Japanese Dental Science Review 56 (2020) 216–223

Contents lists available at ScienceDirect

Japanese Dental Science Review

journal homepage: www.elsevier.com/locate/jdsr

Review Article

Current perspectives on dental adhesion: (3) Adhesion to intraradicular dentin: Concepts and applications

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ARTICLE INFO

Article history:
Received 9 August 2020
Accepted 24 August 2020

Keywords:
Adhesion
Dentin
Fiber posts
Intraradicular dentin
Posts
Root canal

ABSTRACT

Adhesion science is one of the greatest contributions to restorative dentistry. Adhesion not only established the current principles of tissue preservation, but also allowed for the production of more hermetic and long-lasting restorations. Although adhesive strategies are routinely used in most clinical situations, adhesion to root dentin is still a major challenge. The presence of humidity together with less intertubular dentin are factors that limit the adhesive potential of root dentin. This situation is more unfavorable in endodontically treated teeth prepared for prefabricated or custom-made intraradicular posts; these procedures may alter the mechanical properties of teeth by modifying the viable dentin surface for adhesion. Also, contaminants deposited on the dentin surface are difficult to remove through conventional techniques. Moreover, root canal morphology has a very unfavorable C-factor, bringing undesirable effects resulting from polymerization contraction of resin-based materials. However, the differences between coronal and root dentin are not a barrier for dentin adhesion. Standardization of procedures and care during clinical steps are fundamental to the success of adhesion to coronal or intraradicular dentin. Thus, it is essential to know the anatomy of the root structure, the factors that interfere with intraradicular adhesion, as well as the current adhesive materials and techniques.

1. Introduction

Adhesion to dental tissues was introduced to dentistry more than 60 years ago [1]. Since then, vital teeth could be successfully restored employing an adhesive strategy. It is known that restorations made with adequate adhesive protocols facilitate good sealing of the cavity, reduction of postoperative sensitivity, prevent marginal staining and recurrent caries [2,3]. However, despite adhesion to dental enamel being a technique with excellent immediate micromechanical retention established between conditioned enamel and adhesive monomers [4], adhesion to dentin is still a major clinical challenge to tackle with [5,6].

Human dentin is a complex tissue that varies with location in the same tooth (superficial, deep, coronary and root dentin), and may present different expressions resulting from responses and/or aggressions from the oral environment, such as carious, tertiary, sclerotic and/or eroded dentin [7,8]. As the mechanism of adhesion to dentin is much more complex than in enamel, clinical approaches are more challenging, and cannot always be standardized for all clinical situations [9].

Among these approaches, adhesion to intraradicular dentin particularly stands out. When pulpless teeth need to be restored using prefabricated or custom-made intraradicular posts, the clinical challenge increases due to the presence of less than ideal factors for proper adhesion [4].The variability of dentin anatomy, unfavorable cavity factor, impaired access and visibility, and difficult polymerization of resin-based luting cements within a deep cavity, require the clinician to have knowledge of adhesive techniques and materials, as well as the morphological and histological characteristics and tissue variations present in the teeth.

2. Characteristics of the dentin substrate

2.1. Coronal versus intraradicular dentin

Dentin is a vital, permeable, elastic and avascular tissue [10,11]. It protects the soft tissue that constitutes the pulp, contributes to the absorption of the loads that the enamel receives dur-

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https://doi.org/10.1016/j.jdsr.2020.08.002
1882-7616/

ing function and has the capacity for synthesis and growth throughout the dental life [12,13]. By volume, sound dentin is composed of approximately 55% of minerals (hydroxyapatite crystals-$Ca_{10}(PO_4)_3(OH)_6$), 30% of organic compounds (predominantly type I collagen fibers) and 15% of water. These percentages vary according to the region analyzed, proximity to the pulp, dental tubular size, location of the tooth in the arch and changes related to age or disease [8]. The large amount of water present in the dentin and its proximity to the pulp result in a tissue with constant moisture [14]. The presence of water increases the dentin viscoelasticity and facilitates the absorption and distribution of energy received by the enamel, reducing the risk of dental fracture [15–17].

Dentinal tubules are present throughout the extension of the dentin, from the pulp in coronal dentin to the dentino-enamel junction (DEJ) and the pulp canal in the root to the cementum-dentin junction (CEJ) [18]. They are protected by peritubular dentin which is a highly mineralized tissue with a low content of collagen fibers. On the other hand, intertubular dentin is a less mineralized tissue with a greater amount of collagen present between the tubules [19]. The tubules are filled with dentinal fluid and extensions of odontoblastic cells that have their origin in the pulp.

Important differences are observed between the superficial and deep dentin, both in the coronal and in the root area. The number of dentinal tubules is lower in superficial dentin (15,000/mm^2) than in dentin close to the pulp (65,000/mm^2), and the tubular density is different in the coronal, middle and apical portions of the tooth, being greater in the coronal portion of the tooth than in the apical [12]. The tubule number ranges from about 42,400/mm^{2}to 8,200/mm^2 from cervical to apical root dentin [20]. In coronal dentin, the opening of the dentinal tubules is approximately 22% close to the pulp and 1% in the EDJ, while its diameter varies from 0.8 μm (EDJ) to 2 μm (close to the pulp) [21]. This results in a decrease in the collagen fibers, from superficial to deep dentin [22].

Similar to coronal dentin, root dentin is a tissue characterized by the presence of dentinal tubules that extend from the pulp to the cementum [23,24], resulting in a permeable and moist tissue [8,14,25,26]. There are small differences between coronal and root dentin [27]. These differences are related to the number, density and diameter of the dentinal tubules which decrease in the apical direction and the amount of intertubular dentin [8,28]. In the apical region, dentin is more irregular and translucent, with sclerotic dentinal tubules, obliterated by minerals that resemble peritubular dentin [29], or even absent [28]. In addition, a layer of non-mineralized organic matrix, known as pre-dentin, contacts the pulp directly throughout its length [26].

2.2. Intraradicular dentin in pulpless teeth

During endodontic treatment, the pre-dentin present in the intraradicular dentin is partially or totally removed by the use of endodontic instruments and/or burs [23,26]. Dehydration that occurs after endodontic therapy results in loss of dentinal plasticity and increased dental stiffness [30,31]. These consequences, associated with the loss of supporting tissues, are mainly responsible for the fragility of pulpless teeth [32,33].

As the root dentin of pulpless teeth is subjected to manual/mechanical instrumentation and the preparation of the root walls to receive posts, these clinical steps collaborate with the loss of strength of the dental structure, especially in teeth with lost marginal ridges [34,35]. Studies suggest that superficial and coronal dentin are more resistant than deeper and apical dentin [12], especially in pulpless teeth [36].

3. Factors that affect adhesion to intraradicular dentin

Despite the differences between coronal and root dentin, such as the smaller proportion of tubular area available for adhesion [37] and the oblique orientation of about 50% of dentinal tubuli [38], these differences do not seem to prevent the bond of the adhesives on the root dentin [39]. However, for durable adhesion to root dentin, other aspects must be taken into account before the adhesive protocol is established.

3.1. Smear layer in pulpless teeth

When dentin surface is cut by rotating or manual instruments, debris of dentin, enamel and/or cement is deposited on the dentin forming a layer [40]. This amorphous layer, known as the šmear layer, is mainly composed of hydroxyapatite and denatured collagen [18], in addition to microorganisms, saliva, fragments of rotating instruments and provisional cements [41].

In the intraradicular dentin, a smear layer is attached to the surface after instrumentation with endodontic files [42,43]. It adheres firmly to the root walls, especially in the apical region. The radicular smear layer has a composition very similar to that of the coronal smear layer, along with the remains of viable and/or necrotic pulp tissue, coagulated proteins, blood cells and bacteria [41,43–45]. Its composition is influenced by the type of instrument used, anatomical characteristics of the root canal and irrigation solutions [42,45].

The radicular smear layer acts as a barrier, partially obstructing and sealing the dentinal tubules (smear plugs), reducing dentin permeability by up to 86% [46], making it difficult for substances used as intracanal medication to diffuse [45], preventing the penetration of the endodontic sealers into the dentinal tubules [47,48], as well as hindering the diffusion of monomers into the dentinal tubules during adhesive procedures [49]. Thus, its removal is commonly recommended in the literature [4,39,42].

From the endodontic point of view, the removal of the smear layer helps to reduce microorganisms and reinfections, increasing dentin permeability and allowing better diffusion of endodontic sealers [48,50]. This results in a better seal of the root canal by the sealers, and endodontic obturation of superior quality [51].

From the adhesive point of view, the removal of the smear layer increases the dentin permeability, allowing better infiltration of the adhesive monomers between the demineralized collagen fibers which results in a better quality of the hydrid layer [52]. It is important to emphasize that in teeth that will receive intraradicular posts, plasticized gutta-percha remains can be incorporated into the smear layer, making it even more difficult to remove [42,53]. This smear layer resulting from the intraradicular preparation must also be partially or totally removed, depending on the adhesive strategy that will be used (etch-rinse or self-etch) [4]. The maintenance of this layer negatively affects the adhesion of posts to the intraradicular dentin [53].

3.2. Irrigation solutions used in endodontics

Despite the smear layer having a weak bond to the dentin substrate, of about 2 to 5 MPa [54], this layer is not easily removed by instrumentation or water [41,42]. Irrigation solutions used during endodontic therapy, which have the main objective of cleaning the root canal [55,56], can facilitate the reduction and removal of the smear-layer [43,57] due to their antimicrobial, solvent and chelating actions [44]. However, the use of irrigation solutions can have an impact on the physicochemical properties of dentin, including wettability, roughness, penetrability of cement into dentin and microhardness [58,59].

Solutions such as sodium hypochlorite (NaOCl), ethylene diamine tetraacetic acid (EDTA), chlorhexidine gluconate (CHX) and peracetic acid (PAA) help to remove the organic and inorganic elements from the smear-layer [42,53,60]. They are used during and after endodontic instrumentation, improving the cutting efficiency of the instruments [43]. The effectiveness of these solutions depends on the chemical nature, quantity, temperature, contact time, age and surface tension of the solution [43].

NaOCl is an irrigating solution widely used for root canal instrumentation because it has antibacterial properties and the ability to dissolve vital and/or necrotic tissue [61,62] and organic components of the smear layer [63]. When NaOCl comes into contact with organic matter, it acts as a solvent, combining the released chlorine with the amino group of proteins and forming the compound chloramine (chloramination reaction). This compound interferes with bacterial cell metabolism, inhibiting the action of bacterial enzymes [57]. However, its use can inhibit the polymerization of resin-based luting cement due to its strong oxidizing property, in addition to affecting the mechanical properties, such as microhardness, elasticity module and resistance to flexion and fatigue [64,65]. An oxygen-rich layer forms over root dentin after irrigation with NaOCl, resulting in inhibition of resin polymerization and reduced adhesion [66].

EDTA, an acid with limited antiseptic capacity, is a chelating agent that reacts with the calcium ions in dentin to form soluble calcium chelates [43,67]. Solubility feature of calcium phosphate results in a 20 to 30 μm deep decalcification [68,69]. The calcium ions are incorporated into the molecules of the chelator and the reaction continues until the solution is saturated [69]. The combination of EDTA at a concentration of 17% and NaOCl can be used in contact with the intraradicular canal walls for a maximum of 1 minute [70], as longer times can lead to dentin erosion and reduced microhardness [67].

CHX, on the other hand, is a broad-spectrum antimicrobial agent used for the control of bacterial plaque, and is commercially presented in solutions with a concentration of 0.1% to 0.2% [71]. As a solution for endodontic irrigation, the 2% concentration is most commonly used, presenting antimicrobial activity within the root canal for up to 12 weeks [72]. Despite its excellent antimicrobial properties and low toxicity, CHX is unable to dissolve organic content and effectively remove the smear layer as NaOCl and EDTA [45,71]. However, it is able to reduce the proteolytic activity of dentin, inhibiting matrix metalloproteinase (MMP) [73]. MMPs are proteolytic enzymes capable of degenerating collagen fibers that are left unprotected after incomplete infiltration of the monomers, allowing progressive degradation of the hybrid layer [42,73]. Depending on the dose and concentration of the product, CHX can inhibit the self-degradation of collagen fibers, contributing to a better bond strength of resin-based materials to intraradicular dentin [74,75].

PAA, an effective disinfectant against bacteria, fungi, spores and viruses, even in the presence of organic matter [60], has also been used as an endodontic irrigation solution [76]. This solution, in concentrations between 1 and 4%, has antibacterial efficacy similar to that of 2.5% NaOCl and 2% CHX. PAA is composed of hydrogen peroxide and acetic acid, and the latter seems to be responsible for dissolving the smear layer, creating complexes with calcium that are more easily soluble in water [77].

3.3. *Endodontic sealers*

Sealers that contain eugenol in their composition are the ones that most interfere in the polymerization of resin-based materials [78]. The negative chemical reaction involves the hydroxyl group of eugenol, which tends to block the reactivity of free radicals formed during polymerization of the resin, reducing its degree of conversion [79]. Studies recommend the use of alcohol, detergent and/or phosphoric acid to clean this phenolic compound from the root walls of the intraradicular preparation, and it is suggested that application is immediately after endodontic obturation [80]. These procedures help remove debris from the eugenol oil layer before performing adhesive procedures [33].

Calcium hydroxide cements can be used to replace eugenol-based sealers [81]. However, low values of adhesive strength have been associated with these sealers [82]. When a calcium hydroxide-based cement is used, the adhesive bonding of the post should be performed immediately after obturation of the root canal [83]. On the other hand, studies suggest that the type of sealer (with or without eugenol) and the cementation time do not affect the retention of fiber posts cemented with resin-based luting cements [84,85] and that the most important factor is to obtain an effectively clean root surface. Epoxy-based sealers (i.e. AH Plus, Dentsply Sirona, Germany) should preferably be used when prefabricated posts will be bonded with resin cement [86].

3.4. *Cavity configuration*

The cavity configuration factor, also known as the “C” factor, is the ratio of bonded to unbonded dentine surface area in a cavity [87], and is often used as a quantitative measure of the geometry of the cavity preparation for bonding [27]. When the polymerization of a resin-based material is carried out, the resin undergoes a volumetric contraction, which may result in the formation of failures in the adhesive interface [88,89]. Consequently, cracks and spaces can be formed between the resin and the preparation, favoring bacterial microleakage [42]. If the cavity preparation has a favorable configuration factor (below 5) [87], the possibility of the resin detaching from the substrate decreases, minimizing these consequences.

Cavities with a high configuration C factor are more prone to adhesive complications, as the polymerization shrinkage of the resin is inevitable. An intraradicular preparation has a high C factor (about 200 to 500) [90], since the cavity geometry has few free interfaces [42]. Due to this configuration, the dissipation of the stresses generated by the polymerization of adhesive resin cement is more difficult, which may result in a rupture of the adhesion and formation of cracks along the entire length of the adhesive interface [91]. Interfacial gaps have been observed in bonded posts [92], and have increased over time [93].

In addition to the unfavorable geometry of the cavity, a resin-based luting cement cannot be inserted and light-cured incrementally as in direct composite resin restorations. Also, a greater thickness and viscosity of the adhesive resin cement contribute to a greater contraction of polymerization [90]. Thus, studies suggest a reduction in the thickness of the adhesive resin cement layer, in order to minimize the effects of polymerization contraction [89]. Reducing the thickness of this layer decreases the volume of adhesive resin cement, and consequently, its volumetric contraction [94]. However, this strategy is not always feasible, since prefabricated posts have standardized shapes and sizes. These posts adapt well to the most apical portions of the preparation, but a larger space remains between the post and the root canal wall in the more coronal portions, resulting in greater thicknesses of cement in this region [42]. The individual adaptation of fiberglass posts to the root canal walls before adhesive resin cementation, has been described in the literature as a technique to avoid this problem [95].

3.5. *Burs selection for intraradicular preparation*

Teeth that will be restored with prefabricated posts need to be prepared with sequential burs to create the space needed to receive the post. Commercial kits have carbide burs standardized according to the size of the posts. As expected, after using burs to partially remove gutta-percha and prepare root canal walls, a new smear layer is formed by dentin debris, sealants and plasticized gutta-percha remains [23]. An effective way to minimize the incorporation of gutta percha into the smear layer is to remove it before using the burs with a heated metal endodontic probe. Thus, the formation of plasticized debris by heat from the active drill will be minimized.

The use of carbide burs during intraradicular preparation produces a radicular smear layer much more resistant to removal with water or phosphoric acid [96]. Studies have reported that after acid conditioning of root dentin prepared with carbide burs, discontinuous areas of intertubular demineralization, areas with open tubules and areas covered by debris and gutta-percha remains were found [97]. On the other hand, the use of diamond burs results in a smear layer that is easier to remove, with open dentinal tubules and less debris formation [96].

3.6. Visibility and access to intraradicular preparation

The adhesive resin cementation protocols to root dentin that are fundamental for an adequate adhesion of prefabricated posts, are considered complex clinical procedures. This is due to the unfavorable configuration of the intraradicular preparation [87], associated with the difficulty of access and complete visibility of the preparation, especially in the apical areas [42]. In the cervical region of the intraradicular preparation there is better visibility of the preparation, favoring resin cement adhesion, as the photopolymerizing unit can be kept very close to the region. However, as the light from the photopolymerizing unit has difficulty reaching the apical areas effectively, dual or chemical adhesives should be selected to ensure effective polymerization [98].

Better access and visibility are also present in extended and tapered preparations, often found in teeth that already have posts. However, the intentional wear of the root walls in order to improve access and visibility to the preparation is totally contraindicated, since thinner root walls are more susceptible to fatigue and fracture [33,99].

It is also important to highlight that as there is intertubular dentin available for adhesion on the root walls of the intraradicular preparation, the adhesive result can be improved if the resin monomers can be applied vigorously and effectively throughout the root wall [42]. Thus, care must be taken by the clinician to minimize the limitations resulting from the lack of visibility of the preparation, such as adequate isolation, effective control of humidity and good illumination of the operating area with the use of individual magnifying lenses with LED lights attached.

3.7. Humidity and operative area control

The general consensus is that adhesive resin cementation is a moisture sensitive technique. Although teeth treated with endodontics have less moisture than vital teeth [30,31], pulpless dentin requires the same care as a vital tooth during adhesive procedures [42,53,92]. This is because humidity control is essential to obtain effective and durable adhesion [30].

Absolute isolation, drying the preparation with absorbent paper tips, efficient aspiration, use of dual polymerization resin cements are strategies that help to maintain a more appropriate area, ideal for an adequate adhesive protocol [42,98].

4. Intraradicular posts

In various clinical situations, pulpless teeth are restored with custom-made posts (metallic and non-metallic) or prefabricated (titanium, stainless steel, fiberglass and ceramic). Fiberglass posts have been the most used, since intraradicular preparations are less invasive and clinical procedures can be performed in a single session [27]. They also offer proper aesthetics [100], are cost-effective and have mechanical properties similar to dentin, such as flexural strength and modulus of elasticity [101].

The longevity of teeth restored with intraradicular posts is affected by post design, length, and thickness, the ferrule effect, and the amount of dental tissue remaining [23]. Teeth restored with fiberglass posts are less likely to fracture than those restored with metal or zirconia posts [102], since the forces absorbed by the post are not transferred completely to the root structure [103], and the set post/resin adhesive cement helps to strengthen the root [104,105]. On the other hand, prefabricated posts do not adapt perfectly to root preparation, which can result in areas with varying thicknesses of cement [42].

Studies report that post displacement and/or loss are the main failures related to this type of restoration [106]. These failures can be attributed to a low bond strength obtained after the adhesive procedures, or to a high number of defects that will compromise the adhesive interface over time [107]. Thus, the quality of the adhesive interface that is established between the intraradicular preparation and the post is critical to the success of this restorative approach.

5. Adhesive systems

The bond between the intraradicular dentin and the post is traditionally achieved by an adhesive resin cement, which will be bonded both on the dentin surface and the surface of the post. In order to achieve this, both surfaces must be prepared prior to cementation, using adhesive protocols that respect the characteristics of each substrate.

In order to guarantee efficient adhesion of the post to the root dentin, three aspects must be considered: the surface treatment, the selection of the adhesive resin system and the polymerization of the cement. The treatment of the dentin surface initially implies efficient removal of the root smear layer [42,50], followed by the infiltration of the adhesive monomers. To this end, etch-rinse (ER) and self-etch (SE) strategies can be used. However, as SE systems are composed of weak acids, they are not as effective as ER systems in removing the root smear layer [4,42]. ER systems are the most commonly used adhesive systems for the treatment of root dentin, because, in addition to promoting a more effective removal of the smear layer, a more uniform demineralization pattern is obtained [18,27].

Although there is still no consensus on the most effective method for the surface treatment of fiberglass root posts, chemical methods such as the use of silane coupling agents prior to the application of adhesive resin cement and micromechanical methods (i.e. air-abrasion and use of acids) have been suggested in the literature [108]. Although some manufacturers recommend the use of silane coupling agents to increase the wettability of the post surface, studies report that the bonding ability of fiber posts has not been improved with their use [109,110]. This seems to be related to the incompatibility of the silane coupling agent with the epoxy resins present in the matrix of these posts [110]. On the other hand, studies have shown that after air-abrasion, the strength of cemented posts increased, and that these results were dependent on the type of post and cement used [101,111]. However, more aggressive methods, such as air-abrasion and the use of acids (e.g. hydrofluoric acid) remove the outer layer of the resin, exposing the fibers and increasing the risk of damage, which could affect the integrity of the post [110].

Dual or chemically activated adhesive resin cements are the most suitable for cementation of fiberglass posts, since, with a longer working time, they allow a better control of the adaptation of the post [33]. In photoactivated systems, the light from the photopolymerizing device does not reach the most apical areas, even in the presence of translucent fiber posts [112,113], as these posts have limited light transmission [114]. Furthermore, the use of photoactivated cements can result in a low degree of conversion of resin monomers as it approaches the apical areas, compromising the integrity of the adhesive interface [115].

6. Durability of the adhesive interface

After adhesive resin cementation, a resin-dentin interdiffusion zone, known as a hybrid-layer, is formed by the infiltration of resin monomers in the spaces created between the demineralized collagen fibers [116]. The quality of the resulting hybridization layer is directly related to the efficiency of this infiltration and the degree of conversion of the adhesive [4,117,118]. Factors such as the viscosity of the adhesive solution and the collapse of the collagen fiber mesh can hinder the infiltration of the bonding agent [18,19,42]. Although studies have shown thinner infiltration zones in apical areas [22,23], the thickness of the hybrid layer does not seem to be related to its adhesive potential [117]. Similar or increased bond strengths have been reported for apical dentin, regardless of the thickness of the hybrid layer [53,119,120]. However, the durability of the adhesive interface can be compromised by the susceptibility of the hybrid layer to hydrolytic degradation [42,116]. Predisposing factors such as the pH of the oral environment, amount of cross-linking, type of filler particles, water concentration in the primer or adhesive, presence of residual water, among others, are constant concerns of many researchers [5,14,19,22,35,66,75,83,89,98,102,104,107,111].

The degradation of the interface results from the hydrolysis of the resin monomers and the disorganization of the collagen fibers exposed to water [2–4,18]. Initially, water is absorbed by the polymer present at the interface [121], and the degradation products are released (unreacted monomers and oligomers), exposing collagen fibers. Unprotected fibers can be degraded by metalloproteinases (MMPs) present in dentin [42,122,123], leading to a reduction in adhesive bond strength, increased microleakage and staining [42,124].

Therefore, the degradation of the adhesive interface is directly related to the incomplete infiltration of resin monomers and an adequate encapsulation of collagen fibers by these monomers. This fact reinforces that the durability of the adhesive interface depends on the execution of a careful adhesive protocol [2]. Although the contribution of these enzymes to the degradation of the adhesive interface is still not completely understood [4], solutions such as CHX, EDTA and benzalkonium chloride (BAC) have been shown to be effective in inhibiting the activity of matrix-bound MMPs [74,75,125,126].

7. Recommended protocol for cementing posts to root dentin

Based on the review of information in the literature, the following clinical protocol for adhesive resin cementation of fiberglass posts to intraradicular preparation is suggested:

Do	Why?
After making the intraradicular preparation, clinical and radiographic assessments and sectioning the fiberglass post to appropriate length, secure absolute isolation of the area. If it is not possible to place a metal clamp, modify the isolation and insert gingival retraction cord to keep the area dry.	Moisture must be controlled when using adhesive techniques to guarantee the success and longevity of adhesion [30,98].
Create roughness throughout the prepared area with a diamond bur. Afterwards, rinse thoroughly with water and dry with an endodontic suction.	Diamond burs produce a smear layer that is easier to dissolve than that resulting from the use of carbide drills [96].
Apply 37% phosphoric acid to all root walls of the preparation. Activate the acid with a disposable brush or paper cone/point for 15 seconds. Wash for an equal amount of time and use clean paper cones to dry the preparation.	It is recommended to use acids in liquid viscosity as they facilitate agitation [127]. They must also have benzalkonium chloride (BAC) or chlorhexidine gluconate (CHX) in their composition. BAC and CHX are known to inhibit the activity of matrix-bound MMPs [126]. The active application of the acid increases the adhesion of the fiberglass posts to the intraradicular dentin [127]. After acid conditioning, the dentin should be gently dried to avoid dehydration before applying the adhesive monomers [4]. In SE 2-step strategies, this step is not necessary.
Apply the primer inside the preparation with a disposable brush and remove the excess with light air jets and paper cones. Afterwards, rub the adhesive vigorously over the surface for 15 seconds and remove the excess in the same way as described above.	In the ER three-step strategy, the primer is applied over the conditioned surface before the adhesive. The solvent of the primer must be volatilized with air to assist the release of residual water that will be removed by the paper cones [2,18].
	If self-adhesive cements are used, this step is not necessary. When the adhesive is applied vigorously, it may be better attracted to the dentin collagen network [128]. More layers of adhesive can be used, as long as they do not interfere with the adaptation of the post [23,27].
Try the post to check its adaptation. Afterwards, remove the post and polymerize the adhesive for 20 seconds, using a photopolymerization unit.	High intensity photopolymerization units (above 1000 mW/cm2) are used to ensure polymerization in the apical region of the preparation. Even in dual-cure cements, polymerization must be carried out [129]. This step is not necessary for self-etching cements.
Apply the adhesive resin cement inside the intraradicular preparation with a cementation tip. Seat the post until it reaches the bottom of the preparation. Remove excess cement with a brush and photo-polymerize for at least 40 seconds.	The cement must be inserted from the apical to the coronal area to guarantee a complete adhesive interface on all the root canal walls [130].
	After effective polymerization, the final restoration can be completed.

8. Conclusions

The adhesive resin cementation of posts to intraradicular dentin is affected by several clinical factors such as the cavity configuration factor, access, visibility and dentin moisture. However, if adhesive procedures are performed meticulously, the challenges of adhesion to intraradicular dentin can be overcome to a great extent. Optimum root canal cleaning, adequate post selection, absolute isolation for effective humidity control, are necessary clinical approaches in order to guarantee long-term durable adhesive results.

Conflicts of interest

The authors declare no conflict of interest.

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