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Fiber Post-Has it Evolved yet-An Evidence Based Analysis?

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Abstract

The restorative rehabilitation of extensively damaged endodontically treated teeth often requires an endodontic post as an additional retention element for core build up. Fiber reinforced post is gaining popularity due to their numerous advantages over metal posts. However, there is no published literature on the disadvantages of the fiber-based post systems. This is the first article which reviews the disadvantages and survival rate of fiber post and also compares the performance of fiber post to metal post systems.

Keywords: Advantages; Disadvantages; Failure; Fiber post

Introduction

The ultimate aim of a post-endodontic restoration is not only to rehabilitate the tooth to function but also prevent the occurrence secondary endodontic infection by providing a good seal as contamination of the root canal system during or after restorative treatment is considered an important factor in the ultimate success or failure. When the tooth has lost a large proportion of its structure, auxiliary means are required to ensure retention of the filling material [1]. Intraradicular posts are used for this purpose in teeth that have undergone root canal treatment [2]. Fiber based post were introduced to overcome the disadvantages of cast metal post i.e loss of retention, root fractures, corrosion, discoloration, necessity of removal of extensive root structure, stress concentration and cannot be used when aesthetic requirement is high [3]. The excellent mechanical properties of Fiber Reinforced Composite materials (FRC) have been used in a diverse range of industrial applications for decades in various sports equipment, and aircraft industry. FRC's was introduced as an alternative to conventional materials for use as endodontic posts. It was suggested that the metallic materials used as posts had a higher modulus of elasticity than the supporting dentin, and this mismatch in modulus could lead to stress concentration in the cement lute leading to failure. This lead to the search for a plastic based material that has a modulus closer to that of dentin.

Fiber post is said to be advantageous due to its lower elasticity modulus leading them to behave similarly to dentine and show similar stress patterns under external impacts which prevents catastrophic fractures, to be able to bond tooth structure which prevents microleakage and also there aesthetic nature which allows there use in aesthetic regions [4-6]. However much emphasis is not been made on the drawbacks of fiber post restorations. Although prefabricated fiber posts have been assessed through various in vitro settings, an analysis of data collected by clinical trials is a more reliable form of evidence-based information on these systems which are suggested to be more beneficial over metallic-intraradicular structures. So the aim of this article was to review the various drawbacks of fiber post restorations and to assess if the fiber-based post has evolved enough to replace custom cast post.

Need for Fiber Post

FRC posts contain a high volume percentage of continuous reinforcing fibers of either carbon, silica or polyethylene embedded in either epoxy based or methacrylate-based polymer matrix which keeps the fibers together [7]. The two main advantages of fiber post are aesthetics and ability to form a monoblock. The term monoblock, literally meaning a single unit. Two prerequisites are simultaneously required for a monoblock to function successfully as a mechanically homogenous unit. First, the materials that constitute a monoblock should have the ability to bond strongly and mutually to one another, as well as to the substrate with which the monoblock is intended to reinforce. Second, these materials should have moduli of elasticity that are similar to the substrate [8,9].

Modulus of Elasticity of Fiber Post – A Flipping Coin

In vitro studies based on three-point bending tests of fiber-based suggest that the success of fiber post is said to be due to their good retention properties under mechanical strain as a result of their low elastic modulus, compared with metal posts which are ten times greater than that of dentin [10,11]. But what is contradictory is that the elastic modulus of dentin ranges from 16-18Gpa. However, the modulus of elasticity of fiber-based post varies among manufacturers in a range between 18-42 Gpa [2,12]. And also the rigidity is not only dependent on the modulus of elasticity but also on the diameter of the post. It is stated that for a post with a modulus of elasticity similar to dentin, to have flexibility similar to dentin, should have a diameter equal to that of dentin. However as the required post diameter is always lesser than that of the radicular dentine diameter, the post becomes more flexible [13]. The unanswered question is whether having a “flexible” post allows movement of the core, resulting in increased microleakage under the crown. This question is especially important when there is minimal remaining coronal tooth structure. Because the post is considerably thinner than the tooth, it may be necessary that the post has a higher modulus of elasticity (greater stiffness) to compensate for the smaller diameter. Posts and core foundations are subjected to repeated lateral forces in clinical function. Because nonrigid posts have a modulus of elasticity and flexural strength close to that of dentin, they flex under occlusal load [14]. The beneficial claims of the fiber post root dentin monoblock could not be validated in independent in vitro and retrospective in vivo studies [15-17].

This flexural will lead to two types of failures i.e cohesive and adhesive failure. Fiber posts were shown to lose flexural strength if they are submitted to cyclic loading or to thermocycling due to degradation of the matrix in which the fibers are embedded [2,18,19]. This degradation leads to water sorption and solubility of fiber composites, which vary according to the brand and the homogeneity of the polymer. This affects the hydrolytic stability of the fiber posts and is found to reduce the strength and stiffness considerably, due to epoxy degradation [20]. Torbjorner *et al.*1996 examined carbon-fiber posts using SEM and concluded that failures occurred in the fiber-matrix interface and as microcracks within the matrix [21]. Hence this utilization in the oral environment enhances their degradation and potentially shortens their clinical life. This can be termed as a form of cohesive failure.

Many in vivo studies stated that insufficient post rigidity leads to excessive deformation and stress concentration zone during function giving rise to marginal failure [22,23]. Also when the type of tooth contact was taken into consideration, it was determined that teeth with no proximal contacts were more prone to failure compared to those having at least one contact. Also, teeth restored with single crowns were associated with higher failure rates compared to fixed bridges. The authors commented that such a result in terms of the presence of contacts was expected as neighboring teeth helped the distribution of occlusal forces. As for single crowns being more prone to failure, an explanation was made as the forces acting on these teeth being in the vestibular-oral direction in spite of the presence of contacts [5]. This kind of marginal failure between the luting cement and dentin will lead to microleakage and is termed as the preliminary failure. Continuous microleakage will cause a break in the bond between the luting cement and dentin along the length of the root and ultimately results in debonding. Cagidiaco 2007 evaluated the 2-year outcome of restorative procedures involving the placement of fiber posts in endodontically treated teeth concluded that the major failure types associated with this treatment type were post debonding reported as 4.3% and endodontic failures reported as 3.0%. Therefore stating that microleakage in fiber-based posts leads to either persistence or emergence of a secondary endodontic infection. Hence such kind of failure is an adhesive failure [24].

Bonding – The Controversial Factor

The basic problems with resin-based restorative materials shrink from 2% to 7%. This shrinkage generates forces of contraction [25,26]. The force of polymerization contraction result in gap formation along the surface with the weakest bond [27]. This weak link in fiber-based post systems is not only between radicular dentin and luting cement but also between luting cement and fiber post. The bond strength required to overcome such forces of polymerization shrinkage is at least 15-24Mpa. Deterioration of the resin bond over time, which is also significantly increased with functional forces leads to interfacial leakage [28-38]. The addition problems in the radicular dentin are the C factor, any ratio greater than 3:1 is considered unfavorable for bonding. Because of this unfavorable geometry, it is not possible to achieve the gap-free interface with current materials and gap formation increases with time and also the bond strength achieved is only 2-5mpa [39-41]. In the root canal system, the ratio might be 100:1, because virtually every dentin wall has an opposing wall and there are minimal unbonded surfaces.25 Further recent work shows that C factor more than 1000 in root canals [8]. Because of this unfavorable geometry, it is not possible to achieve the gap-free monoblock suggested in the advertisements of some products and this gap formation increases with time [41]. Adhesion to radicular dentin is reported to be more unpredictable than to coronal dentin, so the quality of the bond may be somewhat compromised and subject to degradation. Because of morphological differences in radicular dentin (i.e. reduction in dentinal tubule density and altered collagen expression and consequently, less resin tag formation during bonding procedures [42,43]. Adhesion is more problematic in apical dentin compared with coronal dentin [42,44,45].

In some apical areas, the dentin is irregular and devoid of tubules [44]. After bonding procedures, the hybrid layer was found to be thinner in the apical areas by some authors [46,47]. A recent article reported that radicular dentin in the apical third is often sclerotic and the tubules are filled with minerals that resemble those from peritubular dentin. This process starts in the third decade of life and progresses in an apical-coronal direction. It is a potential impediment to effective dentin adhesion and will require further investigation [48].

Problems with Adhesive Materials

Technique Sensitivity

Uniform application of material and evaporation of alcohol or acetone carrier deep in the canal is nearly impossible to achieve due to the complex anatomy of the root canal [49]. Once the primer is applied, the volatile carrier must be evaporated. This can also be problematic in the apical one-third [50]. Bouillguet 2003, reported bonding to flat radicular sample produces higher bond strengths [51]. An excessively thick layer of luting around a fiber post to compensate for the fit of the post is an unfavorable factor for the long-term success of post-retained restorations, owing to the high polymerization shrinkage leading to a high frequency of decementation [12,52]. Also resins in thin layers generate very high forces from polymerization contraction [53-56]. Passive retention of the post is improved if it fits snugly into the prepared space and if the luting layer is fine and even. Post decementation generally occurs at the dentine/cement interface due to the bubbles and pores that form as a result curing shrinkage [12,57-59].

Total Etch Vs Self-Etch Systems

Endodontic instrumentation produces a thick smear layer, total etch removes this thick endodontic smear layer, residual dentin debris and produces higher bond strength than self-etch systems [60-62]. Some studies have demonstrated similarities between bond strengths for self-etch and etch-and-rinse adhesives in different regions of coronal dentin [63-66]. Numerous authors have reported that fiber post cementation with the resin cement associated with etch-and-rinse adhesive may generate greater bonding potential than self-etch adhesive, which may be due to mild etching effect of self-etch [67-70]. But there are problems of technique sensitivity with total-etch systems such as those of over-etching, control of humidity within the canal, incomplete infiltration, bond deterioration and nanoleakge. Hence it was suggested that self-etch systems could be used in a simplified manner [71,72].

Light Curing

Resin adhesive systems can be classified as light cured, self-cured, dual-cured and self-adhesive cements. Irrespective of the type of bonding agent, limited access to curing light within the root canal may hinder the photopolymerization of the adhesives. Light transmitting posts had light transmitting capacity of 0-40%, decreasing from coronal to apical level and also that even without a post, the luminous intensity inside the canal decreased to levels that are insufficient for polymerization, especially in the apical third [73,74]. Based on these findings, the use of light-cured resin cements for post placement cannot be recommended. The benefits of light-transmitting posts are unclear [75,76]. Studies show higher bond strengths and improved hybridization along the root canal for self or dual-polymerized adhesives [77-79].

Self or Dual-Polymerized Adhesives

Self-cured materials, however, offer worse handling characteristics due to their relatively fast, uncontrolled polymerization and lower bond strengths. Because the acid is not rinsed off after application, residual acid can partially neutralize the high pH amines in the self-cured component of the adhesive or sealer, making them less effective in the chemical polymerization process [80-83]. It has been demonstrated, however, that the attenuated light penetration interferes with the cement polymerization toward the apical areas of the root canal and sometimes even when translucent fiber posts are used and the self-cure mechanism for dual-cured materials alone is not only slower but also less effective than the use of light-activation [84-90]. It is also known that self or dual-cured resins cements are not compatible with simplified adhesives (i.e., two-step etch-and-rinse or self-etch agents). This incompatibility is due to the low pH of simplified adhesives, which may react to the basic tertiary amines used as self-cure co-initiators, interfering with proper polymerization, Thus, non-simplified adhesives (three-step etch-and-rinse systems, for instance) should be used for bonding fiber post to root canals using regular resin cements [84].

The second problem with the self-etching adhesive systems when used with self- or dual-cured resins is that they are highly hydrophilic and act as permeable membranes. The chemical polymerization process is slow. Extended setting time for self-cured resins is beneficial for stress relief, but the prolonged time allows diffusion of moisture from the dentin through the hydrophilic primer, which creates water blisters along the interface with the slow polymerizing resins. This moisture contamination reduces bond strength and facilitates leaching of water-soluble components from the resin, which may further contribute to the breakdown of the bond [81,83,91-94].

Self-Adhesive Cements

Studies have reported, however, limited etching potential for self-adhesive cements compared to etch and- rinse and self-etch adhesives when luting fiber based post. Self-adhesive cements may also present lower degrees of C - C conversion and poorer mechanical properties than regular resin cements [95-98]. The lower etching aggressiveness and suboptimal properties may account for the low early (immediate) interfacial strengths reported for fiber post luted with self-adhesive cements [99].

The results of a recent systematic review and meta-analysis of *in vitro* studies suggest that the use of self-adhesive resin cement could improve the retention of glass-fiber posts as compared with regular resin cements, the authors concluded that articles included in this meta-analysis showed high heterogeneity and high risk of bias [100].

Effect of Irrigants and Sealers

NaOCl and chelating agents that contain hydrogen peroxide leave behind an oxygen-rich layer on the dentin surface. Oxygen is one of the many substances that inhibit the polymerization of resins. When dentin bonding agents are applied to an oxygen-rich surface, low bond strengths are achieved and microleakage is increased [101-103]. It has been expressed that residual calcium hydroxide paste could prevent effective bonding in some areas; that it can act as a physical barrier, and that the high pH may act to neutralize the acid primer in self-etching adhesives [104-106].

Retreatment is always a concern with a new material. Resilon is soluble in chloroform and other solvents, and several studies show it is easily removed by a variety of methods. Epiphany, on the other hand, like other resins, is not soluble in the solvents commonly used in dentistry. Removal of resin sealers from fins and accessory canals or deep bifurcated canals is difficult. Removing bonded resin is likely to be that much more difficult [107-109]. Eugenol is one of many substances that inhibits the polymerization reaction of resins and can interfere with bonding [110,111].

Custom Fiber Post

Individual post fitting system is to use a fiberglass mesh, inserting it into the canal to act as the post. This technique showed that the number of gaps observed with a scanning electron microscope was greater with this system than with prefabricated posts [112].

Silanization

Silanization is the technique used most often to enhance the bond strength of fiber-based post to the luting cement achieve this goal. Silane coupling agents are bifunctional molecules, with one end of the molecule capable of reacting with inorganic glass-fiber and the other with an organic resin. The highly crosslinked polymer matrix of a fiber-based post is virtually non-reactive, therefore, only the exposed fibers on the post surface could provide sites for chemical bonding with the silane molecules. The use of silanes to improve the bonding of resin luting agents to fiber-based post is, however, a controversial topic. Randomized controlled trials are needed to confirm whether the use of silane influences the bond strength of fiber-based post [113].

Bond Deterioration

Another limitation of dentin bonding is deterioration of the resin bond with time. This is a process that is well documented *in vitro* and *in vivo* [28-38]. Interfacial leakage increases as the bond degrade [114,115]. In the root canal system where torsional and flexural forces stress the dentin/resin interface repeatedly during function and parafunction, the bond degradation is enhanced. Repeated stress causes microfractures and cracks in the resin. Unpolymerized resin also contributes to the breakdown of the bond [116].

One of the most important factors in the strength and stability of the resin/dentin bond is the completeness of resin infiltration into the demineralized dentin. If the resin doesn't completely infiltrate, fluid movement between the hybrid layer and unaffected dentin speeds the degradation of the bond [117,118]. This process is enhanced by enzymes released by bacteria and from the dentin itself [119]. The breakdown products diffuse out of the interfacial area, which weakens the bond, and allows more fluid to ingress. Collagen degradation is thought to occur via host-derived matrix metalloproteinases (MMPs) that are present in dentin and bacterias and released slowly over time [116]. Prolonged etching times may create a demineralized zone that is too deep for effective resin infiltration, resulting in a weaker bond and accelerated degradation [120,121].

Interesting Fact

Just when these problems were been reported, studies found that the bonding of fiber-based post to the dental structure may be related more to the friction of the post along the canal walls than to the adhesive bonding to root dentin [82]. The use of resin cements, however, has been found to significantly increase the retention of fiber posts and improve the fracture resistance of the bonded structures when compared to other cements [96,122,123].

Another interesting finding is that custom cast posts showed significantly greater bond strength than prefabricated posts when luted with either resin or zinc phosphate cements, which questions the second advantage of fiber-based post [124-126].

Aesthetics vs Survival

It is undeniable fact that fiber-based post provide better aesthetic than cast post. Aesthetics plays important role in the smile zone, i.e the anterior region. However, a long-term study that evaluated 10-year survival of glass fiber supported prosthodontic restorations revealed relatively high annual failure rate of glass reinforced fiber posts. On the other hand, anterior teeth were more prone to failure [127]. In another prospective study for detecting the major risk factors for failure. In terms of tooth location, higher failure rates were detected in anterior teeth compared to the posterior. It was also found that incisors or canines had about 3 times the failure rate of restorations placed in premolars or molars Hence the significance of the third major advantage of the fiber-based post is also lost [5,58].

Other Problems

The radiopacity is very less compared to metal post [128]. A study employing finite element analysis has suggested that fiber-posts produce greater stresses within the root canal when exposed to thermal change than metal post systems. They state that the high thermal conductivity of metal posts leads to a reduced temperature gradient throughout the restored system whereas a reduced heat flow into dentine with non-metal posts may cause a concentration of thermal stresses and this may lead to cement failure and recommend the use of a metal post and core [19].

Survival Rate - Cast Post Vs Fiber Post

The first and foremost problem with studies on fiber based is lack of considerable follow of studies i.e ranging from few months to a year to two. Unlike the studies on cast post which have a follow up ranging from 10-25 years. Glazer (2000) who reported the results of a perspective with 47 patients a follow-up period ranged between 6.7 and 45.4 months [129]. There were no fractures. The overall failure rate was 7.7% and the cumulative survival rate was 89.6% at the end of the follow-up period. (Of which 3.9% failures were due to the occurrence of periapical lesions) However, the authors criticized their findings by indicating that the length of the follow up was relatively short to make a definite generalization. Naumann *et al.* 2005 conducted a prospective study and evaluated glass fiber reinforced composite post restorations [5]. 105 posts received by 83 patients were followed up to a period of 2 years. One and 2-year failure rates of fiber reinforced composite post restorations were 4 and 12%, respectively. Signifying that the failure rate was three times in the second years. Similar results were also obtained by another retrospective study by Ghavamnasiri *et al.* 2009 who evaluated the success rate in endodontic-treated premolars restored with composite resin and fiber reinforced composite posts with ages ranging between 1 and 6 years [130]. Thirty-eight patients with endodontically treated premolar and anterior teeth that were then restored with a coronoradicular quartz fiber post and extensive composite resin restorations were selected for participation in the study. The overall cumulative survival rate (48.8%) was determined, while the survival probabilities after 1, 2, 4, 5, and 6 years of service were 88.37%, 60.95%, 45.71%, 32.65%, and 0%, respectively. The influence of the remaining coronal structure on the survival of root-filled teeth was explained by some authors. Glazer *et al*, Ellner *et al.*, Naumann *et al.* and Bitter *et al.* have indicated at least 2 mm of the ferrule to fiber post placement [6,43,129,131]. The percentage of failures increased when the remaining dentin wall was less than 2mm. A 10-year retrospective study by Markus 2007, reported an 11% failure over 10 yrs for cast post. Torbjorner et al. 1996 reported a 2.1% failure rate per year for 788 teeth with metal posts during a 5-yr period. Another study calculated the median survival rate of teeth with metal posts to be 17.4 yr [132]. Weine *et al.* 1991 reported 9 failures of 138 teeth restored with cast post and cores [133]. The minimum recall time was 10 yr. In a study with a 25-yr follow-up, the longevity of teeth restored after endodontic treatment with a cast post and core and crown was the same as teeth with vital pulps and crowns [134]. Hence these studies clearly validate the success of cast post over a fiber-based post.

Conclusion

The two sides of the current debate pit the possibility of flexure producing micromovement of the core, cement breakdown, leakage, and failure versus the possibility of reduced catastrophic root fracture. In the absence of an adequate ferrule, failure will occur and the debate centers on whether it is better to have re-restorable failures in the short term or unrestorable failures after a long time in function or at high-stress levels. The few clinical trials suggest, at least in the short term, reasonable success for fiber-based post restorations. However that before these posts are adopted fully in the clinical practice, high-quality long-term randomized controlled prospective clinical trials are necessary, investigating the success of fiber-based post restorations and newer materials such as quartz-fiber posts.

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