

### Reinforcement of the root canals

To ensure that the bond formed solely through micromechanical interaction when dentin was etched prior to composite application, the root canal spaces were prepared by etching the surface with 37 percent phosphoric acid (Total Etch etching gel, Ivoclar Vivadent, Schaan, Liechtenstein) for 15 seconds, followed by a 30-second rinse with water and air drying. Two thin consecutive coats of OptiBond Solo Plus single bond adhesive system (Kerr CO., Orange, CA, USA) were applied, gently air dried for 5 seconds, and the adhesive was light cured for 10 seconds using a light-emitting diode unit (Wood Pecker, LED, Germany).

### Group assignment

Specimens were divided into control and experimental group (n=30) according to the reinforcement of the canal dentin with composite resin. Then divided according to the type of post used (n=15), whether it was formed individually or was prefabricated.

To reinforce the root canals, a light-transmitting 1.5-mm diameter plastic post (Dentatus USA Ltd, New York, NY) was used to create post space and to facilitate using of a light polymerizing composite resin. Using a 21-mm Navitip needle tip, a flowable light-polymerizing composite resin Permaflo (Ultradent Products Inc, South Jordan, Utah) was injected into the canal space. Each light transilluminating post was coated with separating medium (White Pe-troleum Jelly; Tyco Healthcare Group LP) and then manually inserted centrally in the root space, followed by compacting the restorative material around the post. The curing light was put at the end of the smooth light transilluminating post to polymerize the restorative material by transmitting light down the length of the post for 1 minute. The smooth light transilluminating post was removed and the light was applied again for another 20 seconds. A post space of standardized length of 8 mm was prepared. A periodontal probe and a radiograph were used to determine the length of the post space.

### Individually formed fiber post

Thirty specimens were received individually formed fiber post. Each everStick post (Stick Tech Ltd, Turku, Finland) was pre-cut to a length of 12 mm by marking the post's measured length on protective paper, trial fitting it into the root canal, and shaping it. After removing the posts from their canals using locking forceps (Kelly, Medline Industries, Inc.), they were thoroughly light cured again for 40 seconds. Stick Resin (Stick Tech Ltd) was applied to the post surface for activation and left for 3 to 5 minutes before being light polymerized for 10 seconds.

### Prefabricated fiber post

Thirty specimens received readymade fiber posts. Using a dual polymerizing adhesive luting resin (Ivoclar vivadent Schaan, Liechtenstein, Germany), all the posts were luted. Each post was marked 12 mm from the apical end. At this point, a line was drawn around the post, and all posts were cut to a length of 12 mm leaving 4 mm of the post head above the preparation. To ensure standard post lengths and posts with tapered designs had similar diameters.

Each post space was etched with 37 % phosphoric acid for 15 seconds, rinsed with water spray, and gently air dried. Excess moisture was dried using paper points. Two thin consecutive layers of Optibond Solo Plus single bond adhesive system were applied using fine microbrushes (Microbrush Corp., Grafton, WI, USA), gently air-dried, and light cured for 10 seconds. On a paper pad, equal parts base and catalyst of Variolink N resin cement were mixed according to the manufacturer's instructions and applied into each post space using a lentulo spiral (Dentsply, Maillefer). Each post was covered with cement, gently seated into the root canal for 10 seconds with finger pressure, and then light cured for 40 seconds directly on the top of the post.

### Core build-up

Composite cores (6 mm in height) were constructed using polyester central incisor matrices (MATRIX ITENA, Itena, France) seated over the post/crown portion and then filled with core build up material (Dentocore body, Itena, France). Each coronal tooth surface was etched with 37% phosphoric acid for 15 seconds, rinsed, and air dried. Two coats of OptiBond Solo Plus bonding agent were applied using a micro brush to the cervical dentin and coronal portion of the post and light cured for 20 seconds. Composite core material was applied to the tooth surface of each specimen to avoid air entrapment. Then, each matrix was filled with core material and polymerized for 40 seconds on all surfaces.

### Fabrication of complete cast crowns

To standardize the preparation dimensions, specimens were prepared on a Computer Numerical Control milling machine (CNC Premium 4820, imes-icore, Eiterfeld, Germany) with a 6 mm distance from margin to occlusal surface, a 2 mm ferrule, a 0.5 mm chamber margin design, and a 6-degree taper. Following preparation of the teeth, the crown portion of each tooth was layered with a 20-millimeter thick lubricant layer (Jingliu, Tokyo, Japan). Then, wax patterns (Gator Wax, Whip Mix Corp) were created directly on teeth. Each specimen was formed with a palatal step design that was 0.3 mm depth and 1 mm wide in order to standardize the loading device's position during testing. Using a conventional lost wax technique, wax patterns were invested with phosphate bonds investment (Bego Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG, Germany) and cast in a Ni–Cr alloy (VeraBond 2V, Aalba Dent, Fairfield, CA, USA). Adjustments were made to the cast crowns until they were completely seated. Crowns were cemented for 5 minutes with glass ionomer cement (GC Fuji I Capsule, GC Corp., Tokyo, Japan),

**Fracture resistance test**

Metallic rings were used to secure the mounted roots. Each specimen was put in the mounting device and aligned at a 45° angle to the tooth's long axis using a specially designed mounting jig. A unidirectional static load was then applied with a 1-mm diameter steel bar, beveled 45° at the terminus using a universal testing machine (Instron 8500 Plus, 100 Royal St. Canton, USA) in compression mode with a cross-head speed of 0.5 mm/min to the locating groove in the palatal concavity of the crown and at an angle of the 135° from the long axis till fracture. For each group measurements were calculated in N then converted into MPa.

**Statistical analysis**

Data were analyzed to compare the mean fracture resistance and standard deviations of all groups in N, and results were compared by two-way analysis of variance (ANOVA) and post-hoc Tukey's test ($\alpha$= 0.05).

**RESULTS**

Two-way ANOVA results (Table 1) demonstrated a statistically significant difference between root canal reinforcement and fiber post type (P< 0.001); however, the interaction effect was not significantly different (P= 0.435).

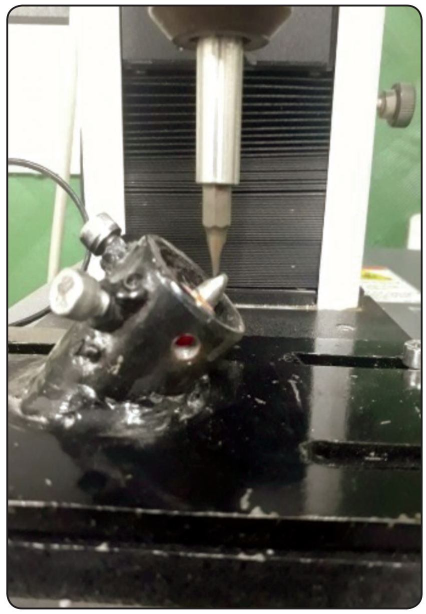

Fig. (1)

Mean values and standard deviations for each fiber post and root canal reinforcement are listed in (table 2). The data indicated that individually-formed posts with reinforced root canal had higher mean fracture resistance (414.50±22.09), and the lower mean fracture resistance was found for prefabricated posts in root canals without reinforcement (372.57±25.66). Regardless of the root canal reinforcement, individually formed posts had the highest fracture strength and the prefabricated posts had the lowest fracture strength.

Regardless of the reinforcement factor tukey's post-hoc test revealed a significant difference between different post types (P< 0.001). Also regardless of the type of fiber post used, Tukey's post-hoc test revealed a highly significant difference between root canal with reinforcement and root canal without reinforcement (P< 0.001).

Regardless of the type of fiber post used, one-way AVOVA (Table 3) showed that root canal reinforcement was significantly different (P< 0.001). The experimental group with root canals reinforced with composite resin recorded higher mean bond strength (403.39±24.82 MPa) than the control group with no reinforcement (378.91±24.79 MPa).

With the same comparison, regardless of root reinforcement, one-way ANOVA (Table 4) disclosed a significant difference between post types (P< 0.001). Individually formed fiber post (399.88±26.68 MPa) recorded higher mean bond strength than prefabricated fiber post (382.42±25.89 MPa) .

TABLE (1): Two-way ANOVA of the study

| Source | *Df* | MS | F-value | P |
|---|---|---|---|---|
| Reinforcement | 1 | 4571.028 | 8.319 | < 0.001 |
| Post type | 1 | 8986.608 | 16.355 | < 0.001 |
| Reinforcement * Post type | 1 | 340.340 | 0.619 | 0.435 |
| Error | 56 | 549.747 | | |
| Total | 59 | | | |

TABLE (2): Means and standard deviations of fracture resistance (MPa) of tested groups

| Post type | No reinforcement | Reinforcement |
|---|---|---|
| Individually-formed | 385.26±22.99 | 414.50±22.09 |
| Prefabricated | 372.57±25.66 | 392.28±22.87 |

TABLE (3) One-way ANOVA test of dependent variable root canal reinforcement

| Sources of variation | *df* | MS | F-value | P |
|---|---|---|---|---|
| **Between Groups** | 1 | 8986.608 | 14.607 | < 0.001 |
| **Within Groups** | 58 | 615.205 | | |
| **Total** | 59 | | | |

TABLE (4): One-way ANOVA of dependent variable post type

| Sources of variation | *Df* | MS | F-value | P |
|---|---|---|---|---|
| **Between groups** | 1 | 4571.028 | 6.612 | P < 0.001 |
| **Within groups** | 58 | 691.336 | | |
| **Total** | 59 | | | |

## DISCUSSION

Teeth that are structurally compromised have thin dentin walls, making them unable to withstand normal forces of mastication and thus prone to fracture, necessitating restorative techniques that do not jeopardize the rest of the teeth[18]. Thus, prior to the placement of extra coronal restorations, reinforcement of structurally weakened teeth becomes necessary if a favorable prognosis for the restoration is expected.

Human maxillary central incisors were used because they have long, relatively straight canals that are typically round, which provides a better seal than oval canals with irregularities[19]. All roots received endodontic treatment; sodium hypochlorite at a concentration of 5.25 % was used as the preferred irrigant during canal preparation, and obturation of roots was done using the traditional lateral condensation technique, which does not require sophisticated equipment and is simple to perform[20]. While root canal sealers containing eugenol inhibit the polymerization of resin-based luting agents. So to complete the endodontic treatment, a eugenol-free epoxy-amine resin sealer (AH-26) was used[21].

Posts were sectioned at 12 mm length prior to cementation to eliminate differences in post length. The luting agent's adhesion to the post and to the intra-radicular dentin prevented FRC posts from dislodging[22]. In general, laboratory studies indicate that resin-based luting cements provide superior post retention[23]. As a result, Variolink N adhesive resin cement was used to secure fiber posts. Additionally, the dual-cure cement may alleviate some of the difficulties associated with light reaching the most apical portions of the root canal[24], as well as its advantage of increasing load capability[25].

The current study used the standard polyester crown to create the core foundation in order to standardize the cores for all specimens. Permaflo flowable composite resin was used to reinforce the roots as recommended by Ayad et al[16], who concluded that an intermediate layer of composite resin used between the root dentin and the post increased the fracture resistance of wide roots significantly more than glass ionomer reinforced roots.

Light-transmitting plastic posts were used because it is possible to transilluminate light through the bulk of deeper, intraradicularly placed composite resin, because the light is transmitted along the entire length of the plastic post. Following polymerization and removal of the plastic post, a patent, precise, and retentive post canal for the intended matching post is immediately established[26].

Two different post systems were chosen for the study; the DT light post was chosen because it has a double taper that conforms closely to the shape of endodontically treated canals, making the restorative work more resistant to fracture; it also reduces the thickness of cement at the coronal level; it decreases polymerization shrinkage; and it decreases microleakage[27]. EverStick posts in structurally compromised root canals have the ability to adapt easily to the shape of the canals, potentially decreasing the voids number and then completely filling the canal with the post. As a result, the adhesive surface and strength in the tooth's most critical area are maximized[28,29]. For everStick post surface activation, stick resin light-cure was used to form secondary interpenetrating polymer networks IPN bonding, and the post was light protected to prevent the activated resin from premature polymerization due to the light[30].

One of the study's objectives was to determine the effect of intraradicular reinforcement with composite resin on the fracture resistance of endodontically treated teeth. Composite resins have the potential to significantly reinforce and strengthen the remaining root[31]. With decreasing dentin wall thickness, fracture resistance becomes increasingly dependent on the reinforcing ability of the materials used to restore the tooth[32]. The results of this study indicated that the root resistance to fracture was significantly greater in the composite-reinforced root canals than in the unreinforced root canals. According to other studies[33,34], the strength of posts decreases as cement thickness increases due to the possibility of procedural error. This finding was also corroborated by Amin et al[18], who found that reinforcing the wide root canal with composite resin improved the fracture resistance of weakened roots when compared to roots that were restored with luting cement. Rocha et al[35] used a conventional nanocomposite resin for relining and a self-adhesive cement for post cementation and found that relined samples had a higher bond strength. Also, thick layers of resin cement contain a greater number of bubbles, cracks, and gaps than thin layers. These defects create a stress concentration area, which acts as a crack raiser and decreases fiber post's bond strength to the root dentin[36].

Additionally, the increased fracture resistance observed in the experimental group reinforced with composite resin versus the control group without reinforcement could be explained by the type of resinous matrix and fabrication process used to promote chemical bonding between fiber and resin[37].

Root fractures may occur as a result of the wedging effect of a loose post within a root canal due to failure of adhesion between root canal dentin and resin cements. The dentin transfers the stress accumulated in the post to the tooth's outer surface. When the dentinal wall is thin and/or the resin cement layer is thick, the load required to fracture the tooth is reduced, as was observed in the control group in this study[38]. This inferior result is to be expected, given the large space between the post and canal wall, which may cause the luting system to be overstressed in terms of high polymerization stresses[39].

The current study's findings indicated that the group restored with individually formed post had significantly higher mean fracture resistance values than the group restored with prefabricated post. These findings corroborate those of previous studies[40-42], who suggested that this may be as a result of the multiphase polymer matrix of the individually formed fiber posts, which contains both linear [polymethyl methacrylate (PMMA)] and cross-linked polymer phases (poly Bis-GMA) (semi interpenetration polymer network, semi-IPN). The monomers in adhesive resins and cements can enter into the linear polymer phase, swell it, and then polymerize to form interdiffusion bonding, which results in decreased stress formation[43]. Additionally, Chunawalla et al[44] demonstrated that the everStick fiber post provides homogeneous mechanical and chemical bonding of all components, reduces the risk of root fracture, and has a modulus of elasticity the same as that of root dentin [44].

When luting cement is bonded to an everStick post, the surface of the post is enriched with a layer of well-polymerized PMMA[45], leaving little, if any, reactivity for free radical polymerization bonding, and thus no actual chemical bonding occurs[46]. The EverStick post system enables the addition of unpolymerized posts in accordance with the canal morphology, resulting in improved adaptation and stress distribution, as demonstrated by Sorensen et al[47], who concluded that when posts are well adapted to the canal walls, an apparent fracture resistance increase of restored teeth can be measured.

There were some limitations in this study. The unidirectional static loading force applied did not replicate the complex dynamic forces present in the oral environment during mastication and with parafunctional habits; however, a unidirectional static loading force was selected in this study and in many other studies of root fractures to minimize the experimental variables. Clinically, root fractures in maxillary anterior teeth restored with post, core and artificial crowns are more likely to occur from cyclic fatigue than single severe impacts. Further laboratory testing should more closely simulate these two factors.

## CONCLUSIONS

1. Reinforcement of the root canal with composite affects the fracture resistance of endodontically treated teeth greatly.
2. Structurally compromised teeth reinforced by using an intermediate composite layer have favorable results on their fracture resistance.

## REFERENCES


1. Bilgi P, Shah N, Patel P, Vaid D. Comparison of fracture resistance of endodontically treated teeth restored with nanohybrid, silorane, and fiber reinforced composite. J Conserv Dent 2016;19:364-7.
2. Pham KV, Huynh TT. Bond Strength and fracture resistance of flowable bulk fill composite posts and cores in endodontically treated teeth. J Int Soc Prev Community Dent 2019;9:522-6.
3. Haralur S, Al-Qahtani A, Al-Qarni M, Al-Homrany R, Aboalkhair A. Influence of remaining dentin wall thickness on the fracture strength of endodontically treated tooth. J Conserv Dent 2016;19:63-7.
4. 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. J Inter Oral Health 2015;7:22-8.
5. Teixeira FB, Teixeira EC, Thompson J, Leinfelder KF, Trope M. Dentinal bonding reaches the root canal system. J Esthet Restor Dent 2004;16:348-54.
6. Ribeiro FC, Souza-Gabriel AE, Marchesan MA, Alfredo E, Silva-Sousa YT, Sousa-Neto MD. Influence of different endodontic filling materials on root fracture susceptibility. J Dent 2008;36:69-73.
7. Javaheri M, Bahmani-Zanjani L, Rakhshan V, Foroozia M. Vertical fracture resistance of endodontically treated teeth restored with four sets of obturation and filling materials. J Dent Sci 2012;7:130-6.
8. Kanat Ertürk B, Saridag S, KÖSeler E, Yiğit D, Avcu E, Yıldıran Avcu Y. Fracture strengths of endocrown restorations fabricated with different preparation depths and CAD/CAM materials. Dent Mater J 2018;37:256-65.
9. Kurthukoti A, Paul J, Gandhi K, Rao D. Fracture resistance of endodontically treated permanent anterior teeth restored with three different esthetic post systems. J Indian Soc Pedod Prev Dent 2015;33:296-301.
10. Moura As, Pereira Rd, Rached Junior Fja, Crozeta Bm, Mazzi-Chaves Jf, Souza-Flamini Le, et al. Influence of root dentin treatment on the push-out bond strength of fibre-reinforced posts. Braz Oral Res 2017;31:29-38.
11. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J 2011;56:77-83.
12. Habibzadeh S, Rajati HR, Hajmiragha H, Esmailzadeh S, Kharazifard M. Fracture resistances of zirconia, cast Ni-Cr, and fiber-glass composite posts under all-ceramic crowns in endodontically treated premolars. J Adv Prosthodont 2017;9:170-5.
13. Clavijo Vgr, Reis Jmdsn, Kabbach W, Silva ALFe, de Oliveira OB, de Andrade Mf. Fracture strenght of flared bovine roots restored with different intraradicular posts. J Appl Oral Sci 2009;17:574-8.
14. Teixeira CS, Silva-Sousa YT, Sousa-Neto MD. Bond strength of fiber posts to weakened roots after resin restoration with different light-curing times. J Endod 2009;35:1034-9.
15. Bonfante G, Kaizer OB, Pegoraro LF, do Valle AL. Fracture strength of teeth with flared root canals restored with glass fibre posts. Int Dent J 2007;57:153-60.
16. Ayad MF, Bahannan SA, Rosenstiel SF. Influence of irrigant, dowel type, and root-reinforcing material on fracture resistance of thin-walled endodontically treated teeth. J Prosthodont 2011;20:180-9.
17. Makarewicz D, Le Bell-Rönnlöf A-MB, Lassila LVJ, Vallittu PK. Effect of cementation technique of individually formed fiber-reinforced composite post on bond strength and microleakage. Open Dent J 2013;7:68-75.
18. Amin RA, Mandour MH, Abd El-Ghany OS. Fracture strength and nanoleakage of weakened roots reconstructed using relined glass fiber-reinforced dowels combined with a novel prefabricated core system. J Prosthodont 2014;23:484-94.
19. Wu MK, van der Sluis LW, Wesselink PR. The capability of two hand instrumentation techniques to remove the inner layer of dentine in oval canals. Int Endod J 2003;36:218-24.
20. Saatchi M, Barekatain B, Behzadian M. Comparing the apical microleakage of lateral condensation and chloroform dip techniques with a new obturation method. Dent Res J (Isfahan) 2011;8:22-7.
21. Bayindir F, Akyil MS, Bayindir YZ. Effect of eugenol and non-eugenol containing temporary cement on permanent cement retention and microhardness of cured composite resin. Dent Mater J 2003;22:592-9.

22. Goracci C, Grandini S, Bossù M, Bertelli E, Ferrari M. Laboratory assessment of the retentive potential of adhesive posts: a review. J Dent 2007;35:827-35.
23. Bitter K ,Meyer-Lückel H, Priehn K, Martus P, Kielbassa AM. Bond strengths of resin cements to fiber-reinforced composite posts. Am J Dent 2006;19:138-42.
24. Galhano GA, de Melo RM, Barbosa SH, Zamboni SC, Bottino MA, Scotti R. Evaluation of light transmission through translucent and opaque posts. Oper Dent 2008;33:321-4.
25. 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.
26. Lui JL. Composite resin reinforcement of flared canals using light-transmitting plastic posts. Quintessence Int 1994;25:313-9.
27. Boudrias P, Sakkal S, Petrova Y. Anatomical post design meets quartz fiber technology: rationale and case report. Compend Contin Educ Dent 2001;22:337-44.
28. Bijelic J, Garoushi S, Vallittu PK, Lassila LVJ. Fracture load of tooth restored with fiber post and experimental short fiber composite. Open Dent J 2011;5:58-65.
29. Kim J-H, Park S-H, Park J-W, Jung I-Y. Influence of post types and sizes on fracture resistance in the immature tooth model. J Korean Acad Conserv Dent 2010;35:257-66.
30. Makarewicz D, Le Bell-Rönnlöf AM, Lassila LV, Vallittu PK. Effect of cementation technique of individually formed fiber-reinforced composite post on bond strength and microleakage. Open Dent J 2013;7:68-75.
31. Lawley GR ,Schindler WG, Walker WA, 3rd, Kolodrubetz D. Evaluation of ultrasonically placed MTA and fracture resistance with intracanal composite resin in a model of apexification. J Endod 2004;30:167-72.
32. Stuart CH, Schwartz SA, Beeson TJ. Reinforcement of immature roots with a new resin filling material. J Endod 2006;32:350-3.
33. 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.
34. Hagge MS, Wong RD, Lindemuth JS. Effect of dowel space preparation and composite cement thickness on retention of a prefabricated dowel J Prosthodont 2002;11:19-24.
35. Rocha AT, Gonçalves LM. Effect of anatomical customization of the fiber post on the bond strength of a self-adhesive resin cement. Int J Dent 2017; 50:107-12.
36. Gomes GM, Rezende EC, Gomes OM, Gomes JC, Loguercio AD, Reis A. Influence of the resin cement thickness on bond strength and gap formation of fiber posts bonded to root dentin. J Adhes Dent 2014;16:71-8.
37. Galhano GA, Valandro LF, de Melo RM, Scotti R, Bottino MA. Evaluation of the flexural strength of carbon-fiber, quartz-fiber, and glass-fiberbased posts. J Endod 2005;31:209-11.
38. Sary S B, Samah M S, Walid A A-Z. Effect of restoration technique on resistance to fracture of endodontically treated anterior teeth with flared root canals. J Biomed Res 2019;33:131-8.
39. Naumann M, Preuss A, Frankenberger R. Load capability of excessively flared teeth restored with fiber-reinforced composite posts and all-ceramic crowns. Oper Dent 2006;31:699-704.
40. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. Am J Dent 2000;13:9b-13b.
41. Demarchi MG, Sato EF. Leakage of interim post and cores used during laboratory fabrication of custom posts. J Endod 2002;28:328-9.
42. Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth J Prosthet Dent 1984;51:780-4.
43. Abo El-Ela OA, Atta OA, El-Mowafy O. Fracture resistance of anterior teeth restored with a novel nonmetallic post. J Can Dent Assoc 2008;74:441-42.196.
44. Chunawalla Y, Zingade S, Bijle MN, Ahmed N, Thanawalla E. Glass fibre reinforced composite resin post & core in decayed primary anterior teeth. Int J Clin Dent2011 ;2:55-60.
45. Mannocci F, Sherriff M, Watson TF, Vallittu PK. Penetration of bonding resins into fibre-reinforced composite posts: a confocal microscopic study. Int Endod J 2005;38:46-51.
46. Bell A-ML, Lassila LVJ, Kangasniemi I, Vallittu PK. Bonding of fibre-reinforced composite post to root canal dentin. J Dent 2005;33:533-9.
47. Sorensen JA, Engelman MJ. Effect of post adaptation on fracture resistance of endodontically treated teeth. J Prosthet Dent 1990;64:419-24.