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Fiber Reinforced Composite Posts - A Review of Literature

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Abstract: ***During the last years a significant progress in the development of bondable fiber reinforced composite (FRC) posts for reinforcing the endodontically treated teeth was observed. A lot of advantages such as high fatigue resistance, low elastic modulus, which is similar to that of dentine, excellent light conductivity etc. are attributed to the FRC posts. There are different types of FRC posts – carbon fiber posts, prefabricated glass and quarz-fiber posts, individual glass fiber posts, polyethylene fiber posts, hollow posts. The surface treatment, adhesive systems and luting agents used for fiber post cementation were described in details.***

Keywords: fiber reinforced composite post, hollow post, surface treatment, adhesion to dentin, luting agents

1. Introduction

The prognosis of endodontically treated teeth depends not only on the success of the endodontic treatment, but also on the type of reconstruction. These considerations include the decision of whether or not to use posts [1]. While metal posts have been the standard for many years, nonmetallic posts have been introduced to address the need for a more esthetic material in the anterior region. In the recent years there have been significant advances in the development of bondable, fiber-reinforced and ceramic esthetic posts to reinforce endodontically treated teeth. The presence of a metal post can cause shadowing of the soft tissues adjacent to the root surface, which will adversely affect the esthetic results required of bonded resin and ceramic restorations in the anterior region [2,3].

1.1 Ceramic zirconia posts

By the end of 1980's partially stabilized zirconium dioxide ceramic material was introduced. It shows excellent chemical stability, good esthetic and physical properties, good radiopacity and superior light transmission properties. However, root fractures were observed due to the high elastic modulus of zirconia posts – 200 GPa. Also if there is a need of endodontic retreatment the reported rigidity and fragility [4] become a significant disadvantage because it is very difficult to remove a zirconia post from the root canal [5, 7].

These posts are indicated in restoration of weakened and grossly destructed tooth structure [6]. It's recommended for bond strength improvement to use resin cements and do surface pretreatment with airborne particle abrasion followed by silanization.

1.2 Fiber reinforced posts

a) Carbon fiber posts
b) Prefabricated glass and quarz-fiber posts
c) Individual glass fiber posts
d) Polyethylene fiber posts
e) Hollow fiber posts

a) Carbon fiber posts
Carbon fiber posts can not be classified as typical esthetic posts because of their dark color and difficult hiding under all ceramic or composite restorations. To overcome this complication coated post are available. Other disadvantages are a lack of radiopacity and poor adhesion to composite resin cores [7]. Although they are easy to manipulate, have good mechanical properties (high impact resistance, increased fatigue resistance, shock absorbtion and have low modulus of elasticity, more similar to that of dentin – 18-42 GPa [8].

b) Prefabricated glass and quarz-fiber posts
They are made of prestretched silanizated glass- or quartz-fibers bounded by methacrylate- or epoxy-polymer matrix with high degree of conversion and highly cross-linked structure that binds the fibers [9]. The fibers offer strength and stiffness, while the polymer matrix transfers forces to the fibers and also protects them from the moisture of the oral environment [10].

These posts have excellent esthetic properties, flexural and fatigue strength, modulus of elasticity similar to that of dentin, they are easy to handle allowing one-visit therapy, biocompatibility, relatively cheap and can be easily removed if necessary and nowadays they are often first clinician choice [3].

c) Individual glass fiber posts
Since the advantages of the prefabricated fiber posts have been well known, a new concept for individually formed fiber reinforced composite (FRC) post was introduced [11]. It is based on minimizing the preparation need to the deeper parts of the root canal thus allowing addition of higher quantity of FRC material to the coronal root canal opening of the tooth. In this way, the concept saves the dentin, minimizes stress at the apical parts of the post and enables stiff and fracture resistant post with larger diameter to the core that forms strong support for the core [3].

Although individually glass fiber posts, in a comparison with prefabricated glass fiber posts, show higher flexural strength , higher fracture resistance, better interfacial adhesion of cement, they are more difficult to use for an inexperienced clinician because of a highly sticky nature of a non-polymerized matrix and fibers propensity to separation [3, 11, 12, 13].

d) Polyethylene fiber posts

A fiber composite laminate endodontic post and core system based on a woven polyester bondable ribbon had been introduced. This reinforcement material is composed of plasma treated ultra-high molecular weight polyethylene fibers woven into three dimensional structure, leno wave or triaxial braid. Due to special patterns of cross-linked threads, a higher mechanical interlocking is provided. Also, the fiber's superficial tension is reduced due to cold gas plasma pretreatment in order to ensure good chemical bond to resin materials.

It has been shown that polyethylene-reinforced resin provides adequate retention required for clinical success of a post and core system and good fracture resistance with increased incidence of repairable fractures in structurally compromised canals. The high price of polyethylene fibers limits their use in daily practice despite the excellent characteristics shown by these posts [3].

e) Hollow fiber posts

The occurrence of gaps, voids, and cavities may occur at the interface between the dentin and restorative material or at the interface of the post and restorative material due to filling shortage and polymerization shrinkage. Vichi et al. reported that the main causes of void formation in restorative material were the viscosity of the restorative material, the structure of the root canal, and the installation method of the post [14]. A new direct core build-up method was developed by Inaba et al., comprising the preparation of a hollow Fiber Reinforced Plastic (FRP) post and a method of applying the restorative material by injecting it into the bottom of the root canal through the hollow post. After they have studied the bending properties of the prepared hollow post and compare with those of a solid fiber post and a commercially available fiber post., the pullout strength and the number and distribution of voids in the core body were observed, and the results, Inaba et al., published the following conclusion: "We have manufactured a cylindrical FRP post and developed a new direct core build-up method which decreases the number of voids in the resulting built-up core body and increases the bonding strength between the FRP post and the restorative material. As a result, the pullout strength was increased compared with that of the conventional method, and the number of voids in the restorative material was further decreased. The present method has been shown to be an accurate and precise direct method of core build-up for clinical practice because it is nearly unaffected by the viscosity of the restorative materials, the structure of the root canal, and the skill of the operator" [15].

2. Indications for using Fiber Reinforced Composite Posts

Post cementation is indicated when the remaining tooth structure is insufficient to ensure the retention of the restoration and the length of the root canal is enough for adequate post placement and the remaining apical sealing should have minimal length of 4 mm [16,22].

The need of post placement in endodontically treated teeth is related with the weakeness due to decreased or altered tooth structure because of:

- Caries and/or previous restorations
- Fracture or trauma
- Endodontic access and instrumentation
- Decreased moisture

The weakness is directly correlated to the quantity of lost dentine [17].

The literature suggests that the use of fiber posts and resin composite cements might reduce the occurrence of root fractures or post debonding. In general, when the remaining coronal structure is insufficient to ensure retention of the restoration, the use of an intraradicular post is indicated [18].

2.1 Contraindications for using fiber reinforced composite posts

- Teeth with failed endodontic treatment
- Teeth with poor and ambiguous prognosis
- Increased tooth mobility
- Teeth with fragile roots
- Teeth with enough remaining structure which restoration could be done without using a post.

2.2 Structure and biomechanical considerations of the fiber posts

The mechanical properties of prefabricated FRC posts depend, among other things, on the type of fibre used, the type of matrix used, the fibre content, and the direction of the fibres. The fibres contribute stiffness and strength to the usually elastic matrix [19].

Epoxy resins and BisGMA are usually used as a resin based material for dental fiber posts [3, 7].

The silica-based fibers can be made of glass or quartz. Quartz is a crystalline form of silica, whereas glass is monocrystalline. It has been found that that the quartz fiber posts have a higher flexural strength than the glass fiber posts [20].

E-(electrical application) and S-(stiff, strong) glass fibers have become the most commonly used reinforcing fibers. Glass fibers stretch uniformly under stress to their breaking point, and on removal of the tensile load short of breaking point, the fiber returns to its original length. E-glass has good tensile and compressive strength, as well as electrical insulation and rather low cost, but relatively poor fatigue resistance, while S-glass has a different chemical composition, giving higher tensile strength and better wet strength retention, but is rather expensive [3].

The fibers in the FRC posts are designed to provide high tensile strength and the resin matrix is supposed to endure compressive stresses and absorb stresses in the whole post system. Because of their different E-moduli stresses can occur at the interface between the glass/silica fibers and resin matrix as the posts are loaded. These stresses can result in cracks, voids, or micro bubbles and may weaken the post system [2].

The highest quality provides the most even distribution of the fiber in the organic matrix possible with the packing of the fibers as dense as possible, a good combination of fibers with the matrix, a high degree of polymerization of the organic components and a homogeneous post structure without blisters and inclusions. After polymerization, the blanks are brought into their final form through a milling process. There are different post geometries, which also exhibit considerable differences in surface quality due to variations in the milling [21].

The modulus of elasticity of composite resins (5.7 GPa to 25 GPa) and FRC posts (16 GPa to 40 GPa) provide elevated shock resistance, weakening of vibration, shock absorption, and augmented fatigue-resistance [2].

2.3 Retention Factors

a) Post length

The length of the post influences stress distribution in the root, and thereby affects its resistance to fracture. When the length of the post is increased the retentive capacity also increases, but a long post preparation increases the risk of root perforation. A common recommendation has been that the length of the post should be equal to or bigger than the length of the crown. Other criteria concern is the apical seal of the root canal. It has been suggested that leaving at least 4-5 mm of root-filling material is necessary to maintain the apical seal [19, 22].

b) Post diameter and remaining dentin

Ideally, the post diameter should be less than one third the diameter of the root at the cementoenamel junction and 1 mm or more of dentin should remain around the post. Post removal, internal resorption, or current coronal flaring to gain access to the apical aspect may result in decreased dentin thickness at the coronal part. The reduced thickness of the coronal walls may reduce the effect of the ferrule. The restorative procedures required for endodontically treated teeth are dependent upon the amount of coronal dentin remaining [15,22].

c) Post design

The design of the post affects the retention and the success of the restoration. Regarding the post taper, parallel-sided posts are more retentive than tapered posts and they distribute stress more uniformly along their length during function: the greater the taper, the less the retention [19].

The shape of the post can be cylindrical, conical or combined. The combined shape is preferred because the cylindrical half is placed at the coronal part of the root and the remaining tooth structure there is larger than the apical half where the conical part of the post is positioned [22].

d) Luting cements

The use of resinous cements has increased, and studies have reported higher retention values and resistance to fatigue for these cements compared to brittle zinc phosphate cements used widely in the past. The modulus of elasticity of resin cements approaches that of dentin, and therefore they may have the potential to clinically reinforce thin-walled roots. Resin cements are technique-sensitive because of their short working time, the number of operating steps involved, and the sensitivity to moisture, compared to zinc phosphate cements. Some of the newest self-etching resin cements may overcome the technique-sensitiveness of conventionally bonded resin cements. Also an increase in the surface roughness of the post space improves the retention of different cements.The influence of the cement layer elasticity in redistributing the stresses, has been shown to be less relevant as the post flexibility is increased [18,19, 24].

3. Surface treatment of the fiber post

Surface treatment is a common method for improving the adhesion properties of a material, by facilitating chemical and micro-mechanical retention between different constituents. These procedures fall into three categories:

1) Chemical bonding between a composite and post (silane coating);
2) Surface roughening (sandblasting and etching);
3) Combination of micromechanical and chemical components by using the two above-mentioned methods [25].

Silane coupling agent is a hybrid organic-inorganic compound that can mediate adhesion between inorganic and organic matrices through intrinsic dual reactivity capability to increase surface wettability, creating a chemical bridge with OH-covered substrates, such as glass. A chemical bond may be achieved between the core resin matrix and the exposed glass fibers of the post at the interface level. Using a silanization as a preparation of the post before the cementation is well investigated and it's known that the interfacial strength is still relatively low because of the absence of chemical union between the methacrylate-based resin composites and the epoxy resin matrix of fiber posts. Many studies show no effect to the bond strength using a silane alone in post surface treatment [26, 27, 28, 29, 30, 31].

Non-treated fiber posts have a smooth surface area that limits mechanical interlocking between the post surface and resin cement. Sandblasting with alumina particles results in an increased roughness of the surface. Sahafi and others tested the efficacy of blasting the surface of zirconia and fiber posts with silica oxide – Co-Jet system. The treatment was considered too aggressive for fiber posts and beneficial when performed on zirconia posts. The main problem related to these techniques is the lack of selectivity – both the matrix and the fibers of the post are affected [32].

Hydrofluoric acid in combination with a silane-coupling agent is often employed to increase the bond strength between composite resins and feldspathic ceramics. Because silica and quartz present in fiber posts are comparable in chemical structure with ceramic materials, hydrofluoric acid has recently been proposed for etching fiberglass posts. It is intended to create a rough pattern on the surface, which allows for micromechanical interlocking with the resin cement and composite. Despite the improvement in post-to-composite bond strength, a remarkable surface alteration, varying from microcracks to longitudinal fractures of the fiber layer, was found. Different etching times also influence the bond strength of glass fiber-reinforced posts. Although the bond strength was increased by prolonged acid etching, the microstructure of the FRC posts might have been damaged. As a consequence it is not possible to suggest general guidelines for using hydrofluoric acid in the surface etching of aesthetic fiber posts [32, 33, 34].

Because these above-mentioned techniques can sometimes damage the glass fibers and affect the integrity of the posts, substances that selectively dissolve the epoxy matrix without interfering with the fibers have been studied. Potassium permanganate, sodium ethoxide, and hydrogen peroxide (H_2O_2) may effectively remove the epoxy resin and expose the fibers, which are then available to be silanated. H_2O_2 at concentrations of 10% and 24% effectively removes the surface layer of the epoxy resin. It is frequently used in dental practice, mainly for dental bleaching, and is easy and safe to use. The main disadvantage in using H_2O_2 is the prolonged time for etching – 20 minutes. Based on the results of a study, the lower concentration (24%) of H_2O_2 used for only 1 minute generated bond strength similar to that obtained with a higher concentration (50%) applied for longer times (5 and 10 minutes), so it is preferable in clinical use [32, 35].

Also 37% H_3PO_4 etching for 15 second is a better and comfortable alternative to other methods in improving the adhesion of fiber post to root canal dentin [36].

The most important dimension in cementation of a fiber post in the root canal is the limitation of the cure rate as a function of the depth. Also the unreacted monomers as a result of incomplete polymerization of the resin cements, might leak through the apical root filling and could result in inflammatory, cytotoxic, and mutagenic reactions of periodontal tissue. Nowadays it is known that the application of surface treatments might negatively affect the light transmission property of fiber posts [37, 38, 39, 40].

4. Adhesive Systems, Adhesion to the Dentin

The type of adhesive system used in association with the resin cement is of great importance. Current adhesive systems can react with the dental structures by either etch-and-rinse or self-etch approaches.

The presence of smear layer has prompted researchers to recommend a preliminary etching step to remove debris from the canal walls and increase post retention.

A lot of authors have reported that glass fiber post cementation with the resin cement associated with etch-and-rinse adhesive may generate greater bonding potential than self-etch adhesive. This result may be explained by the fact that the acidic monomers responsible for substrate conditioning in self-etch adhesives are less effective in etching the dental structure than the phosphoric acid used in the etch-and-rinse approach. The etch-and-rinse strategy, however, requires a wet dentin substrate for optimal bonding, and controlling the humidity within the root canal is critical. Because the self-etch approach does not require moisture control after etching, these systems can potentially simplify the technique [41, 42, 43, 44, 45].

There is contradictory evidence that some single-bottle adhesive systems (fifth generation) do not bond well to self-cure and dual-cure composite resins because of the acidity of the single-bottle primer/adhesive. Studies demonstrating either a decreased bond or no effect have been reported [41, 46, 47].

The depth of penetration of the curing light within the root canal to polymerize the adhesive that is placed is very important. Total-etch, fourth generation and dual-cure adhesives are the adhesives of choice when cementing a post within a root canal where light penetration and depth of cure will be limited. Also, self-etch, dual-cure composite resin cements have been introduced. These cements offer an alternative to multiple steps and potential contamination within the root canal. This family of new resin luting agents has self-adhesive capability and eliminates the need for separate etching, rinsing and drying, primer, and adhesive steps: BisCem, Bisco; RelyX Unicem, 3M ESPE; MultiLink Automix, Ivoclar Vivadent etc. [48, 49, 50, 51].

The dentin surface in the root canal is often smeared by canal sealer, gutta-percha, temporary cement, and the grease of an impression material. It seems reasonable that phosphate etching and sodium hypochlorite or chlorhexidine irrigation can be helpful to remove contamination and any smear layer before post cementation [52]. However, some investigations have demonstrated that pretreatment with etching or irrigation may negatively influence the resin cement bond efficacy [52, 53, 54]. Also, in many cases, the clinician may not know what type of sealer was used within the root canal. Tjan and Nemetz studied the effect of eugenol-containing endodontic sealer on the retention of prefabricated posts cemented with an adhesive resin technique, and found that the presence of eugenol resulted in significant loss of retention. They also found that the remnants of eugenol in the root canal could be removed without any effect on retention of the post by irrigating the canal with ethyl alcohol (ethanol) or etching with 37% phosphoric acid [55].

5. Luting Agents

Contemporary resin cements may be classified into two main groups, according to the adhesive approach.

In the first group (regular resin cements), the cement is used in association with an adhesive system, while in the second group (more recently introduced) the cement is self-adherent - no pre-treatment of the dental substrate using acid or primers is necessary, allowing simultaneous bonding between the intraradicular dentin and post. These latter materials are known as self-adhesive (or self-etching) resin cements and may simplify the adhesive luting procedures [18].

The regular resin cements were used successfully for many years. The most important disadvantage is the sensitive to mistakes technique. The residual water after the acid rinsing is the main problem that have been discussed in using these cements. The self-adhesive ones were introduced in 2002. The adhesion mechanism is related with the micromechanical bonding and chemical interaction between the acid monomers and hydroxylapatite [56].

The smear layer, occurred during the canal preparation for a post, cannot be removed using self-adhesive cements and this may result negatively on the bond strength. Many studies show that the bond strength, achieved with the regular cements is higher than the self-adhesive ones, but the latter are also a good choice in daily dental practice [24, 56].

Resin cements may also be classified according to their polymerization mode as photopolymerized, self-polymerized, or dual-polymerized materials.

Photocured cements cannot be used for post cementation because they need the curing light to penetrate into the bulk of the material. Self-cured (or chemically-cured) cements have no problems related to their polymerization in the apical areas because the curing process is initiated by a redox mechanism, which is triggered upon the mixing of the base and catalyst pastes. Self-cured materials, however, have worse handling characteristics because of their fast, uncontrolled polymerization.
Dual-cured resin cements are mostly used for luting glass-fiber posts. These materials theoretically combine the favorable properties of extended working time and the capability of reaching proper polymerization in either the presence or absence of light.

It is also known that self or dual-cured resins cements are not compatible with simplified adhesives - two-step etch-and-rinse or one-step self-etch agents [18].

5.1 Advantages of the fiber posts

- High fatigue resistance (1440 MPa) [7];
- Low elastic modulus, which is similar to that of dentine: 18-42 GPa. This biomechanical behaviour avoids the appearance of root fractures (8,57, 58, 59);
- They are chemicaly inert and non-toxic
- Easy post removal in case of failure (22, 60);
- Excellent light conductivity (11mm) – they can be cemented with dual-cure resin cements
- Fiber posts translucency give them excellent esthetic properties so they are preferable in the anterior teeth restorations [22];
- Fiber-reinforced post is bonded within the root canal it dissipates functional and parafunctional forces, reducing the stress on the root [14].

5.2 Disadvantages of the fiber posts

While the use of posts is the standard of care when restoring many endodontically treated teeth, there are disadvantages and risks, which include:
- Requiring additional preparation of the root canal and removing dentin within the root canal, especially the apical end of the root;
- Placing a post is an additional procedure when restoring the tooth;
- The post can interfere with endodontic retreatment through the root canal if retreatment is necessary;
- The post can place undue force on the root and tooth in function that may put the tooth at risk in the future [48].
- Bonding to intraradicular dentin is challenging for clinicians due to the complexity and sensitivity of the technique [61, 62].
- Various resin cements and adhesives are used in clinical practice, it is imperative to know how they perform in relation to incompatibilities between adhesives and resin cements which can lead to possible clinical failures [63].

Biomechanical failures associated with post-treated teeth are common. Loss of retention seems to be the most frequent type of failure in post-restored teeth. Root fracture (3%) is still the complication that leads to the greatest damage and usually results in extraction of the tooth. The prevalent cause of failure of endodontically treated teeth is fracture and the fracture resistance of endodontically treated teeth to horizontal and vertical forces is related to the amount of healthy dentin remaining. Maximum preservation of dentin should therefore be a major objective during both endodontic therapy and following restorative procedures. Minimal tooth cutting is the most effective measure for preventing vertical root fractures. The longevity of the restored endodontically treated tooth is related to the adequate height (1.5-2 mm) of sound tooth structure, or ferrule, between the core and the crown margin. The ferrule provides bracing or casing action to protect the integrity of the root [17].

6. Conclusions

The mechanical properties of prefabricated FRC posts such as high fatigue resistance, low elastic modulus similar to that of dentin, depend, among other things, on the type of fibre used, the type of matrix used, the fibre content, and the direction of the fibres. The fibres contribute stiffness and strength to the usually elastic matrix. Fiber posts have an excellent translucency so they are preferred if anterior esthetic restoration is needed. Surface treatment of the post with different agents – silane, hydrofluoric acid, sandblasting, hydrogen peroxide is recommended for improving the adhesion properties. However, none of the methods of pre-treatment of the post is effective enough in itself to recommend its use in the daily practice of the clinicist. The type of adhesive system used in association with the resin cement is of great importance. It was reported that glass fiber post cementation with the resin cement associated with etch-and-rinse adhesive may generate greater bonding potential than self-etch adhesive. The bond strength, achieved with the regular cements is higher than the self-adhesive ones, but the latter are also a good choice in daily dental practice. If a failure occur and root canal retreatment is necessary fiber post removal is considered as easy. All of these advantages determine the fiber posts as the first means of choice in restoring endodontically treated teeth.

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