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Post-endodontic treatment using composite resin cement and fiber post

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Abstract:
Adhesive post-endodontic treatment does not yet have a generally accepted clinical protocol. We perform this procedure in our clinical practice since 2006. We have developed a clinically successful protocol. Tissues and materials which relate to the the procedure are described following available research. Protocol is described in step-by-step.

Keywords: post-endodontic treatment, fiber-post, FRC, endodontics, dentin adhesion

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INTRODUCTION

The effort to preserve non vital teeth for their further function has been a challenge since the advent of dentistry as an independent medical field. We must focus on the next phase of treatment: how to restore the tooth to its original occlusal function for as long follow-up period as possible without damaging residual tooth structure with postendodontic treatment, from the advent of modern endodontics during the second half of the 20th century, after the introduction of new tools, techniques and improved knowledge of biomechanics.

This task is a very common challenge for physicians, especially in the anterior teeth, where the force acting on the tooth during mastication is mostly non-axial and where tooth trauma occurs more frequently [1].

In the past, in cases where the "ferrule effect" was not respected, the physician had limited options for achieving retention in the root canal. They either made an individual root superstructure, or used self-tapping active posts that wedged in the root canal walls. In the market, we have encountered (and in part still do) a large number of prefabricated posts for this purpose. Unfortunately, there is a lot of evidence that (especially for more rigid types) posts are very destructive [2-8].

Several factors have been identified that are associated with these aggressive posts: active pressure acting on the inner wall of the canal, preparation of the canal wall leading to weakening of the dentin, and rigidity of the posts resulting in trauma following tooth treatment. It must also be said that the variant of three visits for the construction of the root extension is very expensive, given the time spent.

The solution is a modern dentin adhesion. Instead of using a non-adhesive, large, rigid post in the root space, we will use the inner walls of the canals as a surface for retention of the fiberglass posts and transmission of masticatory forces. To create sufficient retention, we no longer have to intervene in the apical third of the root canal (Fig. 1).

This whole procedure, together with the restoration of the tooth crown, represents a major change in the established treatment method [9]. A change that offers a stable and reliable solution in one visit.

ANALYSIS

The problem of post-endodontic treatment is so complex that it is difficult to simulate for acceptable clinical use [10-12]. Most of the available literature is not clear on the clinical side of things, which is crucial for the outcome. To describe the entire clinical procedure, it is necessary to understand the principle of individual steps, because their quality will determine the outcome of the entire treatment. The following factors will be discussed:

1. dentin
2. adhesion of cement to dentin
3. composite resin cement
4. prefabricated post
5. adhesion of cement to the post
6. subsequent prosthetic treatment (crown)

1. Dentin

Dentin is the tubular structure of a tooth that accounts for most of its volume. The dentin of the human tooth consists of 70% inorganic, 18% organic material and 12% water. In the long run, due to its mechanical properties, it is considered to be the most important structure in terms of resistance to load [9, 13]. Some studies show reduced shear resistance of the tooth in endodontically treated teeth [14-17]. Each dentin removal weakens the tooth and increases the risk of fatigue fracture. Thanks to today's possibilities, however, we do not need to sacrifice dentin at the expense of material for further dental treatment (Fig. 2). Removal of healthy dentin can be described as unnecessary. Steel instruments used in the past for endodontic treatment

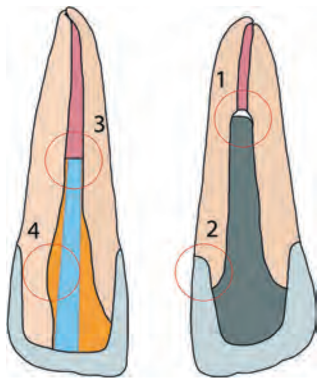

Fig. 1. **Comparison of post and core superstructure and superstructure with fiber post. 1. Stress concentration at the end of the cast superstructure. 2. More aggressive preparations hiding unaesthetic completion. 3. Biological preparation of the root around the tip of the post. 4. The ability of the dual resin to fill sub-curves.**

did not create enough space in the root space to place the posts without using a pre-drill for the post. However, it has created a preform for the use of the intended post disrupting the walls of the canal, for example, even when used correctly in straight canals. The saddle-shaped apex of such a preparation was a site of stress concentration after post fixation (e.g., superstructure), which increased the probability of an irreparable fracture [18]. Another risk was the perforation formation in the curved root canals. With the advent of Ni-Ti rotation systems came the increased conicity of apical preparation. This allowed better availability of the root system for rinsing agents and better adaptation of the gutta-percha during thermal condensation. To place the post at higher conicities, we no longer need to reduce and further pre-drill the root canal wall: we will keep it smooth without places where there would be a concentration of stress. The difference in structure between dentin near the dentin-enamel junction and near the pulp is well documented. But we know less about the structural differences between coronal and radicular dentin. An increase in the number of dentinal tubules in the apico-coronary direction is described [19]. The research is not consistent in the evidence of the strength of the adhesive bond, but several studies show reduced dentin adhesion in the root dentin compared to the crown dentin. One explanation may be the difficulty of cleaning the cavity and, with it, removing the smear layer in the deeper parts of the root canal, which can disrupt the bonding of the adhesive. However, the removal of the smear layer in the root space is necessary due to the possible penetration of bacteria through the dentinal tubules from the outside of the tooth and into the smear layer as such. EDTA solution 17% is the most commonly recommended agent for this purpose. Other endodontic lavage solutions, especially sodium hypochlorite, reduce the bonding of all dentin adhesives. It doesn't even matter if we used multi-step or one-step adhesive systems. Therefore, before each adhesive preparation, the layer of damaged dentin should be removed, either with a carbide rotary tool or by sandblasting [20]. But we must keep in mind that the root space is not easily accessible for sanding.

Clinical implications:

Considering the possibility of adhesive post-endodontic restoration, reducing the clinical crown, which previously preceded endodontic treatment as standard, may not be the rule.

Dentin should be treated with care to prevent unnecessary removal of otherwise healthy tissues. To achieve this goal, the use of an operating microscope is very useful. For better adhesion results, it is recommended to remove a thin damaged layer of dentin.

2. Adhesion of dentin / composite resin cement

Adhesion of all parts (Dentin / Cement / Post / Crown) is necessary for the stress distribution. If the tooth does not have sufficient ferrule, the most likely site of failure is the adhesive bonding between the dentin and the cement [21, 22].

In general, there are two techniques for achieving a combination of dentin and composite. The etch-and-rinse technique removes the smear layer and demineralizes the dentin with phosphoric acid, which leaves an exposed thick layer of collagen fibers into which the primer penetrates and, after the adhesive is applied, forms a network of collagen fibers with a composite called a hybrid layer. The self-etch technique combines etching and adhesive processes in one step, with or without smear layer removal and hydroxyapatite demineralization, and the hybrid layer is formed by self-limiting acidic substances in the adhesive. Previous generations of self-etch adhesives have shown many disadvantages [23]. But the latest generation of ultra-mild self-etch adhesives shows promising results [24].

As already mentioned, some studies show a decreasing bond strength apically in the root space, while others disagree. This discrepancy between studies may be due to the same level of adhesion quality in the root canal, which is difficult to achieve, especially if the space is very narrow [25]. However, most studies show a lower bond strength in root dentin compared to coronary dentin. It is clear that this procedure is a clinical challenge and needs to be given great attention and care [26]. It is a matter of further examination whether it would be better to remain in the coronary third of the root and have better adhesion control or to try to achieve adhesion deeper in the root, but with less predictable results [27, 28].

During 15 years of working with fiber posts as part of our clinical practice, we gradually reduced the length of the adhesive surface in the root from 12-18 mm to 8-10 mm based on observations (Fig. 2).

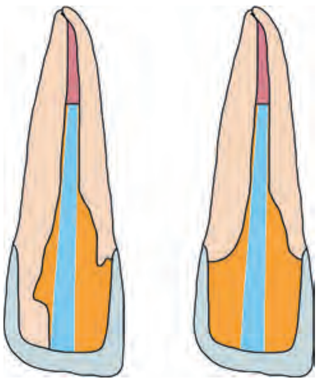

Fig. 2. **Proper tissue preservation when using the fiber post (left) and unnecessary tissue loss in the drainage situation (right)**

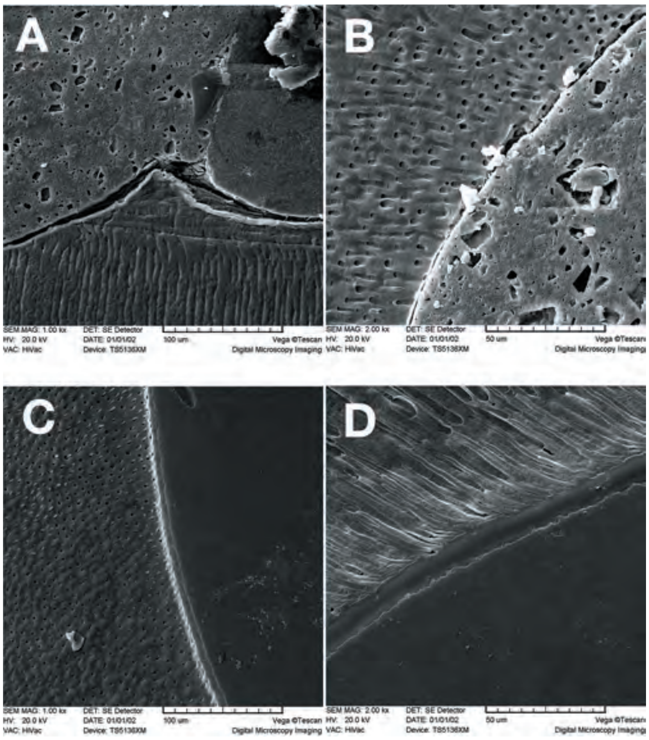

Fig. 3. **SEM image from the tip area of the fiber post located to a depth of 16 mm. A thick smear layer and the absence of adhesion are visible (A, B). For SEM comparison, image of the same tooth just below the level of the medullary cavity. A well-formed hybrid layer (C, D) is visible. Figure author: Dr. Lenka Roubalнkovб, Ph.D.**

Clinical effects:

Today, etch-and-rinse adhesives are still considered to be the best option for dentin light adhesion, so whenever light polymerization can be achieved, this procedure is recommended [29]. However, when the depth reaches more than 8 mm, the use of a catalyst can help to achieve better polymerization of the hybrid layer (Fig. 3). The etching time can be extended to 30 seconds to remove the thicker smear layer. The light polymerization time should be extended to 60 seconds.

3. Composite resin cement

Composite resin cement is a material with a similar composition to a filler composite resin, but the filler content is lower, usually below 50% by volume. Today, however, there are already cements on the market with a filler content approaching 50% by volume, which is the stated boundary between cements and filler composites. The physical properties of cements with a higher filler content are close to those of filler composite resins, with the exception of consistency (they are less viscous) and abrasion resistance, which is much lower than that of filler resins. Composite cements are used as a fixing material in prosthetics. As such, they are usually self-polymerizing or dual-curing. These cements bond to the hybrid layer in the same way as filler resins. The setting time is between 3-5 minutes, which allows the operator to manipulate at least 60 seconds to position the desired one or more posts. Due to the high filler content, the stress caused by polymerization shrinkage inside cavities with a high C-factor is a much bigger problem (Figures 5, 6). While most studies compare self-curing, dual, or light-curing materials, it is not observed whether during dual-curing, the material is first allowed to solidify chemically prior to light polymerization alone. Slow chemical solidification before light curing leads to a reduction in polymerization stress and helps to improve the internal structure of the material before the onset of the gel phase and to avoid unwanted craze lines [30-32].

Another problem with dual-setting cements is the presence of air bubbles. The oxygen contained in the bubbles prevents the resin from solidifying in the immediate vicinity, which can theoretically lead to a deterioration in the physical properties of the material. However, we did not confirm this hypothesis in our observations.

In the search for the best possible adhesion and strength, composite resin cement is a better choice than so-called "self-adhesive cements, " which usually consist of resins modified with glass-polymer cement. They do not require adhesive preparation of dentin, except for surface cleaning, although some articles recommend conditioning with polyalkenic acid, which they say improves the adhesion of cement to radicular dentin. In terms of compressive strength, there is not much difference between resin cement and resin-modified glass-polymer cement.

It was found that the optimal cement thickness for post fixation is approximately 200µm.

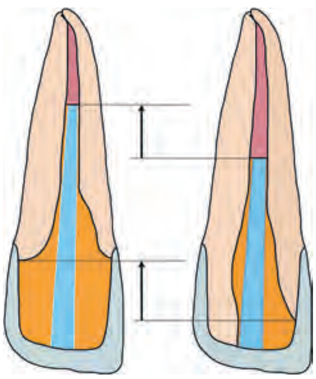

Fig. 4. **In a situation of greater destruction of the clinical crown, the fiber post extends deeper into the root to replace the adhesive surface.**

Many pre-drill systems do not have such a difference between a pre-drill and a post, and therefore a pre-drill one size larger than the corresponding post size could be better served. [33]

The use of dual-setting cements is also discussed for their conversion rate. Available research favors shorter posts for better light polymerization. [34]

Clinical effects:

If the choice of fixing material for fiber posts is based on the best possible physical properties and retention, then a high filler composite cement should be used. On the other hand, if the situation does not require the highest possible bond strength and the post serves as a more or less prepolymerized filler, it is much easier to use self-adhesive cements instead.

When applying cement and placing the post, it is recommended to let the cement polymerize chemically for 3-4 minutes and then with light to reduce polymerization stress.

4. Prefabricated post

The technology of fiber posts penetrated post-endodontics in 1990. [35] Composipost (RTD, France) contained carbon fibers and was the subject of the first clinical studies. [36-38]

The reason why fiber posts are considered a better option than previously used titanium or other metal posts is not only their aesthetics, but also their physical properties – the modulus of elasticity much closer to natural dentin. [39, 40] Fiber posts also create less stress on dental tissue during potential failure. Unlike more rigid posts, the compressive forces in the fiber posts result in debonding or a post fracture that retains the root. [3, 8, 41] This mechanism is considered to be an advantage of fiber posts (fail-safe), especially when using shorter posts. [28]

In the last ten years, the situation between prefabricated fiber posts has changed dramatically. Ten years ago, there was limited information on how they work and many products on the market failed even in simple stress tests. [42, 43] Today, however, there are several products available that can withstand 2 million load cycles without failure. [44] Glass and quartz are the most commonly used fibers today, the matrix is usually epoxy resin, UDMA or other acrylates. The shape and size of the pins should correspond as closely as possible to the root space so that the forces inside the root are evenly distributed, so that

Fig. 5, 6. **Situation with an extensive root cavity of the middle incisor. The use of three root posts helps to compensate for polymerization shrinkage.**

the most suitable prefabricated shape is conical or double taper. Such a shape creates a rigid neck portion and a relatively flexible tip. [45] Concerning the diameter of the fibers, their density and their distribution in the posts, there are still questions to be answered. We strive for a balance between strength, durability, flexibility and bending resistance. However, it is clear that better internal integrity (less porosity within the material) increases fatigue resistance. Many other factors need to be considered for clinical significance, especially root adaptation and a fixation method that distributes stress more evenly. Several studies indicate that individually made fiber posts have greater fracture toughness compared to prefabricated pins, but this benefit has not been demonstrated in the long term. [46, 47]. In addition, it is a relatively complicated clinical process that may not show the expected results due to its own procedural errors and internal defects.

Clinical effects:

When deciding which prefabricated posts to use, it is advisable to find current information about their physical properties. Some of the products do not reach the expected quality. It is likely that we will see further improvements in the physical properties of the posts and fixation.

5. Adhesion of cement to the post

Because fiber posts are made of glass or quartz fibers and various matrix resins, the recommended adhesive protocol for fiber posts includes enlarging the adhesive surface (sandblasting, HF etching), silanization, and subsequent application of the adhesive. [48, 49] This is a relatively complicated procedure for making in the office, but it is necessary if we want to achieve the maximum possible force of adhesion. As mentioned above, the clinical outcome depends not only on the quality of the dentin, cement and pin, but also on the interconnection of all these components. Inhomogeneous interconnection of all substrates can significantly affect the result of the whole system.

There are several products on the market that offer an adhesively pre-prepared surface of the posts using PVD (Physical Vapor Deposition) technology, which is activated by embedding in a dual-setting composite cement. [50] The result is not better than the above-described procedure in adhesive preparation, but a relatively useful and time-saving solution in everyday practice.

Clinical effects:

We have put into practice for most of our cases quartz fiber posts with an industrially prepared adhesive layer in search of maximum quality and at the same time ease of use. In the case of posts without this surface treatment, alcohol cleaning and adhesive preparation must be carried out before application.

6. Prosthetic treatment (crown)

The crown, regardless of the material used, is intended to return the tooth to its original or optimal shape and function. It is also another and, according to some, more important barrier that prevents reinfection of the root system and should increase or at least not worsen the resistance of the remaining dental tissues.

Like endodontic treatment, preparation for the crown requires the preservation of as much dental tissue as possible. Any tissue reduction must be done with great caution. The advantage is adhesive fixation, where the adhesion to the preserved enamel is much stronger than the adhesion to the dentin. [51]

The most important factor in the design of the preparation is the shape and amount of ferrule. The principles of preparation for the crown have been described in detail, and for this purpose a small convergence of the stump is important. However, the amount of tissue both horizontally and vertically in the area of the neck of the crown, the so-called ferrule, is considered crucial for a good prognosis. It has been shown that a 1mm ferrule doubles the prognosis of a tooth compared to a situation where no ferrule is present and the only retention basis for the crown is the extension fixed to the root canal. The optimal size of the ferrule is at least 2 mm vertically and at least 1 mm horizontally. [52, 53] If such a ferrule cannot be obtained, we must consider surgical extension of the crown or orthodontic extrusion (Figs. 7, 8) [54].

Clinical implications:

If the tooth is prepared so that we have 2 mm or more ferrule, it is often not necessary to use fiber posts for molars. In the case of premolars and anterior teeth, their use is beneficial for a more advantageous transmission of forces and higher retention of completion. The situation may be unclear when we do not know the quality of future preparation (especially in reported endodontic cases), it is appropriate to use posts to ensure retention.

Clinical procedure

1. Insulation

Adhesively created extensions require absolute control of the working field. If the edge of the cavity is deep, advanced insulation skills are often needed to ensure an absolute dry field. Stable buckles should be used and a thicker latex membrane is an advantage. Occasionally, additional precautions are necessary because the time between application of the cement and its setting is a few minutes and any rise can be dangerous for adhesion. The worst case scenario would be the release of the buckle on the uncured cement with a post. If necessary, we perform a pre- or single-phase surgical extension of the crown (Fig. 9).

2. Caries excavation

Before starting further treatment, the caries is first removed to determine the reconstructability of the tooth. After removing the rigid

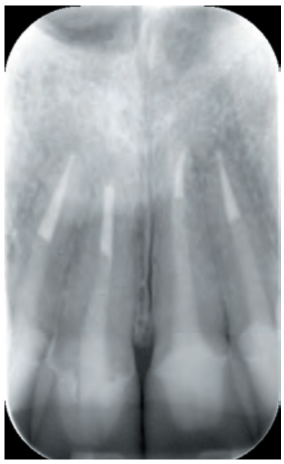

Fig. 7, 8. **Extreme condition of use of fiber post at tooth 21. Minimal ferrule only on a part of the preparation circumference. Align tooth 11 with the normal condition of the adhesive backing. Clinical picture and intraoral X-ray 10 years after fabrication. Unilateral extension of the clinical crown would lead to an unaesthetic condition. Crowns: Dr. Radek Mounajjed, DDS, PhD.**

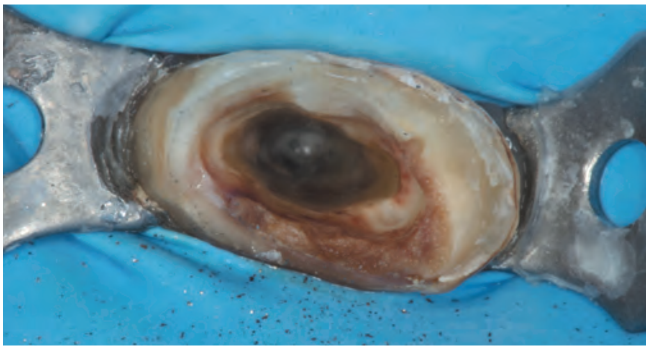

Fig. 9. **Operating field isolation. Original superstructure removed.**

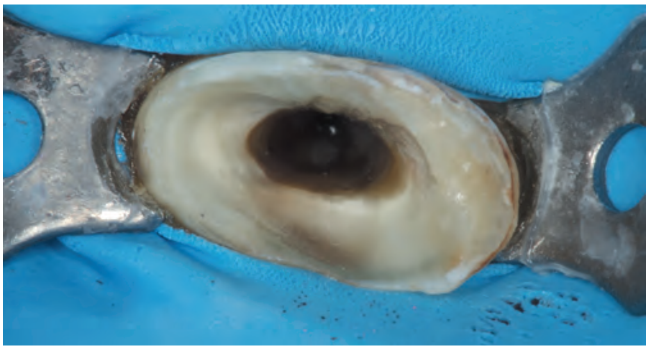

Fig. 10. **Condition after excavation of the carious lesion.**

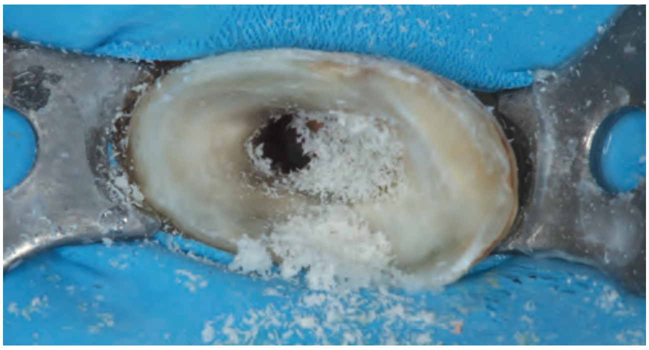

Fig. 11. **Superficial revitalization of dentin (fresh cut) after completion of endodontic treatment.**

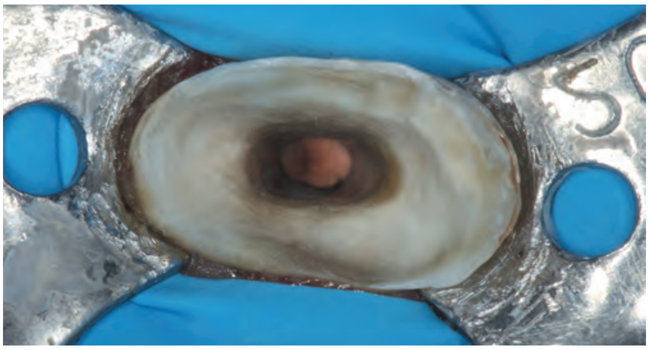

Fig. 12. **Condition of dentin substrate after cleaning.**

posts, check for possible infections under an operating microscope (Fig. 10).

3. Filling the root canal

The root filling should be deep enough with a flat gutta-percha surface perpendicular to the root wall to accommodate the adhesive backing. The recommended depth from the edge of the cavity is 8mm (Fig. 4).

4. Cavity dressing

In situations where natural undercuts occur in the walls of the canal, the presence of gutta-percha or other impurities should be checked to avoid a reduction in retention forces. The presence of a sealer on the walls of the root canals should be avoided. If the sealer has already solidified on the roofs, it will be removed during dentin cleaning and revitalization. If an uncured sealer is present, it must be thoroughly removed. In our practice we use AH 26 (Dentsply, Germany), which is greasy and difficult to remove. The combination of ultrasound (PS tip, EMS Dental, France) with massive cooling and a microbrush (Microbrush International, USA) is usually sufficient.

5. Dentin refreshment (fresh-cut)

Since dentin is degraded by endodontic lavages and may also contain more oxygen due to the interaction of NaClO with organic substances, it is necessary to obtain freshly prepared dentin using a ball drill of suitable size and length. Use 2000-3000 rpm, without cooling and without pressure (Fig. 11, 12).

Pre-drills, which should be one size larger than the planned fiber posts, should be treated in a similar way as in the previous step. It is not suitable to use it as an extension tool. Slow speeds without leverage and pressure should be used.

All dentin sawdust must be removed. The best option is ultrasound with a blunt tip and intensive cooling.

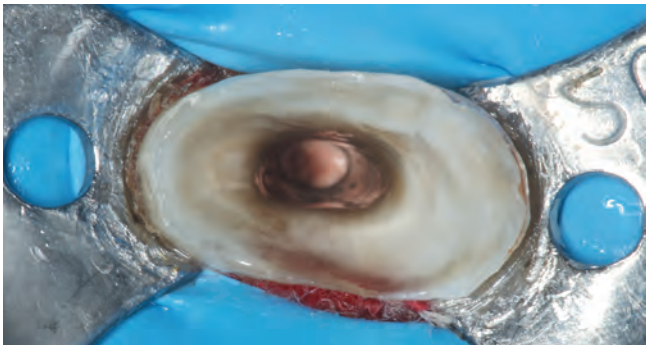

Fig. 13. **Adhesive preparation. 4th generation adhesives. (Optibond FL, Kerr Corporation, Orange, USA) The retraction fiber is used as an adjunct to maintain a dry operating field (Ultrapak # 3, Ultradent, USA).**

6. Adhesive protocol

A phosphoric acid gel (37%) was applied to the entire cavity and allowed to act for 30 seconds, then rinsed with a continuous stream of water for an additional 30 seconds. If the root canal is narrow and deep, it is necessary to use a thinner cannula, ideally Stropko irrigator (Stropko, USA). All acid and dissolved hydroxyapatite residues must be removed. Excess water can be removed with the tip of the suction cup and in narrower cavities using a microdose or paper pins.

Subsequently, a large amount of primer is applied using a microbrush or a narrow brush with long bristles. Excess is removed with a suction cup and chip-blower. Watch for water droplets coming out of the air gun to prevent the primer from washing out. The bond is then applied for 20 seconds and then the excess is blown out again with air. If necessary, paper pins are used.

Fig. 14. **Dual composite cement (EnaCem, HF, Micerium SpA, Italy) is applied and the pin is placed (DT Light SL, VDW GmbH, Germany).**

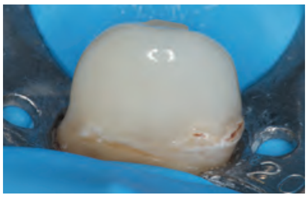

Fig. 15. **Addition of hybrid filling resin to the desired shape (Enamel HRi, Micerium SpA, Italy).**

The polymerization must last at least 60 seconds to achieve sufficient light intensity at the bottom of the root canal cavity (Fig. 13).

7. Application of composite cement

There is a relatively high risk of air bubbles forming in the dual-setting cement without suitable appliance. The best solution is a carpule applicator with a metal cannula (AccuDose 20ga NeedleTube, Centrix, USA). Cement is applied from the bottom up under visual control (yellow filtered light), where we can immediately locate and remove bubbles. Special porosity must be paid to undercuts so that air is not trapped in them.

A certain time is given for the application of cement, which depends on the type of cement used. Personally, I prefer dual-setting cements with a longer handling time of up to 90 seconds and a setting time of 3 or more minutes.

8. Fiber post placement

Fiber post placement is a simple process for a single root tooth or using only one post. Whenever we use more than one post, there is a risk of incorrect placement, especially if they are of different sizes. It is not advisable to move them too vertically in the cement to prevent air entrapment in the material. Conversely, a slight vibrational motion can help to evenly spread the cement around the insert post.

When placing multiple posts, it must be tested in advance that they do not interfere with the pulpal cavity. In this case, we must determine the order of insertion of the pins or one of them can be shortened. Personally, I do not see a benefit in the implicit shortening of posts before insertion into the canal. On the contrary, I see it as an advantage to leave the post in their original length whenever possible. This will provide better handling, preserve their color coding, and further reduce the risk of breaking the adhesive layer of the post.

The insertion of the post must be done passively, without wedging and creating permanent stress on the cavity wall.

After placing the post, we can add more dual-setting cement to the empty narrow spaces and around the post and cavity walls (Fig. 14).

Fig. 16, 17. **Condition immediately upon completion.**

Fig. 18. **Intaroral periapical radiograph immediately upon completion.**

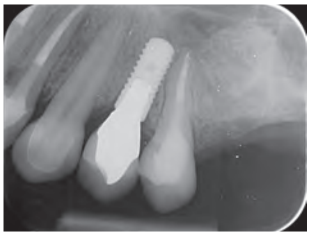

Fig. 19. **Intraoral periapical radiograph 6 years post-op. Crown made of pressed lithium disilicate. (Dr. Radek Mounajjed, DDS :, PhD.)**

Allow the cement to set on its own. It usually takes 3-4 minutes. Then shine on each side for 20 seconds.

Shorten the pins with an air-cooled fine-speed high-speed handpiece with a fine diamond drill bur.

If a larger amount of finishing material is required, remove the composite sawdust with unfilled resin (EnaSeal, Micerium, Italy) and adjust the stump by adding a light-curing hybrid composite to the desired shape (Fig. 15).

9. Final polymerization

The completed finish must be covered with glycerin gel and illuminated for another 40-60 seconds, depending on the size of the finish (Fig. 16-19).

It is recommended to provide the tooth with a crown or temporary temporary crown over several weeks or to cover the post with a small amount of flow composite to prevent bacteria from penetrating along the fiber post.

CONCLUSIONS

Advances in fiber post technology, composite resins, and adhesion technology allow for a more conservative approach and ensure long-term prognosis with less risk of subsequent trauma or fatigue. In a retrospective study, we achieved a success rate of almost 97% after an average of more than 7 years in 300 teeth of the frontal section [55].

At the same time, many clinical situations can be addressed in other ways than the post and crown. If sufficient tissue from the clinical crown is preserved, a direct composite filling, overlay or endocrown can be used instead of the classic procedure [56, 57].

Much of the clinical features still need to be explained and a standard defined [58]. However, knowledge on the use of fiber pins and adhesion is evolving rapidly, creating pressure for further medical training.

СПИСОК ЛИТЕРАТУРЫ / REFERENCES.

1. Ritwik P, Massey C, Hagan J. Epidemiology and outcomes of dental trauma cases from an urban pediatric emergency department. Dent Traumatol. 2015 Apr;31(2):97–102.

2. Akkayan B, Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. J Prosthet Dent. 2002 Apr;87(4):431–7.

3. Fokkinga WA, Kreulen CM, Vallittu PK, Creugers NHJ. A structured analysis of in vitro failure loads and failure modes of fiber, metal, and ceramic post-and-core systems. Int J Prosthodont. 2004 Jul;17(4):476–82.

4. Dietschi D, Ardu S, Rossier-Gerber A, Krejci I. Adaptation of adhesive post and cores to dentin after in vitro occlusal loading: evaluation of post material influence. J Adhes Dent. 2006 Dec;8(6):409–19.

5. 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 Feb;39(2):117–29.

6. Hayashi M, Sugeta A, Takahashi Y, Imazato S, Ebisu S. Static and fatigue fracture resistances of pulpless teeth restored with post-cores. Dent Mater. 2008 Sep;24(9):1178–86.

7. Theodosopoulou JN, Chochlidakis KM. A systematic review of dowel (post) and core materials and systems. J Prosthodont. 2009 Aug;18(6):464–72.

8. A Alharbi F, Nathanson D, Morgano SM, Baba NZ. Fracture resistance and failure mode of fatigued endodontically treated teeth restored with fiber-reinforced resin posts and metallic posts in vitro. Dent Traumatol. 2014 Aug;30(4):317–25.

9. 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 Oct;38(9):733–43.

10. Cagidiaco MC, Goracci C, Garcia-Godoy F, Ferrari M. Clinical studies of fiber posts: a literature review. Int J Prosthodont. 2008 Jul;21(4):328–36.

11. Baba NZ, Golden G, Goodacre CJ. Nonmetallic prefabricated dowels: a review of compositions, properties, laboratory, and clinical test results. J Prosthodont. Blackwell Publishing Inc; 2009 Aug;18(6):527–36.

12. Marchionatti AME, Wandscher VF, Rippe MP, Kaizer OB, Valandro LF. Clinical performance and failure modes of pulpless teeth restored with posts: a systematic review. Braz Oral Res. Sociedade Brasileira de Pesquisa Odontológica; 2017 Jul 3;31(0):e64.

13. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod. 1989 Nov;15(11):512–6.

14. Carter JM, Sorensen SE, Johnson RR, Teitelbaum RL, Levine MS. Punch shear testing of extracted vital and endodontically treated teeth. J Biomech. 1983;16(10):841–8.

15. Musikant BL, Deutsch AS. Post design and its impact on the root and crown. Compend Contin Educ Dent. 2006 Feb;27(2):130–3.

16. Scotti N, Rota R, Scansetti M, Paolino DS, Chiandussi G, Pasqualini D, et al. Influence of adhesive techniques on fracture resistance of endodontically treated premolars with various residual wall thicknesses. J Prosthet Dent. 2013 Nov;110(5):376–82.

17. Zicari F, Van Meerbeek B, Scotti R, Naert I. Effect of ferrule and post placement on fracture resistance of endodontically treated teeth after fatigue loading. J Dent. 2013 Mar;41(3):207–15.

18. Wiskott HWA, Meyer M, Perriard J, Scherrer SS. Rotational fatigue-resistance of seven post types anchored on natural teeth. Dent Mater. 2007 Nov;23(11):1412–9.

19. Ferrari M, Mannocci F, Vichi A, Cagidiaco MC, Mjör IA. Bonding to root canal: structural characteristics of the substrate. Am J Dent. 2000 Sep 30;13(5):255–60.

20. Bitter K, Eirich W, Neumann K, Weiger R, Krastl G. Effect of cleaning method, luting agent and preparation procedure on the retention of fibre posts. Int Endod J. 2012 May 7.

21. Cagidiaco MC, Radovic I, Simonetti M, Tay F, Ferrari M. Clinical performance of fiber post restorations in endodontically treated teeth: 2-year results. Int J Prosthodont. 2007 May;20(3):293–8.

22. Rasimick BJ, Wan J, Musikant BL, Deutsch AS. A review of failure modes in teeth restored with adhesively luted endodontic dowels. J Prosthodont. Wiley/Blackwell (10.1111); 2010 Dec;19(8):639–46.

23. Tay FR, Pashley DH, Loushine RJ, Weller RN, Monticelli F, Osorio R. Self-etching adhesives increase collagenolytic activity in radicular dentin. J Endod. 2006 Sep;32(9):862–8.

24. Krämer N, Tilch D, Lücker S, Frankenberger R. Status of ten self-etch adhesives for bonding to dentin of primary teeth. Int J Paediatr Dent. 2014 May;24(3):192–9.

25. Ferrari M, Grandini S, Simonetti M, Monticelli F, Goracci C. Influence of a microbrush on bonding fiber post into root canals under clinical conditions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002 Oct 31;94(5):627–31.

26. Tay FR, Loushine RJ, Lambrechts P, Weller RN, Pashley DH. Geometric factors affecting dentin bonding in root canals: a theoretical modeling approach. J Endod. 2005 Jul 31;31(8):584–9.

27. Scotti N, Scansetti M, Rota R, Pera F, Pasqualini D, Berutti E. The effect of the post length and cusp coverage on the cycling and static load of endodontically treated maxillary premolars. Clin Oral Investig. Springer-Verlag; 2011 Dec;15(6):923–9.

28. Zicari F, Van Meerbeek B, Scotti R, Naert I. Effect of fibre post length and adhesive strategy on fracture resistance of endodontically treated teeth after fatigue loading. J Dent. 2012 Apr;40(4):312–21.

29. Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, et al. State of the art etch-and-rinse adhesives. Dental Materials. 2011 Jan;27(1):1–16.

30. Faria-e-Silva A, Boaro L, Braga R, Piva E, Arias V, Martins L. Effect of immediate or delayed light activation on curing kinetics and shrinkage stress of dual-cure resin cements. Oper Dent. Operative Dentistry, Inc; 2011 Mar;36(2):196–204.

31. Soares CJ, Bicalho AA, Veríssimo C, Soares P, Tantbirojn D, Versluis A. Delayed Photo-activation Effects on Mechanical Properties of Dual Cured Resin Cements and Finite Element Analysis of Shrinkage Stresses in Teeth Restored With Ceramic Inlays. Oper Dent. 2016 Sep;41(5):491–500.

32. Spinell T, Schedle A, Watts DC. Polymerization shrinkage kinetics of dimethacrylate resin-cements. Dent Mater. 2009 Jul 31;25(8):1058–66.

33. D'Arcangelo C, Cinelli M, De Angelis F, D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. J Prosthet Dent. 2007 Sep;98(3):193–8.

34. Navarra CO, Goracci C, Breschi L, Vichi A, Corciolani G, Cadenaro M, et al. Influence of post type on degree of conversion of a resin-based luting agent. Am J Dent. 2012 Feb;25(1):17–20.

35. Duret B, Reynaud M, Duret F. [New concept of coronoradicular reconstruction: the Composipost (1)]. Chir Dent Fr. 1990 Nov 22;60(540):131–41contd.

36. Fredriksson M, Astbäck J, Pamenius M, Arvidson K. A retrospective study of 236 patients with teeth restored by carbon fiber-reinforced epoxy resin posts. J Prosthet Dent. 1998 Aug;80(2):151–7.

37. Glazer B. Restoration of endodontically treated teeth with carbon fibre posts--a prospective study. J Can Dent Assoc. 2000 Dec;66(11):613–8.

38. Ferrari M, Vichi A, García-Godoy F. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. Am J Dent. 2000 May;13(Spec No):15B–18B.

39. Bitter K, Kielbassa AM. Post-endodontic restorations with adhesively luted fiber-reinforced composite post systems: a review. Am J Dent. 2007 Nov 30;20(6):353–60.

40. Plotino G, Grande NM, Bedini R, Pameijer CH, Somma F. Flexural properties of endodontic posts and human root dentin. Dent Mater. 2007 Sep;23(9):1129–35.

41. Salameh Z, Sorrentino R, Papacchini F, Ounsi HF, Tashkandi E, Goracci C, et al. Fracture resistance and failure patterns of endodontically treated mandibular molars restored using resin composite with or without translucent glass fiber posts. J Endod. 2006 Aug;32(8):752–5.

42. Grandini S, Goracci C, Monticelli F, Tay FR, Ferrari M. Fatigue resistance and structural characteristics of fiber posts: three-point bending test and SEM evaluation. Dent Mater. 2005 Feb;21(2):75–82.

43. Chieruzzi M, Pagano S, Pennacchi M, Lombardo G, D'Errico P, Kenny JM. Compressive and flexural behaviour of fibre reinforced endodontic posts. J Dent. 2012 Nov;40(11):968–78.

44. Zicari F, Coutinho E, Scotti R, Van Meerbeek B, Naert I. Mechanical properties and micro-morphology of fiber posts. Dent Mater. 2013 Apr;29(4):e45–52.

45. Soares LP, de Vasconcellos AB, da Silva AHMDFT, Sampaio EM, Vianna GA de DC. The relationship between fibre post geometry and flexural properties: an assessment through a modified three-point bending test. Eur J Prosthodont Restor Dent. 2010 Dec;18(4):158–62.

46. Cauwels RGEC, Martens LC, Verbeeck RMH. Fracture resistance of bone samples filled with fibre-reinforced composite posts: an ex vivo model. Int Endod J. 4 ed. 2013 May;46(5):434–41.

47. Gomes GM, Gomes OM, Gomes JC, Loguercio AD, Calixto AL, Reis A. Evaluation of different restorative techniques for filling flared root canals: fracture resistance and bond strength after mechanical fatigue. J Adhes Dent. 2014 Jun;16(3):267–76.

48. Kelsey WP, Latta MA, Kelsey MR. A comparison of the retention of three endodontic dowel systems following different surface treatments. J Prosthodont. 2008 Jun;17(4):269–73.

49. Mazzitelli C, Papacchini F, Monticelli F, Toledano M, Ferrari M. Effects of post surface treatments on the bond strength of self-adhesive cements. Am J Dent. 2012 Jun;25(3):159–64.

50. Edelhoff D, Weber M, Spiekermann H, Marx R. [PVD-layering for increased retention of glass fibre reinforced endodontic posts]. Schweiz Monatsschr Zahnmed. 2006;116(10):992–9.

51. Mounajjed R, Salinas TJ, Ingr T, Azar B. Effect of different resin luting cements on the marginal fit of lithium disilicate pressed crowns. J Prosthet Dent. 2017 Nov 15.

52. Ferrari M, Cagidiaco MC, Grandini S, De Sanctis M, Goracci C. Post placement affects survival of endodontically treated premolars. J Dent Res. 2007 Aug;86(8):729–34.

53. Mancebo JC, Jiménez-Castellanos E, Cañadas D. Effect of tooth type and ferrule on the survival of pulpless teeth restored with fiber posts: a 3-year clinical study. Am J Dent. 2010 Dec;23(6):351–6.

54. Nethravathy R, Vinoth SK, Thomas AV. Three different surgical techniques of crown lengthening: A comparative study. J Pharm Bioallied Sci. 2013 Jun;5(Suppl 1):S14–6.
55. Černý D, Eckert S, Mounajjed R. Retrospective 9-Year Clinical Outcome Report on Adhesive Post-endodontic Treatment of Anterior Teeth Using Prefabricated Fiber Posts. Int J Prosthodont. 2018 Oct 29;32(1):14–6.
56. Zarow M, Devoto W, Saracinelli M. Reconstruction of endodontically treated posterior teeth--with or without post? Guidelines for the dental practitioner. Eur J Esthet Dent. 2009;4(4):312–27.
57. Biacchi GR, Basting RT. Comparison of fracture strength of endocrowns and glass fiber post-retained conventional crowns. Oper Dent. 2012 Mar;37(2):130–6.
58. Goracci C, Ferrari M. Current perspectives on post systems: a literature review. Aust Dent J. 2011 May 31;56:77–83.

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