Post-endodontic restorations with adhesively luted fiber-reinforced composite post systems: A review

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ABSTRACT: Purpose: To review the literature on adhesive luting of fiber-reinforced composite posts (FRC) to provide evidence for the clinical procedure of restoring endodontically treated teeth using FRC posts. **Methods:** Data focusing on bonding behavior between root canal dentin, luting agent, and FRC post *in vitro* as well as *in vivo* performance of teeth restored with FRC posts were reported. These data were identified by searches of "PubMed", "Scopus", and "Cochrane Library" databases with the terms "post-endodontic restoration", "fiber post", "adhesive luting", "root canal dentin", "clinical study", and "pre-treatment fiber post". Papers published up to September 2007 were selected, and most relevant references were chosen. Cross-referencing of significant papers identified additional relevant articles. **Results:** FRC posts seem to have become increasingly popular for the restoration of endodontically treated teeth. Compared to metal posts, FRC posts revealed reduced fracture resistance *in vitro*, along with a usually restorable failure mode. Bonding behavior among FRC post, luting agents, and root canal dentin demonstrated varying results. Bond strengths between FRC posts and resin cements can be enhanced by using various pre-treatment procedures; however, bonding to root canal dentin still seems to be challenging. Most clinical studies investigating survival rates of teeth restored with FRC posts revealed promising results, but risk factors (*e.g.,* the loss of coronal tooth structure) have not been studied intensively. In addition, randomized controlled clinical long term trials are scarce. (*Am J Dent* 2007;20:353-360).

CLINICAL SIGNIFICANCE: Evidence-based recommendations are still not possible, and further research using standardized protocols is warranted.

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Introduction

Coronal leakage (facilitating access of bacteria or microbial endotoxins) has been discussed as a potential cause of endodontic treatment failure.[1-3] Although some data suggest that the problem of coronal leakage may be of minor importance,[4] other studies identified coronal leakage as a common factor associated with endodontically treated teeth requiring non-surgical retreatment,[5] and the coronal restoration quality has been found to be more influential on the presence of apical periodontitis if compared to the quality of the root canal obturation.[6] As a consequence, it can be concluded that a sufficient and tight coronal restoration is an important aspect with regard to the clinical success of endodontically treated teeth.

Adhesively luted fiber-reinforced composite (FRC) posts were introduced in 1997,[7] and have been increasingly used for the restoration of endodontically treated teeth in recent years. Published *in vitro* and *in vivo* studies have focused on bond strengths among luting agents, post surface, core materials, root canal dentin, and on fatigue resistance of the posts as well as on the clinical performance. Nevertheless, conflicting results regarding the bond strengths of various resin cements to root canal dentin and fiber post surfaces as well as the small number of *in vivo* studies still make it difficult for the practitioner to judge the clinical behavior of these posts.

This paper reviewed the literature to analyze the indication for insertion of a root canal post and the type of post-endodontic restoration. Furthermore, differences with regard to available fiber-based post systems, adhesive luting of posts, and degradation patterns of the bonding interface were evaluated.

Materials and Methods

The databases "Pub Med" and "Scopus", as well as the "Cochrane Library" were searched using the keywords: "post-endodontic restoration", "fiber post", "adhesive luting", "root canal dentin", "clinical study", and "pre-treatment fiber post." Inclusion criteria were: (1) articles that were related to the mentioned keywords; (2) only papers from refereed dental journals; (3) only papers available in English. Thus, papers published up to September 2007 were selected and the most up-to-date or relevant references were chosen. Cross-referencing of significant papers identified additional relevant articles and those of historical value.

Published *in vivo* studies were classified according to selected criteria in order to judge the reliability of these studies. These criteria were described by the Cochrane Library; only controlled randomized clinical trials were to be included, fulfilling several quality criteria (*e.g.,* generation of randomization sequence, allocation concealment, blind outcome assessment and completeness of follow-up). A clear explanation of withdrawals and drop-outs in each treatment group had to be provided. Since clinical trials evaluating the restoration of endodontically treated teeth meeting these criteria were hard to find, all clinical trials evaluating FRC posts that could be found up to September 2007 were included. This has been approved by a recently published Cochrane Library review that only included two clinical studies fulfilling the mentioned criteria.[8]

All articles were studied in order to provide evidence for the clinical procedure in restoring endodontically treated teeth using fiber posts.

Restoration of endodontically treated teeth

The choice of the definitive restoration is strongly dependent on the amount of the remaining tooth structure, the morphology of the tooth, its position in the dental arch, functional loading on the tooth and the esthetic requirements.[9] It is gener-

ally accepted that endodontically treated teeth with minimal loss of coronal tooth structure should be restored conservatively with a direct bonded restoration to obturate the access cavity.[10,11] Posts or crowns are not required until a great deal of tooth structure is lost as a result of caries or trauma, since fracture resistance of endodontically treated teeth is mainly attributed to the remaining tooth structure.[12,13]

According to the weakening effect due to access preparation prior to endodontic treatment, it has been recommended to restore posterior teeth with already existing restorations involving the marginal ridge or those with extensive loss of tooth structure with cuspal coverage restorations.[14] Few clinical studies evaluated the clinical performance of direct composite restorations in combination with fiber posts.[15-17] Mannocci *et al*[15] compared the clinical success rates of endodontically treated premolars with Class II carious lesions and preserved cusp structure that were either restored with carbon fiber posts and direct composite restorations or with full-coverage metal-ceramic crowns in a randomized controlled clinical trial. No difference in failure frequencies could be detected between the two groups after 3 years. In a similar design the same working group compared amalgam restorations and direct composite restorations using a carbon fiber post in premolars. No statistically significant differences regarding the failure rates could be observed after 5 years.[16] However, failure modes differed significantly. For amalgam restorations more root fractures occurred, whereas for direct composite reconstructions significantly more caries could be detected. Grandini *et al*[17] reported good performance after 30 months of clinical service for anterior and posterior teeth restored with quartz fiber posts and direct composite restorations. In this investigation, anterior teeth with at least 50% of residual sound tooth structure remaining and posterior teeth with two to three sound residual coronal walls were included. Thus, it can be concluded that direct composite restorations demonstrated an acceptable clinical behavior in situations with sufficient remaining sound tooth structure. Nevertheless, the mentioned investigations did not include a control group without posts to evaluate the respective necessity in these situations.

Posts provide retention for the core and the coronal restoration but do not strengthen the root.[18] In addition, post space preparation led to a further loss of dental hard tissue, which contributes to reduced fracture toughness.[13] Endodontically treated molars often exhibit more coronal tooth structure and a larger pulp chamber to retain a core build-up compared to anterior teeth.[10] As a consequence, the type of tooth has to be considered with respect to the decision whether a post is to be inserted or not. Anterior teeth with extensive loss of tooth structure more often require a post due to the lateral and shearing chewing forces and the smaller pulp chamber compared to molars.[19]

To categorize the loss of coronal tooth structure, there was a three grade classification including small, middle and high loss of coronal tooth structure.[20] The insertion of root canal posts is only recommended in situations with a high loss of coronal tooth substance.[20] A recently published paper suggested a restorability index of endodontically treated teeth in which each tooth is divided into sextants. Each sextant is furthermore classified into three grades according to the height and thickness of the remaining dentin walls. The index is evaluated cumulatively with respect to the grades of each sextant.[21] According to the authors, teeth exhibiting restorability scores of less than 10 become less suitable for a plastic core without posts.[21] Nevertheless, these classifications and recommendations seem to be imprecise, and do not consider other relevant risk factors influencing the longevity of restorations of endodontically treated teeth (*e.g.*, tooth type, type of restoration, proximal contacts, stress loads, alveolar bone loss).[22,23]

Selection of post type

The requirements for an ideal post-and-core system should consider physical properties such as modulus of elasticity, compressive strength, and coefficient of thermal expansion that are close to that of dentin. Additionally, posts should demonstrate high retention, good biocompatibility, esthetics and retrievability.[10] Since the cast gold post-and-core has been used for decades, this type of restoration can still be judged as the gold standard for restorations of teeth with great loss of substance, and a retrospective study revealed a success rate of 90.6% over 6 years using a cast post-and-core as the foundation restoration.[24] Nevertheless, a systematic review demonstrated that no conclusive evidence exists to favor cast over direct post-and-core restorations.[25]

Fiber-reinforced composite (FRC) post systems have been introduced with the proclamation of avoiding root fractures due to a modulus of elasticity close to that of dentin.[26] Esthetic requirements were fulfilled with the development of quartz and glass fiber posts. Due to the fact that practitioners judged these posts as a viable alternative to metal posts,[27] a significant number of different fiber posts was introduced onto the market. In order to evaluate their mechanical properties and clinical performance *in vitro*, scanning electron microscopy (SEM) and fatigue testing of various brands of fiber posts have been performed.[28] Differences among the various brands in terms of their structural characteristics and fatigue resistance could be demonstrated. Two (DT Light Post,[a] and FRC Postec[b]) of eight different fiber post systems revealed sufficient ability to resist fatigue stress, thus suggesting considerable reliability of these materials when used clinically. The determining factors for the differing flexural strengths have been described as integrity, size, density, and distribution of the fibers and the nature of the bond between matrix and fibers.[29] Therefore, the type of the resin matrix and the fabrication process applied to promote bonding between fiber and resin may be one of the key factors concerning the flexural strength of the fiber posts,[30] however, much of this information is kept confidential by the manufacturers.

A commonly used *in vitro* design for investigating post-and-core restorations is fracture load testing. Irrespectively, this design has been criticized due to the relatively high standard deviations regarding the measured fracture loads.[31] Moreover, static loading used in an *in vitro* study may not be representative of the *in vivo* situation.[32] Overall, *in vitro* testing of post systems investigating the fracture load revealed controversial results after continuous or cyclic loading. A recent overview[19] demonstrated conflicting results revealing a slight tendency towards higher fracture resistance of metallic posts compared to FRC posts; at the same time, a favorable failure mode for FRC

posts was revealed. In detail, a lower fracture strength of FRC posts compared to metal posts could be demonstrated in several *in vitro* studies.[33-35] Nevertheless, a modulus of elasticity close to that of dentin decreased the incidence of root fractures,[36] and in case of failure, teeth reconstructed with FRC posts are more likely to be restorable.[37,38]

Due to the large variability of results obtained from the described *in vitro* studies, finite element (FE) analysis of post-restored teeth have frequently been performed.[31,39,40] Results of FE analyses are expressed as stresses distributed in the structures under investigation. Deformations and stresses in any point of the model can be evaluated and the stressed areas can be visualized.[40] It has been described as advantageous that the FE method does not produce a variability of results and is only restricted to the number of modules and elements used in the model and the elastic constants attributed to the elements.[31] A conventionally luted cast gold post-and-core system produced high stress concentration in FE analysis at the post-dentin interface. This may be attributed to the brittleness of zinc-phosphate cements, leading to post loosening or root fracture due to stress concentrations at the post apex.[40] Evaluating a FRC post, the FE-model resembled nearly the situation of a natural tooth except a stress concentration at the cervical margin that might result in microleakage or gaps at the restoration margins.[40]

Adhesive luting of FRC posts

Post decementation turned out to be the most frequent failure of endodontically treated teeth restored with post-and-core systems,[41] whereas vertical root fractures were the most serious type of failure.[42,43] Adhesively luted posts revealed improved retention compared to conventionally cemented posts,[44-46] and thus might reduce the incidence of decementation.

FRC posts are luted adhesively into the root canal. In addition, FE analysis demonstrated that bonding of posts turned out to be a major factor in reducing stresses inside the root canal, and, consequently, this should be a major factor in preventing root fractures.[31] This strengthening effect of adhesively luted posts on root integrity has been described previously.[47] Moreover, adhesive fixation of posts turned out to be more relevant for post retention compared to the post design.[46]

In those cases where posts are luted conventionally, the retention of the post increases with the insertion depth of the post. Nevertheless, the risk of perforation is also increased with the insertion depth and the post length is less important for fracture resistance compared to the ferrule effect.[48] Due to the enhanced retention of adhesively luted posts, traditional guidelines for the insertion depth of root canal posts should be questioned. The length of the remaining gutta-percha should be 3-6 mm to guarantee the apical seal.[49,50] Generally accepted guidelines for the insertion depth of root canal posts have suggested that the post length should be equal to the clinical crown height;[51] moreover, the post length should take one half to two thirds of the remaining root,[52] and the post length itself should be one half of the length of the root that is supported by bone.[53] Up to now there are no recommendations available in the literature whether these guidelines should be changed for adhesive luting of FRC posts. Therefore, studies focusing on evaluation of these questions are clearly warranted.

Pre-treatment of FRC posts

The aim of the restoration of endodontically treated teeth with adhesively luted post systems is to establish a unity among post, luting agent, core material, and root canal dentin in order to imitate the original tooth structure. To withstand clinically occurring stresses, each interface of this unit has to be sufficiently strong, and the bond strength between post and luting agent is as important as the bond strength between luting agent and root canal dentin. *In vitro* studies have shown that bond strength to fiber posts was affected by the type of luting agent,[54-57] and that bonding to root canal dentin can be limited by the bond strength between luting agent and post surface.[58] Accordingly, several pre-treatment procedures of pre-fabricated FRC posts have been investigated to enhance the bond between FRC post and luting agent (*i.e.*, silanization alone,[54,59-61] tribochemical coating,[54-56,62] conditioning with hydrogen peroxide,[63,64] hydrofluoric acid,[54,63,65] sodium ethoxide,[66] potassium permanganate alone and with hydrochloric acid[67] followed by the application of silane).

Silane solutions can be described as hybrid organic-inorganic compounds that are able to promote adhesion between organic and inorganic matrices due to an intrinsic dual reactivity.[68] Therefore, chemical adhesion after silane coupling of FRC posts' surfaces can only be established between luting agents and exposed fibers or filler particles of the post. Due to differences in chemistry, no bonding can be expected between the methacrylate based resin of the luting agents and the epoxy resin matrix of pre-fabricated FRC posts.[64] Thus, the surface texture and the composition of various types of FRC posts might lead to varying effects of silanization on bond strength to luting agents. Studies focusing on this topic revealed controversial results, and two studies[60,69] reported an increasing effect of silanization compared to untreated controls, whereas other studies[54,56,61] did not detect any difference between silanated and untreated control posts. Therefore, the wetting capacity of the silane plays a key role for improved adhesion after silanization; however, the entire silane reaction mechanism still remains not fully understood.[68] In addition, a recently published paper revealed that the effects of pre-treatment on bond strength were affected by the applied adhesive system.[65]

Several chemical treatments have been investigated to dissolve the epoxy resin matrix or methacrylate-based resin matrix of FRC posts in order to increase the surface area and expose fibers and filler particles that can be reached by the silanization process. The pre-treatment of FRC posts using hydrogen peroxide (10% and 24%),[63] sodium ethoxide,[66] or potassium permanganate[67] (followed by silanization) resulted in increased bond strengths to resin core materials with dissolving the resin matrix of the post's surface and concomitant exposure of undamaged fibers. The use of hydrofluoric acid and tribochemical coating followed by silanization resulted in damaged fibers at the surface of FRC posts[56,63] and, thus, these procedures cannot be recommended for clinical use due to possible weakening effects on the stability and integrity of the posts.

It can be summarized that adhesion to FRC posts can be enhanced by the mentioned chemical treatment procedures creating micromechanical retention followed by chemical bonding using a silane coupling agent. However, combinations of two-

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component silane solutions and simplified one-step adhesives have to be further investigated, since the obviously enhanced bond strengths compared to two-step adhesive systems seem to be accompanied by an increased nanoleakage at the post-adhesive interface, and this might result in hydrolytic degradation.[66]

Interpenetrating polymer network posts

Pre-fabricated FRC posts exhibit a highly cross-linked polymer matrix between the fibers; this might be responsible for the reduced bonding between these posts and adhesive luting agents, since the monomers of the applied adhesive systems cannot penetrate into a cross linked polymer matrix and no free radical polymerization can occur.[70] A recently developed new FRC material consists of continuous unidirectional glass fibers and a multiphase polymer matrix. This polymer matrix reveals a semi-interpenetrating polymer network (IPN) exhibiting both linear polymer phases, polymethylmethacrylate (PMMA) and cross-linked poly Bis-GMA phases. On the surface of this FRC material an enriched layer of PMMA is located. Monomers of adhesive resins can penetrate into the linear polymer phase and form an interdiffusion bonding by polymerization.[71] Therefore, it is necessary that the adhesive systems have solubility parameters close to that of PMMA. Adhesive systems containing Bis-GMA with hydroxyethylmethacrylate (HEMA) or triethylene glycoldimethacrylate (TEG-DMA) have been proven to be effective for that purpose.[72]

In a recent study[73] higher flexural properties were recorded for the new FRC material with the IPN structure compared to commercially prefabricated FRC posts. Furthermore, IPN posts revealed better interfacial adhesion to resin cements compared to prefabricated FRC posts.[59,70,74] However, *in vivo* studies focusing on the long term clinical behavior of these posts are currently missing.

Structural characteristics of root canal dentin

In a scanning electron microscopy study, the apical part of the root canal demonstrated an irregular structure consisting of accessory root canals, areas of partially repaired resorption, occasional presence of attached, embedded and free pulp stones, cementum-like tissue, and a low number of dentin tubules.[75] In addition, variability in terms of tubule density and orientations inside the root canal depending on the location has been detected.[76] The density of the tubules was significantly higher in the cervical third compared to the middle and apical part of the root canal. After etching the root canal using phosphoric acid the tubule surface increased to 202% in the cervical area and to 113% in the apical area. Using a one-step etch-and-rinse adhesive, measurements of the hybrid layer thickness revealed a thicker layer for the cervical third compared to the middle and apical part.

These results could partially be confirmed by a confocal laser scanning microscopy study[77] that demonstrated more resin tags in the cervical part of the root canal; however, no correlation between hybrid layer thickness and localization inside the canal could be found. The application of etch-and-rinse adhesives resulted in a higher number of resin tags and an increased hybrid layer thickness compared to self-etching adhesive systems. Consequently, it has to be questioned whether these qualitative analyses of the resin-root canal dentin interdiffusion zone and anatomical features correlate with bond strength measurements. Furthermore, it has to be considered that bonding to root canal dentin might be hampered by the lack of direct inspection and a highly unfavorable cavity configuration factor.[78] Moisture control after the application and removal of phosphoric acid as well as incomplete infiltration of the resin into the dentin significantly affected bond strengths.[79] In contrast, self-etching systems are generally applied on dry dentin, do not require rinsing of the acid, and therefore, might be less technique sensitive. Nevertheless, possible interactions between the smear layer inside the root canal after preparation and self-etching adhesive systems may occur.[80] In addition, degradation patterns of the resin-dentin interface created by self-etching adhesive systems due to water sorption and induced collagenolytic activity may adversely affect the longevity of adhesively bonded posts.[81]

Bond strength measurements

In vitro studies[57,58,80,82,83] demonstrated significant differences among various adhesive systems and luting agents. The results of these studies are difficult to compare due to the different testing methods and experimental set-ups.[84] Consequently, no recommendations can be provided concerning a certain system. Nevertheless, application according to the manufacturers' recommendations and combination of adhesive systems and luting agents seem to be of major importance.[85] A recently published[86] paper suggested the use of glass-ionomer-based cements for luting fiber posts, which revealed higher bond strength after water exposure due to hygroscopic expansion compared to a resin cement. The authors concluded that mainly frictional retention contributed to the clinical success and stability of fiber posts. It can be stated that bonding to root canal dentin exhibited lower bond strength values compared to coronal dentin,[82,83] and, thus is still challenging.[84] At the same time, the creation of a durable and sufficient bond inside the canal for luting posts still seems to be questionable. Additionally, the influence of the region inside the root canal has been studied. Two recent studies[83,87] did not report any influence of the region in the root canal on bond strengths, whereas others[58,88] revealed higher bond strengths in the apical third than in the other parts of the root canal. In contrast, further studies observed decreased bond strengths in the apical region of the root canal.[82,89] As a result, it can be concluded that bond strength to root canal dentin seem to be related more to the area of solid dentin than to the density of dentin tubules.[87,90]

Longevity of bonding to root canal dentin

The longevity of the bond between root canal dentin, luting agent and post surface has to be taken into consideration. A recently published investigation[90] revealed degradation of collagen fibrils due to bacterial colonization, release of bacterial enzymes, and host derived matrix metalloproteinases in root dentin after clinical function. These authors speculated that these enzymatic activities may also occur within incompletely resin-infiltrated subsurface regions of hybrid layers that may have been created by contemporary adhesive systems. Therefore, hydrolytic degradation of the interface between dentin, luting agent and post, as well as the long term performance of adhesively luted posts have to be further investigated. Interest-

Table 1. Prospective studies reporting the failure rate of endodontically treated teeth restored with fiber posts.

Author	Year	Mean observation period	No. of teeth included	Category of defect extensions	Brand of fiber post	Type of post	Type of restoration	Type of teeth	Overall failure rate	Study design
Glazer[91]	2000	28 months	59	Not specified	Composipost[a]	Carbon fiber	All-ceramic/metal-ceramic full crowns	All	7.7%	Prospective
Malferrari[90]	2003	30 months	180	3 categories; no further specification	Aesthetic Plus[a]	Quartz fiber	All ceramic/metal ceramic full crowns	All	1.7%	Prospective
Monticelli[88]	2003	24 months	225	2 coronal walls left	Aesthetic Plus	Quartz fiber	All ceramic full crowns	Premolars	6.2%	Randomized controlled prospective
					DT Post	Quartz fiber				
Naumann[89]	2005	24 months	105	3 categories; 60% gingival level	FRC Postec Luscent Anchor[c] FiberKor[d]	Glass fiber Glass fiber	Not specified	All	12.8%	Prospective
Grandini[16]	2005	30 months	100	Anterior teeth: 50% residual sound tooth structure			Direct composite restoration	All	5%	Prospective
				Posterior teeth: 2-3 sound coronal walls	DT Post	Quartz fiber				
Ferrari[93]	2007	24 months	240	6 categories: all coronal walls to no coronal walls with less than 2 mm dentin present	DT Light Post	Quartz fiber crowns	All ceramic/metal	Premolars	18.7%	Prospective
Cagidiaco[101]	2007	24 months	162	2 categories: More than 2 coronal walls; 2 and fewer coronal walls	DT Light Post	Quartz fiber crowns Direct composite restorations	All ceramic/metal	All	7.3%	Prospective

Table 2. Retrospective studies evaluating the failure rate of endodontically treated teeth restored with fiber posts.

Author	Year	Mean observation period	No. of teeth included	Category of defect extensions	Brand of fiber post	Type of post	Type of restoration	Type of teeth	Overall failure rate	Study design
Frederiksson[95]	1998	32 months	236	Not specified	Composipost	Carbon fiber	All-ceramic/ Metal-ceramic Full crown	All	2%	Retrospective
Ferrari[94]	2000	31 months	1,304	Not specified	Composipost Aesthetic Post Aesthetic Plus	Carbon fiber Quartz fiber	All-ceramic/ Metal-ceramic Full crown Direct composite restoration	All	3.2%	Retrospective
Hedlund[102]	2003	26 months	65	Not specified	Composipost Endopost	Carbon fiber Full crowns/ veneers	All-ceramic/ Metal-ceramic	All	3%	Retrospective

ingly enough, bonding of FRC posts revealed no decrease in bond strength after mechanical fatigue testing, whereas zirconia posts demonstrated a significant reduction in bond strength.[91]

Outcome of *in vivo* studies

Evidence of clinical trials is considered meaningful if randomized controlled studies are conducted according to the CONSORT guidelines. However, only few studies[15,16,92,93] were found that could be judged as randomized controlled studies. In addition, clinical trials on the effect of baseline characteristics, like amount of remaining tooth structure, on the survival rate or prognosis of FRC post based restorations are very rare.[93] Tables 1 and 2 present an overview on published prospective and retrospective clinical studies of FRC posts focused on the survival rate that is affected by the differences in study design, inclusion criteria, number of participants and observation periods. One prospective clinical study focusing on risk factors for endodontically treated teeth restored with FRC posts revealed a failure rate three times higher for restorations placed in anterior teeth compared to premolars or molars. In addition, the number of proximal contacts and the type of restoration had a significant impact on the survival rate.[22]

A recently published prospective investigation[94] demonstrated a failure rate of glass fiber posts of 12.8% after 24 months. The most frequent types of failure were post fractures or loss of retention. Two types of glass fiber posts differing in post design (tapered *vs.* parallel) were evaluated, but no difference regarding the post type was observed. Post types were not randomly assigned in that study. The relatively high failure rate was explained with the included defect extensions, since ap-

proximately two thirds of the restored teeth exhibited defects at the gingival level (c-factor of 0.2).

Another prospective study[95] focused on the clinical evaluation of endodontically treated teeth restored with quartz fiber posts and all-ceramic or metal-ceramic crowns over an observation period of 30 months and reported a failure rate of 1.7%. All failures occurred during removal of the temporary crown and two cases demonstrated a complete loss of remaining coronal sound tooth structure. Unfortunately, the distribution of the samples with respect to the remaining tooth structure was not mentioned. These data are supported by a prospective randomized controlled study that demonstrated a failure rate of 6.2% out of 225 premolars restored with three different types of fiber posts and all-ceramic full crowns.[92] Again, all post failures occurred during removal of the temporary crown. Inclusion criteria dictated two coronal walls left; as a consequence, the clinical performance of fiber posts restoring teeth with defects at the gingival level were not evaluated. A further prospective study[96] of carbon fiber posts also revealed an overall failure rate of 7.7% after 28 months.

One prospective[97] and one retrospective study[98] compared the gold standard cast post-and-cores with carbon fiber posts. The retrospective study, which included 200 restored teeth, demonstrated significantly more failures with teeth restored with cast post-and-cores including unrestorable root fractures after an observation period of 4 years.[98] In contrast, the prospective study[97] evaluating 27 maxillary anterior teeth restored with metal-ceramic crowns over a mean observation period of 87 months revealed a reduced survival rate of 71% for the carbon fiber posts compared to 89% for the cast post-and-core based restorations. Nevertheless, both studies did not consider the amount of remaining tooth structure and variations of the tooth type as having influenced these contradictory results. A recently published study investigated the effect of the amount of residual coronal dentin and of post placement on the survival rate of endodontically treated premolars that all received crowns.[93] After a 2-year observation period the results revealed that post placement resulted in a significant reduction of failure risk and that the failure risk was significantly increasing for teeth that had lost all coronal walls.[93]

A retrospective study[99] evaluating 1,304 teeth restored with three different types of fiber posts from 1-6 years without recording the loss of coronal tooth structure, reported a failure rate of 3.2%, which is in accordance with the prospective studies mentioned above. In addition, another retrospective study[100] evaluating the clinical performance of carbon fiber posts with an observation period from 2-3 years revealed a success rate of 98%.

Conclusions

In summary, most of the published clinical trials were not randomized and controlled, and do not report the loss of coronal tooth structure. Therefore, it still remains unclear whether clinical success depends on a rigid or flexible post material, on the type of cementation, an interaction of both, or the remaining tooth structure. Furthermore, only few clinical trials considered the loss of coronal tooth structure and the need of post insertion. Therefore, more controlled, prospective clinical trials investigating the longevity of post type and type of cementation in regard to the coronal defect extensions are clearly warranted.

In vitro studies demonstrated less fracture resistance of FRC posts compared to metal based post systems, along with a restorable failure mode. Frequent failure modes of FRC posts were predominantly post fractures and loss of retention. Various brands of FRC posts revealed differing mechanical properties, and this fact should be considered with regard to the selection of posts for clinical use. Evaluation of the bonding among posts, luting cement, root canal dentin, and core material, reported varying results. Bonding to pre-fabricated FRC posts could be increased by various pre-treatment procedures; bonding to root canal dentin is inferior compared to coronal dentin and seems to be a critical factor on the bonded assembly of post, luting agent, and root canal dentin. This may also be influenced by the limited visibility, anatomical features and high configuration factor inside the root canal.

Most of the clinical studies revealed promising results with low failure rates, although long term trials are scarce. Moreover, randomized controlled study designs with regard to the risk factors of endodontically treated teeth restored with fiber posts are lacking. Longevity and degradation of bonding to root canal dentin as well as the clinical long term performance of a flexible and less rigid post material have still to be investigated to develop definite recommendations.

a. RDT, Grenoble, France.
b. Ivoclar Vivadent, Schaan, Liechtenstein.
c. Dentatus, New York, NY, USA.
d. Generic Pentron, Wallingford, CT, USA.

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