European Journal of Prosthodontics and Restorative Dentistry (2020) **28**, 54-63

Fiber Reinforcement of Endodontically Treated Teeth: What Options Do We Have? Literature Review

Keywords

Fiber-Reinforced Composites
Endodontically Treated Teeth
FRC Post

Authors

Sufyan Garoushi *
(BDS, PhD)

Johanna Tanner § ‡
(DDS,PhD)

Filip Keulemans *
(DDS, PhD)

Anna-Maria Le Bell-Rönnlöf §
(DDS,PhD)

Iippo Iassila *
(DDS,MSc)

Pekka K. Vallittu ^
(DDS,PhD,Professor)

Address for Correspondence

Sufyan Garoushi *

Email: sufgar@utu.fi

* Department of Biomaterials Science and Turku Clinical Biomaterial Center-TCBC, Institute of Dentistry, University of Turku, Turku, Finland

§ Department of Prosthetic Dentistry and Stomatognathic Physiology, Institute of Dentistry, University of Turku, Turku, Finland

‡ Department of Oral and Maxillofacial Diseases, Turku University Hospital, Turku, Finland

^ City of Turku Welfare Division, Oral Health Care, Turku, Finland

Received: 29.10.2019
Accepted: 05.02.2020

doi: 10.1922/EJPRD_2002Garoushi10

ABSTRACT

The restoration of endodontically treated teeth (ETT), even though practiced for many years, remains a major concern in dentistry. There is a variety of materials and clinical techniques advocated for restoring ETT and hundreds of studies devoted to this subject have been published in the dental literature. This narrative review article was undertaken to answer a question regarding restoration of ETT with available evidence: What fiber reinforcement options do we have other than prefabricated fiber post? Using a Medline search (up to 2019) and resulting cross-references, authors selected original research on the topic of fiber-reinforced composite (FRC) and restoration of ETT. Of the assessed articles selected (n=79), most were laboratory-based research with various test specimen designs and only 15 articles were clinical reports. From the reviewed studies, using individually formed FRC posts and short-FRC resin showed promising characteristics, and therefore, might be recommended as an alternative treatment option in restoring ETT. However, long-term clinical trials are needed in order to evaluate the usefulness of these alternatives.

INTRODUCTION

The success of restoring endodontically treated teeth (ETT) depends on various aspects during the course of therapy. Coronal restoration of ETT is considered of crucial importance to the clinical outcome of the teeth.[1,2] It represents a major concern, for both dentist and patient. The major issues with ETT seem to be the coronal destruction by caries, fractures of previous restorations, dentine loss due to the removal of the roof of the pulp chamber and the weakening of the peri-cervical dentine during access preparation.[1] Many studies have showed that indirect full crown or overlay restorations and direct complex amalgam or composite restorations can be used for final restorations.[3,4] However, the best way to restore ETT has long been and still is a subject of debate.

Restoring a tooth with adhesive procedures and direct composite restorations reduces the need for sacrificing sound tooth tissue and over-preparing in terms of retention. Moreover, composite restorations are more economic than indirect restorations and are considered less time consuming.[5] Adhesive dentistry has rapidly developed during the last few decades. A variety of new and innovative techniques have changed the conventional treatment methods as applications of new dental materials give better outcomes than traditional ones. Composites too, have undergone many changes and improvements.[6] One of the most effective changes to increase durability and damage tolerance of composite materials was the incorporation of fibers with particulate filled composite (PFC).[7-10] Fiber-reinforced composites (FRCs) have made it possible to use composites in high stress-bearing structures such as fixed partial dentures and root canal posts. The parameters which have been developed to their maximum potential within classic composites, are flexural strength and fracture toughness. FRCs have excellent mechanical properties, and their strength to weight ratios are superior even to those of most alloys.[7,8]

The structural integrity of ETT is severely compromised due to loss of coronal tooth tissue as well as radicular tooth tissue.[11] Radicular tooth tissue is mainly lost by caries, root canal treatment and post space preparation.[11,12] Furthermore, the use of mechanical NiTi endo files might additionally weaken the roots of ETT resulting in vertical root fractures.[13,14] On the other hand, the coronal part of ETT is weakened by the loss of marginal ridges due to caries, trauma or removal of the pulpal roof during endodontic access cavity preparation.[11,15] As a result of the compromised structural integrity, tooth stiffness of ETT is reduced and an increased fracture tendency during normal function is observed.[2,15-17] In accordance, a survey among Dutch general practices by Fennis *et al.*, pointed out that ETT suffered more catastrophic or non-reparable cusp fractures in comparison to vital teeth.[18]

Nowadays, the use of prefabricated FRC posts is recommended only in cases of severe loss of remaining coronal tooth structure to promote the retention of the final restoration and to optimize the biomechanical behavior of the remaining tooth structure.[15,17,19] It has to be stated that if ETT still has substantial amount of remaining sound tooth structure (over 50%), a post does not improve its longevity, but instead bear substantial risks when placing one.[3,19]

There is wide variation between FRC posts in respect of fiber types, fiber surface treatments and methods of incorporating the fibers into the resin matrix. Glass FRCs are the most widely used reinforcing fibers with high tensile strength and good bonding to the resin matrix. Several studies validate the utilization performance of glass FRC posts over the other types of fiber posts.[20-22]

Despite the favorable biomechanical behavior of prefabricated glass FRC posts,[22] there has been discussion about the shortcomings as well.[24-28] The preset shape and diameter of a prefabricated FRC post rarely follows the anatomy of the root canal. Consequently, when inserting a prefabricated FRC post, a big space will be filled with resin cement coronally and a needless amount of dentine may have to be removed apically. To avoid unnecessary preparation, a prefabricated FRC post with a smaller diameter is often chosen, which may result in a post-core system with an insufficient stiffness and load-bearing capacity.[27] Another shortcoming is the inadequate bonding ability of a cross-linked prefabricated FRC post to resin cements, composite core materials and root canal dentine.[29] By time, a poor bonding between FRC post and resin cement may result in marginal breakdown and further in secondary caries. In addition, a prefabricated FRC post positioned in the center of the root canal is not able to carry the load, give mechanical support and consequently diminish the tensile stress at the crown margin.[5,27,28] Accordingly, the latest guidelines for restoration of ETT by Zarow and his colleagues, FRC post is recommended only in anterior and premolar teeth with compromised tooth structure that have less than 50% of remaining coronal structure.[30]

Therefore, taking into account the positive effect of fiber reinforcement, negative side effects of prefabricated FRC post, extra costs and chairside time, the aim of this narrative review article was to answer the following question: what fiber reinforcement options do we have other than prefabricated fiber post?

MATERIALS AND METHODS

SEARCH PROCESS AND SELECTION OF STUDIES

Two authors (SG, FK) performed a Medline (via PubMed) search in April 2019 using the term “fiber reinforced endodontically treated teeth” OR “reinforcement of endodontically treated teeth” OR “fiber reinforcement of endodontically treated teeth” OR “ endodontic fiber post” OR “restoration of endodontically treated teeth” OR “fiber reinforced composite and endodontics” OR “fiber reinforced composite restoration” in order to identify studies answering the focus question: what fiber reinforcement options do we have other than prefabricated fiber post?

During the review process, the relevant literature was further obtained through the reference sections of the retrieved articles to provide more supportive information.

INCLUSION/EXCLUSION CRITERIA

Studies eligible for inclusion in this article were laboratory studies and clinical reports dealing with glass fiber reinforcement of ETT, published in English language, in peer-reviewed Journal. The articles selected had to include the search terms either in the title or abstract. Published articles that were full-text were preferred. Conference abstracts, personal communications, background information, and advertisements were filtered and excluded.

RESULTS AND DISCUSSION

A thorough electronic literature search was done, using PubMed. After exclusion of repetition, a number of 79 full text published articles was included; 64 articles were *in vitro* studies and 15 were clinical reports (*Figure 1*). Depending on available related data on those papers and after having studied the

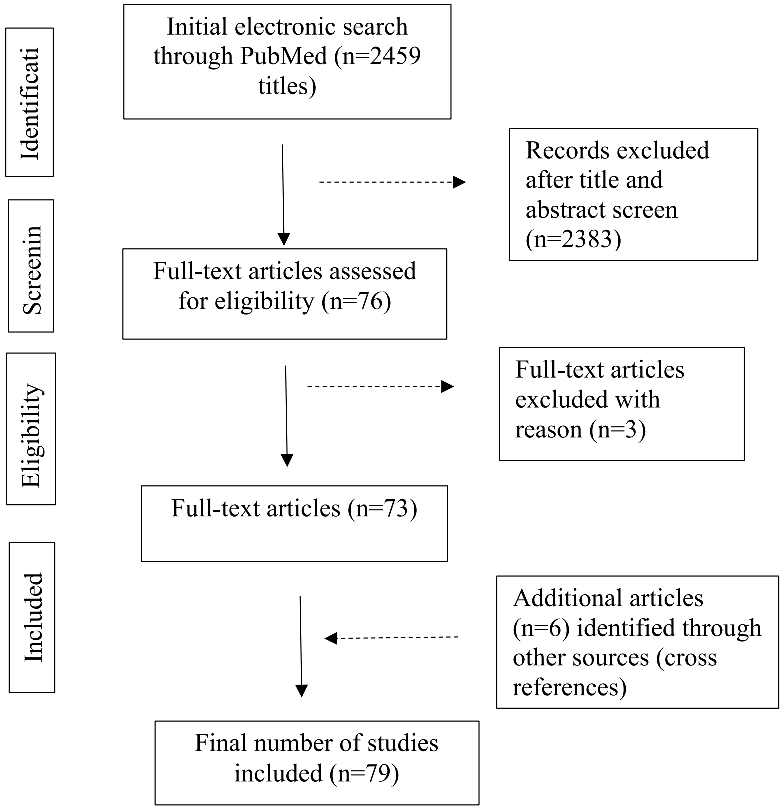

Figure 1: Flow diagram (PRISMA format) of the screening and selection process

whole reviewed articles thoroughly and in detail, the focused question was discussed according to the following parameters:

- Loading performance
- Adhesion and adaptation performance
- Clinical performance

1. SHORT FIBER-REINFORCED COMPOSITE (SHORT-FRC): BIOMIMETIC COMPOSITE RESTORATIONS

Efforts have been made to reinforce composite restorations of ETT by using FRC as a substructure with different orientations in order to enhance composite strength and toughness.[31-36] This bilayered composite structure is a restoration that includes both FRC and PFC composites. Studies have shown that the FRC substructure supports the composite restoration and serves as a crack-prevention layer.[37,38] The FRC substructure's thickness has prior importance, as it influences the failure mode and the crack-arresting mechanism. Furthermore, the type of FRC substructure and the thickness of the veneering composite also play a significant role.[39-41] In order to simplify the clinical technique of using FRC inside cavities, many studies in the literature introduced short-FRC as a dentine-replacing material (bulk/core) or post-core foundation *(Figure 2)* under surface layer of enamel-replacing material (PFC), i.e. biomimetic or bilayered composite restorations.

Garlapati *et al.*, studied the *in vitro* fracture resistance of ETT restored with different core materials, and concluded that among the materials tested, teeth restored with short-FRC composite base showed superior fracture resistance and a favorable failure mode.[42] Gürel *et al.*, evaluated the fracture strength of endodontically-treated premolars reinforced by the bulk base of short-FRC.[43] Biomimetic short-FRC based composite restorations showed higher fracture resistance and more restorable fracture type than other tested restorations. In addition, they stated that the traditional way of using prefabricated FRC post is a multistep application, which is more complex and sensitive technique in comparison with using short-FRC as post-core foundation. Gürel *et al.*, highlighted that this biomimetic restorative approach of using short-FRC material is promising for the posterior region.[43] This is in line with Forster *et al.*, and Fráter *et al.*, who studied different designs of restoring endodontically-treated premolars, and found that the application of direct-layered short-FRC as post and core in endodontically-treated premolars performed statistically similarly in the studied conditions as natural teeth and higher than all other tested restoration designs.[44,45] They also emphasized that the direct-layered short-FRC based biomimetic composite restoration is a promising alternative technique in restoring ETT. Garoushi *et al.*, measured the static load-bearing capacity of direct composite restorations on severely damaged crowns made of biomimetic technique compared to bulk-fill and conventional PFC restorations. It

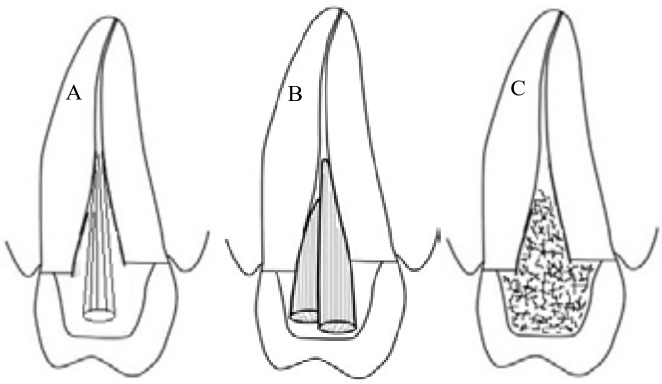

Figure 2: Schematic representation of an endodontically treated tooth restored with a direct post and core restoration using different approaches. (A) prefabricated FRC post + PFC core; (B) individually formed FRC post + PFC core; (C) short-FRC composite as post and core material.
(Modified from Tanner and Le Bell-Rönnlöf. Fiber-reinforced materials in the restoration of root-canal treated teeth (book chapter). In: Perdigặo J. (ed.) Restoration of root canal-treated teeth: An adhesive dentistry perspective. Springer publishing 2016:67-86)

was observed that short-FRC based restorations presented the highest load-bearing capacity compared to other direct composite restorations.[46,47]

Interestingly, Ozsevik *et al.*, found that placing short-FRC as core material under conventional PFC composite restorations of ETT (molars) provided strength that was very similar to that of intact teeth and superior to that of the plain PFC composite and the continuous-FRC reinforced restorations.[48] They stated that, although molar teeth with big cavities were included in the study, other types of teeth with smaller cavities dimensions would be difficult for a long/ continuous fibers placement under surface PFC composites. In contrast, Tekçe *et al.*, reported no difference in the fracture resistance of deep class II composite restorations reinforced either by short-FRC or continuous-FRC base.[49] In another congruous study, Eapen *et al.*, discussed the performance of short-FRC based biomimetic restorations. They concluded that short-FRC can be used as a direct core build-up material that effectively resists heavy occlusal forces against fracture and reinforces the remaining tooth structure in ETT.50 Soares *et al.*, reported that large direct MOD composite restorations can perform as well as indirect inlays (CAD/CAM) when a short-FRC base is used.[51]

In addition to the above-mentioned studies, Shafiei *et al.*, Kemaloglu *et al.*, Yasa *et al.*, Vahid *et al.*, and Fráter *et al.*, also evaluated short-FRC as bulk base for large mesial-occlusal-distal (MOD) cavities in ETT.[52–56] They concluded that the restoration of severely weakened teeth with the use of short-FRC combined with conventional PFC composites might have advantages over conventional PFC composites alone. They claimed that this could be an alternative technique to prevent cuspal fracture on ETT with MOD cavities. It was observed also from the statistical data that the application of short-FRC with an oblique layering technique yielded better fracture thresholds and more favorable fracture patterns than any other studied material/technique combination.[56]

A recent study by Gaintantzopoulou and her colleagues, showed that a combination of short-FRC core with PFC diminished the catastrophic root fractures induced by prefabricated FRC posts, at a similar or higher fracture load.[57] Previous studies by Garoushi *et al.*, and Bijelic *et al.*, found that the restoration of anterior ETT with short-FRC yielded a better load-bearing capacity as opposed to the application of FRC post.[58-60] This was partly confirmed by Forster *et al.*, and Fráter *et al.*, in endodontically treated premolar teeth with class I cavity. In those studies, the directly layered short-FRC post and core groups displayed promising performance concerning fracture behavior.[44,45]

A recently published article by Lassila *et al.*, presented that restoration of structurally compromised incisors with flowable short-FRC as core material and prefabricated FRC post displayed promising performance regarding load bearing capacity and failure mode.[61] However, still the question arises whether the short-FRC material could have adequate curing also inside the root canal. Fráter *et al.*, and Lassila *et al.*, showed by measuring the surface microhardness of the composite inside the root canal that short-FRC can be cured safely up to 6 mm.[45,61]

Bijelic-Donova *et al.*, and Nagata *et al.*, showed that fracture resistance of oblique-loaded anterior single crown restorations using short-FRC yielded better static and fatigue resistance than conventional PFC restorations. They emphasized that short-FRC should be used in high stress-bearing areas to yield enhanced toughness and make biomimetic restorations more resistant to fracture and crack propagation.[62,63]

de Kuijper *et al.*, investigated the mechanical behavior of severely compromised ETT molars restored by means of various types of composite buildups, full-contour lithium disilicate crowns (with or without post) or a lithium disilicate endocrown.[64] They showed that restorations reinforced by short-FRC obtained significantly more repairable fractures than the other restorative methods.

Confirming the previously-mentioned laboratory data, many authors have demonstrated in their clinical reports that using short-FRC as a bulk base or core under direct composite restorations for posterior teeth can be considered an economical and practical measure that could obviate the use of extensive prosthetic treatment.[65–69]

In contrast to the previously-mentioned laboratory studies, Özyürek *et al.*, Atalay *et al.*, Rocca *et al.*, and Barreto *et al.*, reported that the incorporation of short-FRC inside the cavity of posterior destroyed teeth restored with thick PFC composite overlays is not useful to increase their load-bearing capacity or to yield a better failure mode after load to fracture.[70-74] They explained that the discrepancy between their studies and previous studies stemmed from a difference in the thickness of overlay PFC composites, loading set-up, and the adhesive system used. Previous studies showed that short-FRC substructure supports the PFC layer and serve as a crack prevention and redirection layer.[37,38] They demonstrated that the mechanism of arresting crack propagation is greatly influenced by the distance between the short-FRC substructure and the surface where the stress initiates. Thus, highly important is how thick short-FRC and PFC layers are applied. It has been observed *in vitro* that optimal thickness of the veneering PFC composite over the short-FRC substructure is between 0.5 – 1.5 mm.[39-41]

The union of enamel and dentine creates an integrated organ that is capable of supporting high masticatory stresses. Dentine is an important structure to integrate the dentition with surrounding supporting tissues. Understanding the mechanical behavior and structure of dentine provides insight into the design strategies to recover tooth functions and helps to improve dental restoration technique, preventing catastrophic failures of ETT.[75] Therefore, dentine could rather be seen as an FRC. Collagen fibers act as crack stoppers and give dentine unique properties by making it resilient, flexible and tough at the same time.[76] For that reason, improvement could be found when taking advantages of a more dentine-like and high toughness composite as dentine replacement material.

Many studies from the reviewed literature reported that fracture pattern changed to predominantly favorable or restorable fractures with biomimetic FRC restorations, compared to the plain PFC restorations. Interestingly, these were similar to natural crown fracture patterns seen in some studies in the literature.[77,78] As explained previously, fracture toughness is a mechanical property that describes the resistance of brittle materials to the catastrophic propagation of flaws under an applied load.[38,77-79] Thus, it describes damage tolerance of the material and can be considered as a measure of fatigue resistance which predicts structural performance. Since modern composite materials are rigid, they do not lack strength, but they lack toughness.[6] The problem of lack of toughness is especially well seen in extensive ETT restorations, as the volume of the material increases.[80] As a result of the above-mentioned disadvantage, direct composite restorations might not be the best solution in the scenario of major loss of tooth structure.

Bijelic-Donova *et al.*, showed that short-FRC had a statistically higher fracture toughness (2.6 MPa $m^{1/2}$) and fatigue limit than conventional PFC composites (range: 0.9-1.1 MPa $m^{1/2}$).[62,79] They managed to show a strong correlation between fracture toughness and fatigue performance, with short-FRC being able to sustain both compressive static and fatigue load.

It is therefore not surprising that inclusion of short fiber fillers within the resin matrix revealed improvements in fracture toughness.

Interestingly, Tsujimoto *et al.*, determined that the relationship between mechanical properties and dentine bond durability of short-FRC using universal adhesive showed improvements compared to conventional PFC composites.[81] Regardless of adhesive type and etching modes, the ratios of shear fatigue strength (SFS) and shear bond strength (SBS) of short-FRC were higher than those of conventional PFC composites. Authors clarified that superior mechanical properties of short-FRC, especially fracture toughness, could improve its bond durability with universal adhesives. They debated that short fiber might have a reinforcing effect on the oxygen-inhibited layer of the adhesive and they emphasised that, with enhanced mechanical properties and bond durability, short-FRC might perform better in high stress-bearing situations. However, many other researchers investigated the SBS and surface free energy of short-FRC using different adhesives, in comparison with other PFC composites. They found that bonding performance of short-FRC to enamel and dentine was the same as for tested PFC composites.[82-86] Bijelic-Donova *et al.*, looked at the effects of thickness of the oxygen inhibition layer of short-FRC in comparison to conventional PFC composites and they evaluated the interlayer SBS for all tested PFCs.[87] They found that the thickness of oxygen inhibition layer of short-FRC to be the highest overall regardless of type of surface treatment. They attributed the reinforcement of fibers and their orientation, which may influence the oxygen inhibition depth by favoring the passage of oxygen. The presence of oxygen inhibition layer improved the interlayer SBS to adjacent composite layers, which led to more durable adhesion. It is important to emphasize that a valuable advantage of using short-FRC is that it enables restoration of the extensively destroyed tooth using direct composite, and this approach reduces the number of sessions required to end the restorative procedure as well as the cost of treatment.

2. BIDIRECTIONAL FIBER-REINFORCED COMPOSITE (FRC-NET)

Adhesive endocrowns\overlays are increasingly used as a restorative alternative to post-core and crowns for ETT teeth. Their advantages are minimal invasiveness, more simple preparation, and optimal coronal seal. The risk associated with these restorations may result in a catastrophic vertical fracture of the tooth-restoration complex, often leading to the extraction of the tooth.[88] Rocca *et al.*, presented a clinical technique of using FRC-net as resin-coating layer for adhesive endocrown restorations.[88] They claimed that using FRC-net may reduce the risk of extensive fractures and thus improve the success rate of endocrown restorations on ETT teeth. Dere *et al.*, demonstrated that FRC-net reinforced overlays, in addition to producing high fracture load values, are also able to produce more favorable fracture patterns.[89] In accordance, other laboratory studies by Monaco *et al.*, showed that, incorporation of FRC-net at the adhesive interface under indirect composite overlays (CAD/CAM) was found to increase the fracture resistance and can favorably influence the fracture mode of the restorations.[90,91] Although, the ability of FRC-net to change the fracture patterns has already been reported previously in many papers,[31-34] their usefulness with endo-crowns\overlays should, however, be confirmed by more *in vitro* and in vivo studies.

3. INDIVIDUALLY FORMED FRC POSTS

As previously stated, despite the favorable biomechanical behavior of prefabricated FRC posts, there has been discussion about the drawbacks/shortcomings as well.[24-28] On the other hand, many studies in literature showed a significant increase in the fracture resistance of restored teeth when the FRC posts were adapted closely to the canal walls where the highest stresses occur.[92-99] Through the use of an individually formed post technique, it is possible to fill large and irregular root cavities more efficiently than with a single, prefabricated centrally positioned post *(Figure 2*). Because of the semi-IPN (interpenetrating polymer network) polymer matrix structure, the individually formed FRC posts have good bonding ability with cement and direct composite core\restorations enabling reliable surface retained applications. Moreover, with an individually formed FRC post, the amount of luting cement can be minimized, thus reducing the residual shrinkage of the cement and resulting in a better adaptation of the FRC post.[100,101]

Dentists should make all attempts to minimize damaging tensile stress at crown margin. A possible answer to lowering the magnitude of damaging tensile stress is to be found inside the root, at the canal opening through placing a larger amount of fibers at the root canal opening and locating the fibers close to the dentine walls, where the highest stresses are located. An editorial letter written by one of the authors of this article stated that thin prefabricated FRC posts should be used only in very limited clinical cases because they do not provide mechanical support and load-bearing capacity, although the material itself may demonstrate adequate strength in mega-Pascals.[27] In fact, many authors also showed in their *in vitro* studies that ETT restored with an individually formed FRC post exhibited significantly higher fracture resistance than those restored with a single prefabricated FRC post.[45,92-99] Authors concluded that with an individually formed FRC posts, the failures of crown restorations may more often be favorable compared to the failures with other posts, which clinically means repairable failures.

Le Bell *et al.*, showed in their studies that contrary to the prefabricated FRC posts, there were no adhesive (post-cement) failures with the individually formed FRC posts, suggesting better interfacial adhesion of cement to these posts.[100,101] This is in accordance with Mannocci *et al.*, who concluded in their study that the ability of bonding resins to penetrate into individually formed FRC post with semi-IPN polymer matrix may give the opportunity to establish a good link between individually formed FRC posts, luting cements and composite cores.[102] As a consequence, Wiskott and his colleagues concluded in their study that the fatigue resistance of the individually formed FRC post was the highest and twice of that of any other tested prefabricated posts.[103]

To compare the flexural property of different commercially available FRC posts, Lassila *et al.*, had determined the flexural strength and modulus of eighteen different FRC posts.[104] Authors showed that considerable variation was found in the calculated strength values of the studied post brands. Commercial prefabricated FRC posts revealed lower flexural properties compared to those of an individually formed FRC post. They have also shown that individually formed FRC posts may possess some benefits over other studied posts due to their modulus of elasticity being closer to that of dentine.[105]

To compare the marginal adaptation and bonding of both prefabricated and individually formed FRC posts to root canal dentine, Erkut *et al.*, and Sari & Özyesil evaluated microleakage in teeth with over flared root canals restored with different types of FRC posts.[106,107] The data from the SEM photomicrographs clarified that individually shaped FRC posts showed less detachment and better continuity at the resin-dentine interface compared with prefabricated FRC posts. This creates lower microleakage at the coronal section compared with the other tested prefabricated FRC posts.[106] This is in line with Makarewicz *et al.*, who showed in their study that individually formed FRC posts directly cured and cemented in the canal have statistically higher bond strength values and less microleakage compared to the posts cemented in a traditional way.[108] According to them, none of the individually formed and cemented FRC posts revealed any dye penetration between the post and the cement. Clinically it is of importance to have the best possible post-curing adaptation of the cement and post to the walls of the root canal. This is important because the physical contact of the post and the cement forms the basis for the dentine bonding. It is also important to receive sealing against possible microbe penetration through the gaps towards periapical region of the restored teeth.

In addition to the previous mention studies, Zaither *et al.*, and Bitter *et al.*, showed that individually formed FRC posts have higher bond strength to flowable resin cement than those obtained with prefabricated FRC posts.[109,110] Mannocci *et al.*, Abo El-Ela *et al.*, and Bitter *et al.*, showed that individually formed FRC post has a higher dentine bond strength values and less microleakage compared to the prefabricated FRC posts.[111-113]

Short-term clinical reports on the restoration of severely compromised maxillary incisors with individual formed FRC post technique were published.[114-121] Authors showed that direct composite crown on an individually formed root canal post could be used as an economical and conservative treatment option. They stated that individually formed posts have better resistance to rotational forces and dislodgement in comparison to prefabricated FRC posts.[114-117] Authors concluded that the individually formed FRC posts provide a reliable retention for direct/ indirect restorations of ETT. The posts can be used in short and wide or curved root canals, where prefabricated FRC posts cannot insure adequate retention. Filling the pulp chamber with additional posts is of top importance to strengthen the most critical area of the post-core restoration.

On the other hand, Salim *et al*., showed no significant difference in marginal dye penetration between prefabricated and individually formed FRC posts.[122] Amižić *et al*., and Alnaqbi *et al*., reported that prefabricated FRC posts exhibited significantly higher retention forces than the individually formed FRC posts.[123,124] This difference can be attributed to the lack of surface pretreatment and curing procedure of individually made FRC posts. Ferrari *et al*., also reported that over a six-year clinical observation period, the placement of a prefabricated or an individually formed FRC post was shown to contribute significantly to the survival of ETT restored premolars. However, this contribution was more effective for prefabricated than for individually made FRC posts.[125] Authors claimed that the stronger mechanical properties of the used prefabricated FRC posts in comparison with the individually made FRC posts have been advocated as a possible explanation for the more satisfactory performance.[125]

In summary, it seems that to date a thick and short individually made FRC posts would be a biomechanically optimal alternative. A semi-IPN post can be light-cured directly to the root canal simultaneously with the dual curing of resin luting cement. Glass fibers of the post transmit the curing light and polymerize the resin matrix of the post.

CONCLUSION

Based on the reviewed studies, short-FRC resin, FRC-net and individually formed FRC posts show several benefits in restoring ETT. The studies indicate notable benefits regarding load bearing capacity, fracture mode and bond strength in adhesive interfaces with these materials. Thus, these alternative materials/techniques could be used in different clinical situations during the restoration process of ETT. However, long-term clinical trials are needed in order to confirm the usefulness of these alternatives.

REFERENCES

1. Naumann M, Kiessling S, Seemann R. Treatment concepts for restoration of endodontically treated teeth: A national wide survey of dentists in Germany. *J Prosthet Dent* 2006; **96**:332-338.
2. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. *Int Endod J* 1995; **28**:12-8.
3. Cheung W. A review of the management of endodontically treated teeth. Post, core and the final restoration. *J Am Dent Assoc* 2005; **136**:611-619.
4. Skupien JA, Cenci MS, Opdam NJ, Kreulen CM, Huysmans MC, Pereira-Cenci T. Crown vs. composite for post-retained restorations: A randomized clinical trial. *J Dent* 2016 ;**48**:34-39.
5. Grandini S, Goracci C, Tay FR, Grandini R, Ferrari M. Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. *Int J Prosthdont* 2005; **18**:399-404.
6. Jack L. Ferracane. Resin composites-State of art. *Dent Mater* 2010; **27**:29-38.
7. Vallittu PK. High-aspect ratio fillers: fiber-reinforced composites and their anisotropic properties. *Dent Mater* 2015; **31**:1-7.
8. Edwards KL. An overview of the technology of fiber-reinforced plastics for design purposes. *Mater Des* 1998; **19**:1-10.
9. Krause WR, Park SH, Straup RA. Mechanical properties of BIS-GMS resin short glass fiber composites. *J Biomed Mater Res* 1999; **23**:1195-1211.
10. Peterson RC. Discontinues fiber-reinforced composites above critical length. *J Dent Res* 2005; **84**:365-370.
11. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. *J Endod* 2010; **36**:609-617.
12. Rundquist BD, Versluis A. How does canal taper affect root stresses? *Int Endod J* 2006; **39**:226-237.
13. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. *J Endod* 2009; **35**:236-238.
14. Bürklein S, Tsotsis P, Schäfer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. *J Endod* 2013; **39**:501-504.
15. Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature--Part 1. Composition and micro- and macrostructure alterations. *Quintessence Int* 2007; **38**:733-743.
16. Rocca GT, Krejci I. Crown and post-free adhesive restorations for endodontically treated posterior teeth: from direct composite to endocrowns. *Eur J Esthet Dent* 2013; **8**:156-179.
17. Qualthrough AJ, Mannocci F. Tooth-colored post system: a review. *Oper Dent 2003*; **28**:86-91.
18. Fennis WM, Kuijs RH, Kreulen CM, Roeters FJ, Creugers NH, Burgersdijk RC. A survey of cusp fractures in a population of general dental practices. *Int J Prosthodont* 2002; **15**:559-563.
19. 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**:117-129.
20. Figueiredo FE, Martins-Filho PR, Faria-E-Silva AL. Do metal post-retained restorations result in more root fractures than fiber post-retained restorations? A systematic review and meta-analysis. *J Endod* 2015;**41**:309-316.
21. Mangoush E, Säilynoja E, Prinssi R, Lassila L, Vallittu PK, Garoushi S. Comparative evaluation between glass and polyethylene fiber reinforced composites: A review of the current literature. *J Clin Exp Dent* 2017;**9**:e1408-e1417.
22. Spazzin AO, de Moraes RR, Cecchin D, Farina AP, Carlini-Júnior B, Correr-Sobrinho L. Morphological analysis of glass, carbon and glass/carbon fiber posts and bonding to self or dual-cured resin luting agents. *J Appl Oral Sci* 2009;**17**:476-480.
23. Figueiredo FE, Martins-Filho PR, Faria-E-Silva AL. Do metal post-retained restorations result in more root fractures than fiber post-retained restorations? A systematic review and meta-analysis. *J Endod* 2015; **41**:309-316.
24. Kramer EJ, Meyer-Lueckel H, Wolf TG, Schwendicke F, Naumann M, Wierichs RJ. Success and survival of post-restorations: six-year results of a prospective observational practice-based clinical study. *Int Endod J* 2019; **52**:569-578.

25. Wierichs RJ, Kramer EJ, Wolf TG, Naumann M, Meyer-Lueckel H. Longevity of composite build-ups without posts-10-year results of a practice-based study. *Clin Oral Investig* 2019; **23**:1435-1442.
26. Naumann M, Schmitter M, Krastl G. Postendodontic Restoration: Endodontic Post-and-Core or No Post At All? *J Adhes Dent* 2018; **20**:19-24.
27. Vallittu PK. Are we misusing fiber posts? Guest editorial. *Dent Mater* 2016; **32**:125-126.
28. Barfeie A, Thomas MBW, Watts A, Rees J. Failure mechanisms of fiber posts: A literature review. *Eur J Prosthod Rest Dent* 2015; **23**:115-127.
29. Rasimick B, Wan J, Musikant B, Deutsch A. A review of failure modes in teeth restored with adhesively luted endodontic dowels. *J Prosthodont 2010*; **19**:639-646.
30. Zarow M, Ramírez-Sebastià A, Paolone G, de Ribot Porta J, Mora J, Espona J, Durán-Sindreu F, Roig M. A new classification system for the restoration of root filled teeth. *Int Endod J* 2018; **51**:318-334.
31. Garoushi S, Lassila LVJ, Vallittu PK. Direct composite resin restoration of an anterior tooth: Effect of fiber-reinforced composite substructure. *Eur J Prosthodont Restor Dent* 2007; **15**:61-66.
32. Garoushi SK, Lassila LV, Vallittu PK. Fiber-reinforced composite substructure: Load bearing capacity of an onlay restoration. *Acta Odontol Scand* 2006; **64**:281-285.
33. Fennis WM, Tezvergil A, Kuijs RH, Lassila LV, Kreulen CM, Creugers NH, Vallittu PK. In vitro fracture resistance of fiber reinforced cusp-replacing composite restorations. *Dent Mater* 2005; **21**:565-572.
34. Fennis WM, Kreulen CM, Tezvergil A, Lassila LV, Vallittu PK, Creugers NH. In vitro repair of fractured fiber-reinforced cusp-replacing composite restorations. *Int J Dent* 2011; **2011**:165938.
35. Khan SI, Anupama R, Deepalakshmi M, Kumar KS. Effect of two different types of fibers on the fracture resistance of endodontically treated molars restored with composite resin. *J Adhes Dent* 2013; **15**:167-171.
36. Khan SIR, Ramachandran A, Alfadley A, Baskaradoss JK.Ex vivo fracture resistance of teeth restored with glass and fiber reinforced composite resin. *J Mech Behav Biomed Mater* 2018; **82**:235-238.
37. Garoushi S, Vallittu PK, Lassila LVJ. Short glass fiber reinforced restorative composite resin with semi-interpenetrating polymer network matrix. *Dent Mater* 2007; **23**:1356–1362.
38. Garoushi S, Sailynoja E, Vallittu PK, Lassila L. Physical properties and depth of cure of a new short fiber reinforced composite. *Dent Mater* 2013; **29**:835-841.
39. Garoushi S, Lassila LVJ, Tezvergil A, Vallittu PK. Static and fatigue compression test for particulate filler composite resin with fiber-reinforced composite substructure. *Dent Mater* 2007e; **23**:17-23.
40. Garoushi S, Lassila LV, Tezvergil A, Vallittu PK. Load bearing capacity of fibre-reinforced and particulate filler composite resin combination. *J Dent* 2006; **34**:179-184.
41. Omran T, Garoushi S, Lassila LVJ, Vallittu PK. Bonding interface affects the load-bearing capacity of bilayered composites. *Dent Mater J* 2019; **38**:1002-1011.
42. Garlapati TG, Krithikadatta J, Natanasabapathy V. Fracture resistance of endodontically treated teeth restored with short fiber composite used as a core material-An in vitro study. *J Prosthodont Res* 2017; **61**:464-470.
43. Gürel MA, Helvacioğlu Kivanç B, Ekıcı A, Alaçam T. Fracture resistance of premolars restored either with short fiber or polyethylenewoven fiber-reinforced composite. *J Esthet Restor Dent* 2016; **28**:412-418.
44. Forster A, Sary T, Braunitzer G, Frater M. In vitro fracture resistance of endodontically treated premolar teeth restored with a direct layered fiber-reinforced composite post and core. *J Adhes Sci Technol* 2017;31 :1454-1466.
45. Fráter M, Lassila L, Braunitzer G, Vallittu PK, Garoushi S. Fracture resistance and marginal gap formation of post-core restorations: influence of different fiber reinforced composites. *Clinical Oral Investigations* 2019 in press.
46. Garoushi SK, Hatem M, Lassila L, Vallittu, PK. The effect of short fiber composite base on microleakage and load-bearing capacity of posterior restorations. *Acta Biomater Odontol Scand* 2015; **1**:6-12.
47. Garoushi S, Mangoush E, Vallittu M, Lassila L. Short fiber reinforced composite: A new alternative for direct onlay restorations. *Open Dent J* 2013; **30**:181-185.
48. Ozsevik AS, Yildirim C, Aydin U, Culha E, Surmelioglu D. Effect of fibre-reinforced composite on the fracture resistance of endodontically treated teeth. *Aust Endod J* 2016; **42**:82-87.
49. Tekçe N, Pala K, Tuncer S, Demirci M, Serim ME. Influence of polymerization method and type of fibre on fracture strength of endodontically treated teeth. *Aust Endod J* 2017; **43**:115-122.
50. Eapen AM, Amirtharaj LV, Sanjeev K, Mahalaxmi S. Fracture resistance of endodontically treated teeth restored with 2 different fiber-reinforced composite and 2 conventional composite resin core buildup materials: An in vitro study. *J Endod* 2017; **43**:1499-1504.
51. Soares LM, Razaghy M, Magne P. Optimization of large MOD restorations: Composite resin inlays vs. short fiber-reinforced direct restorations. *Dent Mater* 2018; **34**:587-597.
52. Shafiei F, Doozandeh M, Ghaffaripour D. Effect of Different Liners on Fracture Resistance of Premolars Restored with Conventional and Short Fiber-Reinforced Composite Resins. *J Prosthodont* 2019; **28**:304-309.
53. Kemaloglu H, Emin Kaval M, Turkun M, Micoogullari Kurt S. Effect of novel restoration techniques on the fracture resistance of teeth treated endodontically: An in vitro study. *Dent Mater J* 2015; **34**:618-622.
54. Yasa B, Arslan H, Yasa E, Akcay M, Hatirli H. Effect of novel restorative materials and retention slots on fracture resistance of endodontically-treated teeth. *Acta Odontol Scand* 2016; **74**:96-102.
55. Vahid NA, Manjunath MK. Comparison of fracture resistance of maxillary first premolars with class II Mesio-Occluso-Distal (MOD) Cavities restored with newer resin based composite-An ex vivo study. *International J of Current Res* 2016; **8**:29814-29820.
56. Fráter M, Forster A, Keresztúri M, Braunitzer G, Nagy K. In vitro fracture resistance of molar teeth restored with a short fibre-reinforced composite material. *J Dent* 2014; **42**:1143-1150.
57. Gaintantzopoulou MD, Farmakis ET, Eliades GC. Effect of Load Cycling on the Fracture Strength/Mode of Teeth Restored with FRC Posts or a FRC Liner and a Resin Composite. *Biomed Res Int* 2018; **2018**:9054301.
58. Garoushi S, Vallittu PK, Lassila L. Direct restoration of severely damaged incisors using short fiber-reinforced composite resin. *J Dent* 2007; **35**:731-736.
59. Garoushi S, Vallittu PK, Lassila LV. Continuous and short fiber reinforced composite in root post-core system of severely damaged incisors. *Open Dent J* 2009; **3**:36-41.
60. Bijelic J, Garoushi S, Vallittu PK, Lassila LV. Short fiber reinforced composite in restoring severely damaged incisors. *Acta Odontol Scand* 2013; **71**:1221-1231.
61. Lassila L, Oksanen V, Fráter M, Vallittu PK, Garoushi S. The influence of resin composite with high fiber aspect ratio on fracture resistance of severely damaged bovine incisors. *Dent Mater J* 2020 [Epub ahead of print].
62. Bijelic-Donova J, Garoushi S, Vallittu PK, Lassila LVJ. Mechanical properties, fracture resistance, and fatigue limits of short fiber reinforced dental composite resin. *J Prosthet Dent* 2016; **115**:95–102.

63. Nagata K, Garoushi SK, Vallittu PK, Wakabayashi N, Takahashi H, Lassila LVJ. Fracture behavior of single-structure fiber-reinforced composite restorations. Acta Biomat Odonto Scandi 2016; **2**:118-124.
64. de Kuijper M, Gresnigt M, van den Houten M, Haumahu D, Schepke U, Cune MS. Fracture Strength of Various Types of Large Direct Composite and Indirect Glass Ceramic Restorations. *Oper Dent* 2019; **44**:433-442.
65. Soares R, Ataide N, Fernandes M, Lambor R. Fibre reinforcement in a structurally compromised endodontically treated molar: A case report. *Restorative Dentistry & Endodontics* 2016; **41**:152-154.
66. Garoushi S, Tanner J, Vallittu P, Lassila L. Preliminary clinical evaluation of short fiber-reinforced composite resin in posterior teeth: 12-months report. *Open Dent J* 2012; **6**:41-45.
67. Tanner J, Tolvanen M, Garoushi S, Säilynoja E. Clinical evaluation of fiber-reinforced composite restorations in posterior teeth - results of 2.5 year follow-up *Open Dent J* 2018; **12**:476-485.
68. Shah J, Raghavendra S, Gathani K, Wadekar S. A practical approach in conservative management of vertical coronal fracture in molar: A case report. *IIOABJ* 2016; **7**:42-44.
69. Yadav K, De Ataide IN, Fernandes M, Lambor R, Alreja D. Endodontic management of a mandibular first molar with radix entomolaris and conservative post-endodontic restoration with CAD/CAM Onlay: A novel clinical technique. *J Clin Diagn Res* 2016; **10**:13-15.
70. Özyürek T, Ülker Ö, Demiryürek EÖ, Yılmaz F. The Effects of Endodontic Access Cavity Preparation Design on the Fracture Strength of Endodontically Treated Teeth: Traditional Versus Conservative Preparation. *J Endod* 2018; **44**:800-805.
71. Atalay C, Yazici AR, Horuztepe A, Nagas E, Ertan A, Ozgunaltay G. Fracture resistance of endodontically treated teeth restored with bulk fill, bulk fill flowable, fiber-reinforced, and conventional resin composite. *Oper Dent* 2016; **41**:131-140.
72. Rocca GT, Saratti CM, Cattani-Lorente M, Feilzer AJ, Scherrer S, Krejci I. The effect of a fiber reinforced cavity configuration on load bearing capacity and failure mode of endodontically treated molars restored with CAD/CAM resin composite overlay restorations. *J Dent* 2015; **43**:1106-1115.
73. Rocca GT, Saratti CM, Poncet A, Feilzer AJ, Krejci I. The influence of FRCs reinforcement on marginal adaptation of CAD/CAM composite resin endocrowns after simulated fatigue loading. *Odontology* 2016; **104**:220-32.
74. Barreto BC, Van Ende A, Lise DP, Noritomi PY, Jaecques S, Sloten JV, De Munck J, Van Meerbeek B. Short fibre-reinforced composite for extensive direct restorations: A laboratory and computational assessment. *Clin Oral Investig* 2016; **20**:959-966.
75. Eltit F, Ebacher V, Wang R. Inelastic deformation and microcracking process in human dentin. *J Struct Biol* 2013; **183**:141-8.
76. Keulemans F, Garoushi S & Lassila L. Fillings and core-built ups (Book Chapter). In Vallittu and Özcan (eds) A Clinical Guide to Principles of Fibre Reinforced Composites (FRCs) in Dentistry. *Woodhead Publishing* 2017.
77. Lassila L, Keulemans F, Säilynoja E, Vallittu PK, Garoushi S. Mechanical properties and fracture behavior of flowable fiber reinforced composite restorations. *Dent Mater* 2018; **34**:598-606.
78. Imbeni V, Kruzic JJ, Marshall GW, Marshall SJ, Ritchie RO. The dentin-enamel junction and the fracture of human teeth. *Nat Mater* 2005; **4**:229-232.
79. Bijelic-Donova J, Garoushi S, Lassila LV, Keulemans F, Vallittu PK. Mechanical and structural characterization of discontinuous fiber-reinforced dental resin composite. *J Dent* 2016; **52**:70-78.
80. Forster A, Braunitzer G, Tóth M, Szabó BP, Fráter M. In Vitro Fracture Resistance of Adhesively Restored Molar Teeth with Different MOD Cavity Dimensions. *J Prosthodont*. 2019; **28**:325-331.
81. Tsujimoto A, Barkmeier WW, Takamizawa T, Watanabe H, Johnson WW, Latta MA, Miyazaki M. Relationship between mechanical properties and bond durability of short fiber-reinforced resin composite with universal adhesive. *Eur J Oral Sci* 2016; **124**:480-489.
82. Tsujimoto A, Barkmeier WW, Takamizawa T, Latta MA, Miyazaki M. Bonding performance and interfacial characteristics of short fiber-reinforced resin composite in comparison with other composite restoratives. *Eur J Oral Sci* 2016; **124**:301-308.
83. Emre Nagas, Isil Cekic-Nagas, Ferhan Egilmez, Gulfem Ergun, Pekka K. Vallittu, Lippo V. J. Lassila. Bond strength of fiber posts and short fiber-reinforced composite to root canal dentine following cyclic loading. *Journal of Adhesion Science and Technology* 2017; **31**:1397-1407.
84. Garoushi S, Vallittu PK, Lassila LVJ. Effect of storage time on microtensile bond strength of short glass fiber-reinforced composite. *Chin J Dent Res* 2007; **10**:7-10.
85. Beldüz Kara N, Kanyilmaz T, Çankaya S, Kara C. Evaluation of the effect of different post materials and adhesive systems on the bonding strength of short-post technique for primary teeth. *Int J Paediatr Dent* 2018 ;**28**:239-248.
86. Omran TA, Garoushi S, Abdulmajeed AA, Lassila LV, Vallittu PK. Influence of increment thickness on dentine bond strength and light transmission of composite base materials. *Clin Oral Investig* 2017; **21**:1717-1724.
87. Bijelic-Donova J, Garoushi S, Lassila LVJ, Vallittu PK. Oxygen inhibition layer of composite resins: effects of layer thickness and surface layer treatment on the interlayer bond strength. *Eur J Oral Sci* 2015; **123**:53-60.
88. Rocca GT, Rizcalla N, Krejci I. Fiber-reinforced Resin Coating for Endocrown Preparations: A Technical Report. *Oper Dent* 2013; **38**:242-248.
89. Dere M, Özcan M, Göhring TN. Marginal quality and fracture strength of root-canal treated mandibular molars with overlay restorations after thermocycling and mechanical loading. *J Adhes Dent* 2010; **12**:287-294.
90. Monaco C, Bortolotto T, Arena A, Krejci I. Restoring Nonvital Premolars with Composite Resin Onlays: Effect of Different Fiber-reinforced Composite Layers on Marginal Adaptation and Fracture Load. *J Adhes Dent* 2015; **17**:567-574.
91. Monaco C, Arena A, Scotti R, Krejci I. Fracture Strength of Endodontically Treated Teeth Restored with Composite Overlays with and without Glass-fiber Reinforcement. *J Adhes Dent* 2016; **18**:143-149.
92. Le Bell-Rönnlöf AM, Lassila LV, Kangasniemi I, Vallittu PK. Load-bearing capacity of human incisor restored with various fiber-reinforced composite posts. *Dent Mater* 2011; **27**:107-115.
93. Hatta M, Shinya A, Vallittu PK, Shinya A, Lassila LV. High volume individual fiber post versus low volume fiber post: The fracture load of the restored tooth. *J Dent* 2011; **39**:65-71.
94. Fráter M, Forster A, Jantyik Á, Braunitzer G, Nagy K, Grandini S. In vitro fracture resistance of premolar teeth restored with fibre-reinforced composite posts using a single or a multi-post technique. *Aust Endod J* 2017; **43**:16-22.
95. Fráter M, Forster A, Jantyik Á, Braunitzer G, Nagy K. Fracture strength of elastic and conventional fibre-reinforced composite intraradicular posts-an in vitro pilot study. *Fogorv Sz*. 2015; **108**:115-119.
96. Bijelic J, Garoushi S, Vallittu P, Lassila L. Fracture load of tooth restored with fiber post and experimental short fiber composite. *Open Dent J* 2011; **5**:58–65.
97. Qiufie Xie , Wei Wu , Peng Liu & Pekka K. Vallittu. Fatigue Resistance of Resin-Bonded Post–Core–Crown Treated Teeth with Flared Root Canal. *Journal of Adhesion Science and Technology* 2009; **23**:7-8.
98. 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.

99. Fokkinga WA, Kreulen CM, Le Bell-Rönnlöf AM, Lassila LV, Vallittu PK, Creugers NH. Fracture behavior of structurally compromised non-vital maxillary premolars restored using experimental fiber reinforced composite crowns. *Am J Dent* 2006; **19**:326-332.

100. Le Bell AM, Tanner J, Lassila LV, Kangasniemi I, Vallittu P. Bonding of composite resin luting cement to fiber-reinforced composite root canal posts. *J Adhes Dent* 2004; **6**:319-325.

101. Le Bell AM, Lassila LV, Kangasniemi I, Vallittu PK. Bonding of fibre-reinforced composite post to root canal dentin. *J Dent* 2005; **33**:533-539.

102. 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.

103. Wiskott HW, Meyer M, Perriard J, Scherrer SS. Rotational fatigue-resistance of seven post types anchored on natural teeth. *Dent Mater* 2007; **23**:1412–1419.

104. Lassila LV, Tanner J, Le Bell AM, Narva K, Vallittu PK. Flexural properties of fiber reinforced root canal posts. *Dent Mater* 2004; **20**:29–36.

105. Alander P, Lassila L, Vallittu PK. The span length and corss-sectional design affect values of strength. *Dent Mater* 2005; **21**:347-353.

106. Erkut S, Gulsahi K, Imirzahoglu P, Caglar A, Karbhari VM, Ozmen I. Mikroleakage in over flared root canals restored with different fiber reinforced dowels. *Oper Dent* 2008; **33**:92-101.

107. Sarı T, Özyesil AG. Microleakage of teeth restored with different adhesive dowel systems: an in vitro study. *J Prosthodont* 2014; **23**:45-9.

108. 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; **26**:68-75.

109. Zaitter S, Sousa-Neto MD, Roperto RC, Silva-Sousa YT, El-Mowafy O. Microtensile bond strength of glass fiber posts cemented with self-adhesive and self-etching resin cements. *J Adhes Dent* 2011; **13**:55-59.

110. Bitter K, Neumann K, Kielbassa AM. Effects of pretreatment and thermocycling on bond strength of resin core materials to various fiber-reinforced composite posts. *J Adhes Dent* 2008; **10**:481-489.

111. Mannocci F, Machmouridou E, Watson TF, Sauro S, Sherriff M, Pilecki P, Pitt-Ford TR. Microtensile bond strength of resin-post interfaces created with interpenetrating polymer network posts or cross-linked posts. *Med Oral Patol Oral Cir Bucal* 2008; **13**:745-752.

112. Abo El-Ela OA, Atta OA, El-Mowafy O. Microtensile bond strength of nonmetallic dowels bonded to radicular dentin with self-etch adhesives. *J Prosthodont* 2009;**18**:167-171.

113. Bitter K, Noetzel J, Neumann K, Kielbassa AM. Effect of silanization on bond strengths of fiber posts to various resin cements. *Quintessence Int* 2007;**38**:121-128.

114. Vilkinis V, Žilinskas J. Direct composite resin crown fabrication on a custom formed root canal post - EverStick®POST. *Stomatologija* 2016; **18**:32-36.

115. Sawant A, Chunawalla Y, Morawala A, Kanchan N, Jain K, Talathi R. Evaluation of novel glass fiber-reinforced composite technique for primary anterior teeth with deep carious lesions: A 12-month clinical study. *Int J Clin Pediatr Dent* 2017; **10**:126-130.

116. Talat M. Beltagy. Rehabilitation of compromised permanent incisors with anatomically adjustable fiber post. *Tanta Dental Journal* 2018; **15**:52–59.

117. Talat M. Beltagy. Fracture resistance of rehabilitated flared root canals with anatomically adjustable fiber post. *Tanta Dental Journal* 2017; **14**:96–103.

118. Deepa VL, Reddy SN, Garapati VC, Sudhamashetty SR, Yadla P. Fracture Fragment Reattachment Using Projectors and Anatomic everstick Post™: An Ultraconservative Approach. *J Int Soc Prev Community Dent* 2017; **7**(Suppl 1):S52-S54.

119. Durkan RK, Ozel MB, Celik D, Bağiş B.The restoration of a maxillary central incisor fracture with the original crown fragment using a glass fiber-reinforced post: a clinical report. *Dent Traumatol* 2008; **24**:71-75.

120. Bagis B, Korkmaz YT, Korkmaz FM, Durkan R, Pampu AA. Complicated subgingivally fractured central and lateral incisors: case report. *J Can Dent Assoc* 2011; **77**:b145.

121. Subramaniam P, Babu KL, Sunny R. Glass fiber reinforced composite resin as an intracanal post--a clinical study. *J Clin Pediatr Dent* 2008; **32**:207-210.

122. Salim NA, Muttlib NAA, Alawi R, Rahman NA, Ariffin Z. Evaluation of Microleakage Between Different Post and Core Systems Under Gradual Loading: an In-Vitro Study. *Acta Stomatol Croat* 2018; **52**:218-226.

123. Amižić IP, Miletić I, Baraba A, Fan Y, Nathanson D. In vitro retention of prefabricated and individually formed posts: A pilot study. *J Prosthet Dent* 2018; **120**:553-557.

124. Alnaqbi IOM, Elbishari H, Elsubeihi ES. Effect of Fiber Post-Resin Matrix Composition on Bond Strength of Post-Cement Interface. I*nt J Dent* 2018; **2018**:4751627.

125. Ferrari M, Vichi A, Fadda GM, Cagidiaco MC, Tay FR, Breschi L, Polimeni A, Goracci C. A randomized controlled trial of endodontically treated and restored premolars. *J Dent Res* 2012; **91**:72-78.

ejprd.org - Published by Dennis Barber Journals.