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Review

Dental Surface Conditioning Techniques to Increase the Micromechanical Retention to Fiberglass Posts: A Literature Review

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Abstract: Glass fiber posts (GFP) have an elastic modulus that shares structural characteristics with dentin. Ineffective removal of the smear layer (SL) in the root canal after post space preparation reduces resin tag formation, compromising an efficient hybrid layer formation leading to a subsequent debonding. In this sense, this review article focuses on the published literature related to dentin conditioning for GFP placement with the use of acidic solutions such as EDTA, citric and maleic acid or prefabricated conditioning solutions such as MTAD and QMix, both with/without activation by sonic or laser devices, analyzed by scanning electron microscopy (SEM) and/or push- out bond strength (POBS) test. The collected information suggested that the conditioning agent that showed better results for dentin conditioning increasing the bond strength of the GFP to the root canal is 17% EDTA without activation.

Keywords: dentistry; dental materials; glass fiber post; irrigant; smear layer; dentin conditioning; push-out bond strength

1. Introduction

Post and crown are dental rehabilitation options for dental organs extensively damaged [1]. Posts could be metallic [2], ceramic [3] or fiber reinforced composite [4]. The glass fiber posts (GFPs) are the most frequently used posts nowadays as they have elastic moduli that share similar to dentin [5,6]. In the clinic, the overall survival rate of the GFPs is 92.8% [7]. Nonetheless, GFPs present an annual failure rate after 5 years of 1.7%, mainly in consequences of root fractures and post-debonding [8]. Post-debonding occurs typically by adhesive failure between dentin-cement (25 and 80%), adhesive failure between post-cement (5 and 15%), cohesive failure with cement (10%), and mixed failure (15 and 75%) [9,10].

The smear layer (SL) is a disorganized, amorphous, and irregular structure formed by organic and inorganic components [11]. To eliminate and reach a successful penetration [12] of root canal sealant, irrigating conditioner solutions are used during the endodontic treatment [13].

During the preparation of the post space, rotary instruments are employed, this create a layer composed of root canal sealant, and gutta-percha remnants that were de-plasticized due to frictional heat generated by instrumentation [6,14] in combination with dentin [15] allowing the formation of the secondary smear layer (SSL) that can develop plugs within the dental tubules of ~40 µm length [11].

To facilitate SSL removal, conditioning solutions are employed, resulting in improvements in the surface conditioning of the intra-radicular dentin to promote adhesion, forming a hybrid layer composed of collagen fiber and resin, through the penetration of cement into dentinal tubules establishing resin tags [9,11,16–22]. Also, irrigant activation is used to enhance removal, promoting the opening of the dentin tubules by employing ultrasonic [16,23–26], laser [17,24,27–29], or sonic devices [30]. Another proposed technique is laser irradiation of the dentin surface [31] in the absence of a conditioning solution.

It is difficult to evaluate in patients if the dentinal tubule cleaning technique was successfully performed, as well as adhesion among GFPs and dentin. Thus, in vitro evaluations by scanning electron microscopy (SEM) and push-out bond strength test (POBS) are employed. The aim of this review was to compile the knowledge about in vitro studies concerning the micro-retention of the GFPs to the root canal and dentinal tubule cleaning employing different conditioning solutions with or without activation evaluated by SEM and POBS analysis.

2. Conditioning Solutions

Conditioning solutions, such as irrigating solutions in the endodontic treatment [13], induce morphological changes in the intra-radicular dentin through alterations in both superficial porosity and the diameter of the dentinal tubules [32]. These processes induce modification at collagen fibers of the dentinal wall; it also affects the calcium/phosphate ratio of the inorganic layer in the dentin, conditioning monomer penetration into the demineralized dentin [12]. These modifications can affect dentin hybridization by reducing the post-endodontic adhesive interface [13], provoking changes in adhesive system impregnation patterns, and reducing the infiltration into peritubular dentin resulting in restoration challenges for clinicians [14,33].

The use of different solutions has been implemented to improve dentin conditioning and an effective remove of the SSL throughout the space created for the fiber post; these solutions include acid solutions, that is, ethylenediaminetetraacetic acid (EDTA) [10,25,34], OA [25,30,34], maleic acid [20], and citric acid at several concentrations such as 10%, 20%, and 50% [9,25]. Also, the use of several combined solutions allows a reduction of superficial tension, facilitating irrigants contact with dentinal walls, and enhancing SSL removal [35]; some examples are MTAD [34,36,37] and Q-mix [18,24]. There activity is summarized in Table 1.

Table 1. Type of activity of conditioning solutions.

Conditioning Solution	Activity
Acidic solutions	
Ethylenediaminetetraacetic acid	Chelating agent [35,38] Removal of the SL [10,11,16,22,25,34,39]
Orthophosphoric acid	Remove the SL and open the dentinal tubules [40]
Citric acid	Demineralizing solution [18]
Maleic acid	Demineralization of the intertubular dentin [18,41]

Table 1. *Cont.*

Conditioning Solution	Activity
Prefabricated solutions	
Biopure MTAD	Antimicrobial activity [34,36] Removing inorganic compounds [41,42] Calcium chelator [41,43] Reduces the surface tension [41]
QMix	Antimicrobial activity [18,24] Chelating agent [35,38] Removal of the SL [10,11,16,22,25,34,39] Inhibit the activity of metalloproteinases [44]

2.1. Acidic Solutions

Ethylenediaminetetraacetic acid (EDTA) can dissolve and chelate inorganic material by the removal of significant amounts of calcium (Ca^{2+}) the root canal dentin [45], including hydroxyapatite, without having an effect on organic tissue [24,25] and producing dentin demineralization to depths from 20 to 30 µm [18]. Interestingly, studies using SEM have shown that 17% EDTA without activation produces a partial [16] or a complete [23] elimination of the SSL from dentinal tubules in the root canal, being an effective conditioning. The above is reflected in the POBS test, which shows a greater bond strength between resin adhesive and root canal, where the highest bond strength is found at the coronal level [10,20,22,46] in comparison with the apical [10,20,22,46,47], meaning that EDTA might not have a good action deep inside the root canal. Moreover, there is evidence that short time canal irrigation by 17% EDTA for 20 s does not cause dentin damage [10]. Nonetheless, surprising one-minute procedures can lead to dentin erosion [11], indicating that the time factor is more relevant than concentration.

Another pivotal factor is the solution form, since EDTA gel conduces to cohesive failure of a specimen cemented [46]. On the other hand, sometimes NaOCl is used as an irrigant solution with poor SSL removal [10,11,20,22,23,27,48,49]; nevertheless, when it is synergically applied with EDTA, their behavior increases from partial to complete removal of the smear layer, which was evaluated by SEM [9–11,20,27,36]. Interestingly, the results in the POBS test are lower in EDTA mixed with NaOCl at cervical, middle [6,27,28,48], and apical levels [9,28].

Orthophosphoric acid (OA) is a universal conditioner used in endodontic procedures to remove the SL, opening the dentinal tubules [40]. It can be found commercially in gel and liquid forms in a wide range of different concentrations from 5% to 37% [30,50]. This conditioner evaluated by SEM showed a good rate for removal of layers, since it acts from partial removal with the gel form [30] to partial–complete removal with the liquid form [25,30,46], alone or combined with EDTA [16]. However, despite the optimal removal of the SSL by the OA in liquid form, better results have been shown in the post adhesion to the cervical, middle, and apical portions of the root canal using the POBS test when the gel form is used compared to the liquid form [30,46].

Citric acid is a demineralizing solution that reacts with calcium ions in dentin [51]. In the endodontic therapy context, it exerts higher chelating effects than 17% EDTA when it is used at 1%, 5%, and 10% concentrations [42], even in the apical third [18]. Interestingly, when the citric acid is used at 10% during 90 s, after 60 s of 5.25% NaOCl treatment, there is a partial removal of the SSL from the root canal [9]. Also, this mixture showed similar bond strength values in the cervical, middle, and apical portions, however, these values are lower compared to bond strength values produced by the NaOCl/QMix, which showed a better adhesion to dentine; the NaOCl/citric acid mix was susceptible to present adhesive failure between the dentin and resin cement [9].

Maleic acid (MA) is a weak organic acid used as an irrigant in dentistry [18], since it produces demineralization at the intertubular dentin level resulting in a reduction of the substrate microhardness over a short period of time [18,41]. Interestingly, it has been found by SEM imaging that treatment with 7% MA for 45 s followed by the application of 2.5%

NaOCl nearly eliminates the complete smear layer, especially in the apical region, resulting in the opening of the dentinal tubules and promoting greater adhesion of the resin cement to the root canal [20], proposing that MA could facilitate an improvement in resin cement penetration into dentinal tubules.

2.2. Prefabricated Conditioning Solutions

Biopure MTAD (Dentsply Tulsa Dental Specialties) is an acidic solution, which consists of 4.25% citric acid, 3% doxycycline, and 0.5% Tween 80 mixture [52]. This solution has a pH of 2.15 and has the capacity to remove inorganic compounds, producing minimal erosive changes on the dentinal surface compared to EDTA [41,42]. It acts as a calcium chelator by the tetracycline content, a chemical chelator similar to citric acid that produces dentin demineralization [41,43]. The detergent Tween 80 produces a reduction in the surface tension of the irrigant and increases its capability to reach the apical area [41]. Altogether, this results in a partial SSL removal from the dentinal tubules, with similar bond strength values among cervical, middle, and apical section. However, it presents a 45% failure rate between resin cement and dentin [36].

QMix (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) is composed of antimicrobial agent CHX, a calcium chelating agent EDTA, saline solution, and cetrimide [53]. It has a slightly alkaline pH, and its use is recommended after NaOCl application during root canal instrumentation due to its effectiveness in SL removal [45]. Additionally, antibacterial activity has been reported [9,54]. QMix was designed as a final irrigant in endodontic treatment to replace the 17% EDTA irrigation protocol [55], and its use has been proposed for post space preparation cleaning due to its capability of inhibiting the activity of metalloproteinases (MMP), such as MMP-2, -8, and -9 [44]. This action is due to the presence of CHX, which prevents decomposition of the hybrid layer and decalcification of the intra-radicular dentin [24]. Interestingly, using SEM, a complete elimination of the SSL and debris have been reported with QMix irrigation, opening dentinal tubules [22]. The above can be associated with the promotion of the bond strength of glass fiber posts to root dentine with or without 5.25% NaOCl before irrigation of QMix. However, higher bond strength values are found in the cervical compared to apical position, suggesting that the improvement of adherence is more in the shallower regions of the canal root [9,22]. The results of smear layer removal with different conditioning solutions are summarized in Table 2, and of push-out bond strength test in Table 3.

Table 2. Results of the smear layer removal by conventional dentin conditioning with or without sonic or ultrasonic irrigant activation and dentin conditioning with laser.

Conventional Dentin Conditioning			
Protocols		**Secondary Smear Layer Removal**	**Reference**
17% EDTA		Partial–Complete	[11,22,23,42,56]
17% EDTA (Gel)		Without Removal	[46]
37% phosphoric acid liquid		Partial	[30]
35–37% phosphoric acid gel		Partial–Complete	[25,30,46]
7% maleic acid		Complete	[20]
MTAD		Partial	[36]
NaOCl		Without removal–Partial	[6,7,16,18,19,23,37,45]
	17% EDTA	Partial–Complete	[9–11,20,27,36]
	10% citric acid	Partial	[9]
	Qmix	Complete	[9,22]
17% EDTA	**37% phosphoric acid liquid**	Partial	[16]

Table 2. *Cont.*

Dentin conditioning with sonic or ultrasonic activation			
Protocols		**Secondary smear layer removal**	**Reference**
17% EDTA		Partial–Complete	[16,23]
37% phosphoric acid gel		Complete	[30]
37% phosphoric acid liquid		Partial–Complete	[16,30]
10% citric acid		Partial	[25]
2.5–3% NaOCl		Without removal–Partial	[25]
2.5% NaOCl	**17% EDTA**	Partial–Complete	[23,25]
17% EDTA	**37% phosphoric acid liquid**	Complete	[16]
Dentin conditioning with laser			
Protocols		**Secondary smear layer removal**	**Reference**
Er: YAG	**17% EDTA**	Complete	[48]
Er: YAG	**MTAD**	Complete	[36]
Er: YAG		Little waste—Partial	[29,36]
Er: YSGG laser		Partial	[29]
Diode		Partial	[27]

Table 3. Results of push-out bond strength test (POBS) of fiber posts applied in root dentin treated with conditioning solutions with or without sonic/ultrasonic activation. (N/D: no data).

Conditioning Solutions	**Type of Activation**		
	Convetional (MPa)	**Sonic (MPa)**	**Ultrasonic (Mpa)**
17% EDTA		**Cervical**	
	10.7–18.63 [10,20,22,46]	N/D	N/D
		Middle	
	11–12. [20,22,46]	N/D	N/D
		Apical	
	8.3–13.49 [10,20,22,46]	N/D	N/D
		Mean	
	10.9–49.08 [34,46]	N/D	N/D
5.25% NaOCl followed by 17% EDTA		**Cervical**	
	5.54–14.9 [9,27,28,48]	N/D	6.95–13.91 [17,28]
		Middle	
	3.65–14.9 [9,27,28,48]	N/D	12.98 [28]
		Apical	
	4.34 [9,28]	N/D	4.96–8.66 ± 1.55 [17,28]
		Mean	
	5.54–11.07 [27,28]	N/D	5.96–11.85 [17,24,28]

Table 3. *Cont.*

Conditioning Solutions	Type of Activation		
	Convetional (MPa)	**Sonic (MPa)**	**Ultrasonic (Mpa)**
Orthophosphoric acid		**Cervical**	
	Gel 8.8–19.1 [30,46] Liquid 6.9 [30]	Gel 7.0 Liquid 9.5 [30]	N/D
		Middle	
	Gel 4.1–21.0 [30,46] Liquid 3.3 [30]	Gel 4.5 Liquid 6.0 ± 1.5 [30]	N/D
		Apical	
	Gel 2.0–18.6 [30,46] Liquid 2.2 [30]	Gel 2.1 Liquid 3.7 [30]	N/D
		Mean	
	Gel 13.2–53.1 [34,46]	Gel 4.6 Liquid 6.2 [30]	N/D
NaOCl 5.25% + citric acid 10%		**Cervical**	
	5.25 [9]	N/D	N/D
		Middle	
	3.79 [9]	N/D	N/D
		Apical	
	4.34 [9]	N/D	N/D
		Mean	
	N/D	N/D	N/D
Maleic acid		**Cervical**	
	12.58 [20]	N/D	N/D
		Middle	
	11.91 [20]	N/D	N/D
		Apical	
	10.80 [20]	N/D	
		Mean	
	N/D	N/D	N/D
Biopure MTAD		**Cervical**	
	11.8 [36]	N/D	N/D
		Middle	
	10.87 [36]	N/D	N/D
		Apical	
	8.47 [36]	N/D	N/D
		Mean	
	10.48–52.47 [34,36]	N/D	N/D
Qmix		**Cervical**	
	8.10–19.0 [9,22]	N/D	N/D
		Middle	
	6.22–15.4 [9,22]	N/D	N/D
		Apical	
	5.92–10.3 [9,22]	N/D	N/D
		Mean	
	N/D	N/D	8.81 [20]

3. Sonic Methods for the Irrigation Solution Activation

Several methods, including the agitation of irrigants with ultrasonic metal tips or non-metallic sonic tips, have been studied with the aim to improve SL removal after post space preparation. Some of the most employed methods are described below.

3.1. Sonic Activation

This device consists of the use of a non-cutting flexible polyamide tip attached to a handpiece, transmitting energy to the irrigating solutions, creating pressure waves, shear forces, and microscopic bubbles [57]. These actions push the solution against the root dentinal surfaces promoting the SSL removal [30]. Mechanically, this method induces oscillation, especially at the file tip, with a frequency ranging from 1 to 8000 Hz [58,59]. Interestingly, comparing the sonic activation of phosphoric acid in gel or liquid forms results in a better removal of the SSL and a great opening of the dentinal tubules than when it is applied without activation. Despite this, the liquid form with sonic activation presents the highest bond strength value compared to the gel form, which leads to a better bonding of fiberglass posts to root canals [30].

3.2. Passive Ultrasonic Irrigation

Passive ultrasonic irrigation (PUI) is the ultrasonic activation of irrigant solution in the root canal that is transmitted through a small ultrasonic oscillating metal file that is placed inside the root canal [28]. It operates at a frequency ranging from 40,000 to 45,000 Hz that generates a microcurrent along the file [58,59]. This technique consists of energy released by the instrument, which leads to an improvement in the physicochemical properties of the irrigation solution as a result of the agitation, the transmission of acoustic waves, and formation of bubbles due to the cavitation phenomena, which detonates and produces temperature increasing and whose pressure results in shock waves against the root canal wall [23,58]. The SSL removal process occurs through the continuous flow of the irrigation solution, which promotes efficient cleaning of the debris inside the root canal [12]. Interestingly, using SEM indicated that irrigation with 17% EDTA for 15 s with ultrasonic activation and subsequent etching with phosphoric acid 37% liquid with ultrasonic activation improves the SSL removal from the root canal compared with other irrigant solutions such as EDTA alone, 37% orthophosphoric acid, or EDTA + 37% orthophosphoric a without activation [16]. Also, 10% acid citric followed by 2.5% NaOCl and ultrasonic activation for 1 min each, could remove the SSL after post preparation, showing an improved removal of the SSL throughout the canal, compared to 17% EDTA, liquid 36% OA, and 5.25% NaOCl [18,25]. However, it has been reported that this effect is not observed if the solutions are used in a different sequence [9], since when 5.25% NaOCl for 60 s followed by 10% citric acid for 90 s is used led to a partial removal of the SSL throughout the root canal [9]. Interestingly, other authors suggested that ultrasonic activation does not improve the removal of the SSL effects of several conditioning solutions, proposing that the use of EDTA alone works better than when activated [23]. In addition, the root canals irrigated with 2.5% NaOCl and 17% EDTA do not improve the bond strength values compared to other techniques such as PIPS [17,28]. Results of smear layer removal of solution activation are summarized in Table 2, push-out bond strength test results are in Table 3.

4. Laser Methods for the Activation of the Irrigation Solution

The removal of the SL through laser-induced cavitation bubbles has been studied for cleaning dentinal surfaces [60]. The laser-activated irrigation technique (LAI) consists of the formation of cavitation phenomena and acoustic transmission in the intracanal irrigation, producing photomechanical effects [11,61]. Currently, several types of lasers have been studied which promote dental conditioning through the activation of irrigating agents or dentin irradiation. Only lasers that cause activation of conditioning agents after post space preparation are described below.

4.1. Er: YAG and PIPS

Erbium: yttrium–aluminum–garnet laser (Er: YAG) (2940 or 2780 nm) uses a fiber tip when it is in contact with the solution and produces a small explosive boil forming cavitation bubbles due to the laser being highly absorbent in water, causing an approximately 1 to 3 μm in penetration depth [60], that effectively removes the smear layer, creating a rough and porous surface in root dentin [36,62]. In recent years, a new technique called photon-induced photoacoustic streaming (PIPS) was invented, in which Er: YAG laser is used with sub-ablative energy (20 mJ, 15 Hz) and ultra-short pulses (50 μs), which leads to intracanal cavitation and shockwaves as a result of photoacoustic and photomechanical effects [63,64]. In this technique, PIPS-specific laser tips remain at the root canal entrance [64], and then short low-energy laser bursts are directed into the canal to propel irrigants throughout the canal system [60]. The photoacoustic shock waves in the PIPS technique allows the irrigant to flow in three-dimensional (3D) directions, resulting in a deeper cleaning of the entire root canal system [63]. The abovementioned has been confirmed by SEM, since activated 17% EDTA as well as MTAD using PIPS promoted SSL whole removal, resulting in the opening of dentinal tubules [36,48]. Additionally, the use of Er: YAG laser activation using a wavelength of 2940 employing 1000 μs pulse and 50 mJ at 10 Hz (average power, 0.5 W) does not show high bond strength values of the post in the cervical and apical positions, however, PIPS laser-activated irrigation showed higher efficiency, avoiding failures [17,48].

4.2. Nd: YAG Laser

Neodymium-doped yttrium aluminum garnet laser (Nd: YAG) works at a power of 1064 nm [65] and has been shown to be effective for SL removal during root canal treatment, even with better results when working at a power of 1320 nm [66]. Interestingly, the protocol of 3 mL 2.5% NaOCl, followed by 3 mL 17% EDTA with activation of both by Nd: YAG laser showed that bond strengths in both the coronal and apical region values do not improve compared to other types of laser activation such as PIPS [17,28].

4.3. Er, Cr: YSGG

Erbium, chromium: yattrium–scandium–gallium–garnet laser (Er, Cr: YSGG) uses sapphire optical fibers with different thicknesses, that can be applied for different morphologies of root canals [31]. It is used at a wavelength of 2780 nm and interacts with water and hydroxyapatite, producing tissue breakdown in an explosive process, resulting in tissue elimination and any contaminants, such as the SSL [65]. In addition, it has the capability of opening dentin tubules, increasing dentin permeability [31], and favoring the penetration of the sealing materials [65]. It has been found that Er, Cr: YSGG laser at a frequency of 20 Hz leads to improvement in the exposure of dentinal tubules by ablation of the dentin surface of the root canal after post space preparation [31]. Curiously, non-significant effects on the bond strength values were found when EDTA was activated by Cr: YSGG laser, as well as poor information evaluating this laser in this context [49].

4.4. Diode Lasers

Diode lasers have thin optical fibers that can transmit energy throughout the root canal, including very narrow areas [49,61]. The working wavelengths of this laser are 635 and 980 nm [62] and can produce a modification of the topography and composition of the dentin [31]. The power output of this laser varies from 0.5 to 7 W, and it can be used with different operating modes, such as continuous wave, pulsed power, and cut mode [59]. Interestingly, 3 mL 2.5% NaOCl, followed by 3 mL 17% EDTA, both activated by diode laser, showed that bond strengths in both the coronal and apical region values do not improve compared to other types of laser activation such as PIPS [17]. Results of POBS analysis of irrigations solution activated by lasers are summarized in Table 4.

Table 4. Range of results of POBS analysis in fiber posts applied in dentin treated with different lasers to activated NaOCl, ethylenediamenettraacetic acid (EDTA), MTAD, and 5.25% NaOCl + 17% EDTA. (N/D: no data).

Diodo Laser (MPa)	Nd: YAG (MPa)	Er: YAG (MPa)	PIPS (MPa)	Er, Cr: YSGG (MPa)
		Cervical		
5.25 [17]	6.15–13.14 [17,28]	6.54 [17]	8.40–17.7 [17,41]	5.02 [49]
		Middle		
N/D	12.28 [17,28]	N/D	16.7 [41]	5.38 [49]
		Apical		
4.62 [17]	5.03–9.47 [17,28]	5.04 [17]	6.21 [17]	4.03 [49]
		Mean		
4.94 [17]	5.59–11.63 [17,28]	5.79 [17]	7.31 [17]	N/D

5. Pre-Treatment Laser Irradiation to Dentin Methods

Nowadays, several authors recommend the use of high-power lasers to pre-treat the dentin before the cementation of a fiber post to improve adhesion [31,67]. However, it can be concluded that dentin surface treatment requires further research to choose the most appropriate method that does not endanger the retention of fiber posts through laser irradiation [49]. Interestingly, dentin pre-treated with Er: YAG, Er: YSGG, and diode lasers promote SSL partial removal [27,29,36]. Specifically, in Er: YAG laser irradiation to dentin showed similar bond strength, compared to a group in which the dentin was treated with other lasers or irrigants [29,68]. Additionally, controversy has been reported with the direct application of Er, Cr: YSGG laser to dentin since non-significant and significant differences in the bond strength values have been reported in comparison to non-irradiated and irradiated samples of other lasers such as Er: YAG [29,31,69]. Also, irradiation dentin with a diode laser with a wavelength of 830 nm showed better results compared to the non-irradiated groups in the bond strength values [27,70]. This improvement can be attributed to the elimination of the SL and the remaining gutta-percha layer in the post space preparation in addition to the removal of the endodontic sealants at the dentinal root canal surface [70]. Results of POBS analysis of dentin irradiation by lasers are summarized in Table 5.

Table 5. Range of results of POBS tests of fiber posts in dentin irradiated by different lasers and output power. W: Watts; N/D: no data.

Er.Cr: YSGG (Mpa)	Er.YAG (MPa)	Diode Laser (MPa)
	Cervical	
1 W–2 W = 15.17 [69]	N/D	5.72 [27]
	Middle	
1 W–2 W = 10.86 [69]	N/D	3.37 [27]
	Apical	
1 W–2 W = 12.20 [69]	N/D	N/D
	Mean	
1 W–2 W = 4.86–12.72 [29,69]	3.90–9.91 [29,68]	4.61 [27]

6. Discussion

Endodontically treated teeth present high levels of structural destruction, which implies, in some cases, the rehabilitation with fiber posts and crowns. It has been observed that one of the main failures is the post-dislodging from the root canal, therefore, it is extremely important to perform pre-treatment of the root dentin with several conditioning techniques that allow the infiltration of the adhesive monomers into the dentinal tubules.

Interestingly, irrigation of 17% EDTA during 20 s promoted higher bond strengths [10]. However, increasing time > 1 min leads to dentin erosion [11], thus, the time factor is critical for maintaining of the dentin structure. On the other hand, combination of EDTA with 5.25% NaOCl facilitates SSL elimination from the root canal [11,27], but NaOCl followed by EDTA can produce great erosion of dentin [39], since NaOCl decomposes into sodium chloride and oxygen. The release of oxygen inhibits the polymerization of resinous adhesive materials, which interferes with the infiltration of resin in the demineralized dentinal tubules, creating a greater probability of debonding of the post from the root canal [10,27,71]. Another conditioning with a high impact on dentin is OA, which demineralizes inter- and peritubular dentin [72], and its etching capacity depends on its ability to fully infiltrate root dentin irregularities [30]. Several difficulties have been described with the use of this conditioning due to its presentation since it can be found in liquid and gel forms. The gel form enhances dentin conditioning due to its viscosity promoting adhesion of the post. Also, this form allows a better control of its application [30,73]. However, it has been shown that the OA in the gel cannot be thoroughly eliminated in the apical third, influencing cement adhesion [50], unlike the liquid form, which allows deeper penetration and leads to an improvement in the acidic conditioning due to its lower viscosity, higher wettability, and lower surface energy compared to the gel form [28,73]. Despite the abovementioned, the liquid form with sonic activation promotes better adhesion to fiberglass posts to root canals compared to the gel form [30].

Interestingly, sonic devices present some advantage such as they do not cause involuntary removal of dentin by their plastic tips [58], however, some sonic devices operate on low power [74]. Nevertheless, ultrasonic devices are more powerful than sonic ones [47]; however, during PUI in ~20% of the time, the oscillating metal file is used and comes into contact with the root canal walls, producing an inadvertent removal of small amounts of dentin and resulting in the deformation of the root canal morphology [56,58]. Also, the reach of this technique is limited in curved canals due to the ultrasound instrument being less likely to oscillate freely [75].

Moreover, it has been suggested that LAI activation has a thermal effect on the fiber head in the root canal, with a melting potential and fusing effect on the root canal wall, producing thermal damage in the tissue [67]. Additionally, some LAI activation could produce carbonization and cracks on the root canal walls when the laser tips are used for root canal preparation [76]. For the abovementioned, PIPS has some advantages, such as this technique generates a minimal thermal effect [63]. Even NaOCl/EDTA combination without activation could be better in promoting bond strength of the fiberglass post versus NaOCl/EDTA activation by PUI and LAI [28].

Additionally, controversy has been reported with direct dentin irradiation, since some results showed an improvement in the adhesion of the fiberglass post to dentin [29]; however, not all research is conclusive about this improvement [69].

7. Future Directions

The success of the restoration on endodontically treated teeth with fiber posts depends on several factors and/or conditions, such as the length and type of post, remaining dental tissue, quality of the hybrid layer, and chemical compatibility between adhesive systems and resin cements. A bond results between the post and the root canal mainly due to the micromechanical retention of the post/cement/dentin interface through the hybrid layer, allowing penetration of the resin in the dentinal tubules and exposure of the collagen fibers.

It is crucial that the conditioning agent presents optimal properties such as compatibility with the dental structure to ensure optimal adhesion, demineralizing properties to remove the SSL and expose the dentin collagen structure, and it must have the ability to penetrate the dentinal tubules to provide a rough and smooth surface, increase adhesive retention, preservation of the tooth structure, and adhesive compatibility [77–79]. The abovementioned is difficult to ensure in only one agent, therefore, improvement by other techniques are necessary. However, the study of these improvements is challenging in vivo, hence, the analysis in vitro is the best option to evaluate them, for example, by SEM and POBS. Nevertheless, another poorly used technique that could be performed is atomic force microscopy.

In addition to the removal of the secondary smear layer, another factor that can affect the fiberglass post adhesion to dentin could be the presence of the metalloproteinases, which have been poorly evaluated, therefore, are a possible future aim to study.

8. Conclusions

Our results of the literature review showed that the best conditioning solution of dentin without activation is 17% EDTA. Until now, no research has been performed to evaluate its application with sonic or ultrasonic activation. For the abovementioned, it is necessary to enlarge the information using these devices, to elucidate if their application improves the fiberglass post adhesion. In addition, when using LAI to activate the solution, the employment of PIPS was the technique with better results. In the case of dentin irradiated by laser, any of these showed promising results. The above mentioned are recommendations based on in vitro studies, hence, we recommend linking this information with clinical studies in the future.

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