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EFFECT OF 4 TYPES OF ROOT CANAL IRRIGATION SOLUTIONS ON THE BOND STRENGTH OF RESIN CEMENTS TO RADICULAR DENTIN: A REVIEW ARTICLE

SINA SAFARI[1], FERESHTEH HOSEINI[2*], MARYAM VOSSOGHI SHESHKALANI[3], ZAHRA AHMADI[4]

1: Department of Prosthodontics, Dental School, kerman University of Medical Sciences, Kerman, Iran. Tel:+98-034-32440400 Email: safari.sn@gmail.com

2: Resident, Depattment of Prosthodontics, Dental School, kerman University of Medical Sciences, Kerman, Iran. Tel: +98-034-32119021 Email: fereshteh.hoseini7@gmail.com

3: Resident, Department of Prosthodontics, Dental School, kerman University of Medical Sciences, Kerman, Iran. Tel: +98-034-32119021 Email: Maryam_vossoghi2003@yahoo.com

4: Resident, Department of Prosthodontics, Dental School, Mashhad University of Medical Sciences, Mashhad, Iran. Tel: 0936 078 7268 Email: Sara.ahmadi591@gmail.com

***Corresponding Author: Resident, Depattment of Prosthodontics, Dental School, kerman University of Medical Sciences, Kerman, Iran. Tel: +98-034-32119021 Email: fereshteh.hoseini7@gmail.com**

ABSTRACT

Statement of problem: Various Root canal irrigation solutions are used during root canal therapy and post space preparation. These chemical agents can affect the bond strength of adhesive cements to root dentin**.**

Objective: The aim of this review article was to evaluate the effect of root canal irrigation solutions on the bond strength to root dentin.

Methods: An electronic search was run in the Pubmed and Google Scholar databases. The key words used in the research were chemical irrigants, chlorhexidine, bond strength and endodontic posts. The abstracts of the articles were read thoroughly by a reviewer. The inclusion criterion was data published from 2000 to 2014 in English language that used conventional irrigants during root canal therapy and post space preparation.

Results: 50 articles were selected for the full text evaluation, after which 19 articles were selected and their results were collected in this review. The results of articles were categorized in 4 groups of chlorhexidine, sodium hypochlorite, ethanol and ethylene Diamine Tetracetic Acid (EDTA).

Conclusion: Bond strength to root dentin is affected by the type of irrigation solutions, their concentrations and the type of the resin cement and bonding agent used. Pretreatment with chlorhexidine often can preserve the bond strength to root dentin. It is recommended to use irrigants which don't remove the smear layer completely while cementing a post with self-etch resin cement.

Keywords: Chemical irrigants, Chlorhexidine, Sodium hypochlorite, Bond strength, Endodontic posts

INTRODUCTION

Endodontically treated teeth that have lost their coronal structures require radicular posts for the restoration of their function [1-2]. An increase in the demand for esthetic posts has resulted in the development of metal-free post-and-core systems, especially zirconium dioxide and fiber posts [3]. Fiber posts have many advantages, including mechanical properties similar to those of dentin, biocompatibility, resistance to corrosion and improved light conductivity [4].

Prefabricated fiber posts are used with resin cements in order to improve the fracture resistance of endodontically treated teeth [4]. Adhesion between the resin and dentin is still a great challenge which is attributed to the high C-factor within the root canal, limited visibility and access, control of moisture and deposition of cementum and secondary dentin [5]. The most important factors affecting the durability of the bond between the resin and dentin are explained by hydrolytic degeneration of the cured resin through water sorption [6], incomplete penetration of resin monomers into the collagen network [7], incomplete replacement of free water, a weak bond with collagen fibrils and degeneration of collagen by endogenous matrix metalloproteinases (MMPs) in the aged bonded dentin [8].

Use of disinfecting agents or medications during preparation of root canals can affect the bond strength to root dentin [9-10-11]. When the post space is being prepared, the drills create a new smear layer, which is rich in gutta-percha and sealer [5]. The best technique to move the residual tissues and

dentin debris produced during preparation procedures is the use of irrigation solutions [12]. Irrigation removes loosely attached, necrotic and contaminated debris before they are inadvertently pushed deeper into the root canal or into the periapical tissues [12-13]. In addition, irrigation procedures provide lubrication, destroy bacteria and dissolution tissues [12]. Various irrigation solutions are used to irrigate root canals, including chlorhexidine (CHX), sodium hypochlorite, normal saline solution, ethanol and Ethylene Diamine Tetracetic Acid (EDTA).

The adhesive system used for the bonding procedure is very important [4]. The adhesives are divided into two groups based on the etching system used: the self-etch system which contains both acidic and hydrophilic monomers and does not require irrigation after the etching procedure, and the etch-and-rinse system, in which the acidic monomer and the boding system are used separately [4-14].

In the articles reviewed in the present study, the teeth have been prepared using two techniques for the evaluation of the effect of irrigations on the bond strength to root dentin. In some studies in which fiber posts have been used, post space has been prepared and the root canals have been sectioned after irrigation of the root canals and boding of fiber posts to the roots, followed by push-out or microtensile tests [4-15-16-17]. In some studies, instead of using a post, the post space has been filled with resin cements in order to evaluate the bond strength of cement to dentin without complicated bonding to posts compared to bonding to dentin [9-18-19-20].

The aim of the present literature review was to evaluate the effect of intracanal irrigation solutions on the bond strength to radicular dentin.

MATERIALS AND METHODS

Data were collected by running a research in the electronic databases of Pubmed and Google Scholar. The key terms used for search consisted of chemical irrigants, medications for root canal treatment, chlorhexidine, sodium hypochlorite, bond strength and endodontic post. The abstracts of the articles were read by a reviewer. The inclusion criterion was data published from 2000 to 2014 in English language that used conventional irrigants during root canal therapy and post space preparation. 50 articles were selected for full text evaluation after which, 19 articles that specially assessed Effect of Root Canal Irrigation Solutions on the Bond Strength of resin cements to Radicular Dentin were selected and their results were collected in this

review. It is beneficial in dental practice to realize what irrigation solution is most compatible with a specific adhesive system.

RESULTS

The root canal irrigation solutions are inspected within 4 categories based on their chemical compositions: chlorhexidine gluconate, sodium hypochlorite, ethanol and EDTA. Studies on each group are assessed separately.

Chlorhexidine

Chlorhexidine gluconate can be absorbed into dentin and prevent microbial colonization on the dentin surface for some time [21-22]. In adhesive restorations, the main problem is the degradation of the hybrid layer. Loss of the bond strength affects the longevity of the restoration [23-24]. Matrix metalloproteinases (MMPs) have been identified in the coronal and radicular dentin [25-26]. Their activation result in the destruction of the organic matrix along the bonded interface of resin and dentin [27]. Previous studies have shown that the improvement in the long-term stability of the hybrid layer and the bond strength with the use of CHX is due to the inhibition of MMPs by CHX [27-28].

In a study by Cecchin et al, the effect of CHX and ethanol on the bond strength of fiber posts to root dentin was evaluated [27]. In this study, 2% CHX gel was used for 5 minutes and 100% ethanol was used for one minute in two different groups. In another group both methods were used respectively for the irrigation of the root canals. RelyX ARC resin cement and Clearfil SE Bond self-etch bonding agent was used. The use of CHX and/or ethanol preserved bond strength in the groups stored in water and oil for 12 months [27].

In another study by Da Silva et al, carbon fiber posts and 4 different irrigation solutions were used along with post space drills, which consisted of normal saline as a control, 2% CHX gel, a combination of NaOCl and EDTA, and xylene [21]. Hi-X resin cement and All Bond 2 bonding agent were used to bond fiber posts. The CHX and xylene groups exhibited higher mean bond strength, with no significant differences between them [21]. It can also be concluded that complete removal of the smear layer by EDTA has a detrimental effect on the bond strength to root dentin.

In a study by Lindblad et al three types of resin cements were used; one of them was the RelyX Unicem self-etch system and the other two were Duo-Link and All Bond 2 etch-and-rinse system [29]. In this study, 2% CHX was used for 60 seconds. The groups irrigated with CHX exhibited higher bond

strength with all the three cement systems compared to the control group. Therefore, CHX does not have a detrimental effect on the push-out bond strength of posts cemented to root dentin and can be used as a final root canal irrigation solution [29].

In a study by Erdemir et al, 5% NaOCl, 3% H_2O_2, 0.2% CHX and a combination of NaOCl/ H_2O_2 were used [12]. Treatment with NaOCl and H_2O_2 and their combination decreased the bond strength to root canal dentin significantly which might be attributed to the release of oxygen as a result of the chemical reaction between NaOCl and H_2O_2, which strongly inhibits polymerization at interfacial areas of the resin-dentin. The teeth treated with CHX exhibited the highest bond strength [12].

In another study by Cecchin et al in September 2011 as a follow-up for the study carried out by the same authors in May 2011 [27], all the procedural steps were similar to previous study except for the fact that Scotch Bond Multi-purpose total-etch bonding system was used [30]. Irrigation with CHX resulted in the preservation of the bond strength in short and long term. However, irrigation with physiologic serum and ethanol, either alone or in combination with CHX, resulted in a significant decrease in bond strength in long term, contrary to the previous study by Cecchin et al [30]. Therefore, pretreatment with chlorhexidine can preserve the bond strength to root dentin with the total-etch adhesive system [30]. Pretreatment with CHX in the previous study, too, preserved the bond strength.

Contrary to the above study, in a study by Leitune et al, CHX did not preserve the bond strength after long-term storage [31]. In this study 0.2% CHX and 2% CHX were used [31]. Scotch Bond Multi-purpose Plus etch-and-rinse bonding system and RelyX ARC dual-cured resin cement were used for the cementation of fiber posts. In the etch-and-rinse systems, root canal irrigation solutions are used after etching. Based on the results, the bond strength in all the groups was higher after 24 hours compared to those after 6 months. There were no significant differences between the groups with the same storage periods. In other words, CHX cannot prevent the decrease in bond strength after 6 months [31]. Differences in the results of different studies might be attributed to differences in bonding systems, resin cements and sample storage periods.

The results from this section has been summarized in table1.

Table 1: Studies which have evaluated the effect of CHX on bond strength

author	year	irrigant	Bonding agent	result
erdemir	2004	5% NaOCl 3%H2O2 0/2%CHX NaOCl+H2O2	C&B Metabond	CHX exhibit the highest and NaOCl+H2O2 shows the lowest bond strength
Dasilva	2005	2% CHX NaOCl+EDTA Xylene	Hi-X cement All Bond 2	EDTA removes the smear layer and reduces bond strength contrary to CHX or Xylene
lindblad	2010	CHX	Rely-X Unicem All-Bond 2 Duo-Link	All Case groups exhibit higher bond strength than control groups
leitune	2010	2% CHX 0/2% CHX	Scotch Bond multipurpose Rely-X ARC	CHX doesn't prevent long term decrease in bond strength
ceccin	2011	CHX Ethanol	Rely-X ARC Clear-fil SE Bond	Use of CHX and/or Ethanol preserve the bond strength after 12 months storage
cecchin	2011	CHX Ethanol	Scotch bond multi-purpose	Irrigation with CHX preserve the bond strength in long term

Sodium hypochlorite

Sodium hypochlorite (NaOCl) is the most commonly recommended root canal irrigation solution due to its dissolving capacity and wide-spectrum antimicrobial activity [32-33]. It removes the organic components of dentin, leaving a clean surface [34]. In addition, it decreases the surface tension of materials and improves the wettability of dentin [35]. On the other hand, elimination of the organic components, especially collagen, by NaOCl might affect the bond strength to dentin [9].

In addition, NaOCl can disintegrate into sodium chloride and oxygen and the released oxygen results in the inhibition of the interfacial polymerization of resin bonding agents[36]. Production of oxygen bubbles at resin-dentin interface can also interfere with the penetration of resin into tubular and intertubular dentin [9]. In a study by Ari et al, 4 adhesive systems were used: three of them were dual-cured, consisting of Panavia F, Variolink II and RelyX, and one of them was C&B Metabond self-curing adhesive system. In each adhesive system, half of samples were irrigated with NaOCL 5% and the other half was irrigated with water. The post space was filled with resin cement. In NaOCl groups, the bond strength of self-curing bonding agents was significantly higher than other groups [9].

In a study by Pelegrine et al, the effects of different concentrations of NaOCl (1.5%, 2.5% and 5.25%) were compared with 2% CHX [37]. Clearfil SE Bond self-etching

bonding agent and the RelyX ARC resin cement were used. No significant difference was observed among the groups. Lack of significant difference might be attributed to utilization of a self-etch system which renders the dentin less permeable to bonding agents and thus reducing the effect of remaining irrigants within dentinal tubules [37]. As a supplement to the above study, Bitter et al carried out a study, in which NaOCl was used at different concentrations of 1% and 5.25% in addition to NaOCl with EDTA with an ultrasonic device, , in comparison to 2% CHX. The positive aspect of the study was that three different adhesives were used for cementation of fiber posts: AdheSE DC self-etch, Smartcem self-adhesive and XP Bond etch-and-rinse systems. Use of 18% EDTA and 5.25% NaOCl resulted in an increase in the bond strength of self-adhesive resin cement and a decrease in the bond strength of etch-and-rinse adhesive systems. Therefore, each adhesive strategy might require adaptation of a specific irrigation protocol [38].

Morris et al carried out a study to evaluate the oxidative effect of NaOCl and the methods that can neutralize such effect [34]. They used normal saline, NaOCl, RC Prep, 10% ascorbic acid (pH=6) and 10% sodium ascorbate (pH=7) to irrigate root canals in different groups. All root canals were obturated with a self-cuing cement (C&B Metabond). 5% NaOCl and RC Prep decreased the bond strength noticeably; the decrease in bond strength was neutralized by ascorbic acid or sodium ascorbate. However, sodium ascorbate was more effective in restoring the bond strength compared to ascorbic acid. It should be pointed out that these results were achieved with a self-curing bonding agent [34]. The decrease in bond strength by RC Prep was attributed to the presence of oxygen in RC Prep, which results in the oxidation of collagen and a disturbance in polymerization; it is difficult to remove it from the root canal space by rinsing [34].

In a study by Demiryurek et al, 5% NaOCl was used in the control groups and in all the other groups an irrigation solution was used, followed by use of 5% NaOCl [4]. The case groups based on the irrigation solutions used consisted of Sikko Tim (ethanol, ethylene acetate and the cleansing agent, acetone) for 15 seconds, 17% EDTA for 60 seconds, 37% orthophosphoric acid for 15 seconds and 10% citric acid for 15 seconds [4]. The fiber posts were cemented with the use of Panavia F dual-cured resin cement and a self-etch bonding system. The highest bond strength was recorded in the Sikko Tim group [4]. However, it was unable to effectively remove

the smear layer and residual layer from the radicular dentin surface [4]. When the self-etch cement system is used, the elimination of the smear layer and opening of the dentinal tubules is not recommended [4]. The lowest bond strength was recorded in the control and 17% EDTA groups [4].

In a study by Mayhew et al, the effects of four different types of irrigation solutions were evaluated on the retention of Dentatus posts cemented with the use of Panavia F self-etch resin cement [39]. The irrigation solutions were used in a combined pattern. Combinations of normal salin/NaOCl, normal saline/citric acid/NaOCl, and normal saline/phosphoric acid/ NaOCl were used. The results showed that irrigation of the root canal with citric acid or phosphoric acid resulted in the highest bond strength [39]. The results of the study conflicted with those reported by Demiryurek, and etching of the root canal space before using a self-etch cement was recommended [4]. In mayhew study, there was no mention of the duration of the application of citric acid and phosphoric acid and it was reported that only 2 mL of acid were used for root canal irrigation. This amount of acid might not be able to completely eliminate the smear layer. The results from this section has been summarized in table 2.

Table 2: Studies which have evaluated the effect of NaOCl on bond strength

author	year	irrigant	Bonding agent	result
May hew	**2000**	**Saline/NaOCl Saline/citricacid/NaOCl Saline/H3PO4/NaOCl**	**Panavia F self-etch**	**Irrigation with citric acid or phosphoric acid renders a higher bond strength**
Morris	**2001**	**Saline NaOCl RC prep 10% Ascorbic acid 10% Sodium Ascorbate**	**C&B MetaBond**	**Ascorbic acid and sodium ascorbate increase the bond strength**
Ari	**2003**	**5% NaOCl water**	**Rely-X Variolink II Panavia F C&B Metabond**	**In NaOCl group a higher bond strength was observed in the self-cure system**
Demiyurek	**2009**	**5% NaOCl Sikko Tim 17% EDTA 37%Orthophosphoricacid 10% citric acid**	**Panavia F self-tch**	**Sikko Tim and EDTA showed the highest and lowest bond strength respectivly**
Pelegrin	**2010**	**1.5% NaOCl 2.5% NaOCl 5.25% NaOCl 2% CHX**	**Clearfil SE bond Rely-X Arc**	**No signicant difference was observed among the groups**
Bitter	**2013**	**1% NaOCl 5.25% NaOCl NaOCl/EDTA 2% CHX**	**Adhe SE DC Smart Cem XP Bond**	**Use of NaOCl/EDTA Results in a higher bond strength in Self-etch groups**

Ethanol

The bonding process within the root canal might be disrupted by insufficient control of moisture and inadequate visibility, especially after irrigation of the root canal with water [5]. Water might remain within the dentinal tubules and disrupting the bonding to root canal dentin and increasing the hydrolytic degeneration of the adhesive-dentin interface [5]. Inadequate control of moisture in the depth of the root canal might be compensated with the use of ethanol [40]. Ethanol makes the collagen matrix more hydrophobic. In addition, ethanol wet bonding results in less leakage at the hybrid layer compared to water wet bonding [5-41].

In a study by Ertas et al, a number of root canal irrigation solutions were used alone or in combination: ethanol, NaOCL, CHX, NaOCl/EDTA, NaOCl/EDTA/CHX, NaOCl/EDTA/ethanol, NaOCl/EDTA/PAD solution [42].

PAD solution or photo-activated disinfectant was injected into the root canals with an endodontic needle and cured for 20 seconds. A dual-cured resin cement was used for the cementation of fiber posts. The highest and lowest bond strength values were recorded in the ethanol and NaOCl/EDTA groups, respectively [42]. A combination of PAD and NaOCl/EDTA did not affect the bond strength [42]. This study suggested ethanol as the final irrigation solution.

In a study by Cecchin et al in May 2011 [27], as referred to in the section on CHX, the bond strength in the CHX and ethanol groups was preserved after 12 months of storage in water and oil [27]. However, in the study carried out by Cecchin et al in September 2011, ethanol resulted in a significant decrease in bond strength after a long-term storage period.

Bitter et al carried out a study in July 2013 and suggested ethanol as the final root canal irrigation solution [5]. They compared irrigation with 99% ethanol and 2% CHX and NaOCl. In this study, XP Bond etch-and-rinse and RelyX Unicem2 cement systems were used. The bond strengths with both types of luting agents were significantly higher in the coronal area and ethanol gave rise to a significant increase in bond strength compared to CHX and NaOCl. The self-etch resin cement group exhibited significantly higher bond strength and the effects of thermocycling and water storage were not significant [5]. The results from this section are summarized in table 3.

EDTA *(*Ethylene Diamine Tetracetic Acid)

EDTA is a mild chelating agent that eliminates hydroxyapatite and non-collagen protein; it also prevents excessive

replacement of collagen fibril structures [27-43]. It effectively removes both the smear layer and debris from the dentin surfaces and dentinal tubules, which might be attributed to the low pH of EDTA that results in demineralization of the root canal dentin surface [27-44].

In a study by Hagashi et al, the effects of irrigation with 17% EDTA for 60 seconds and 5% NaOCl for 15 seconds and a combination of the two above in association with the use of Uni-tech one-step etch-and-rinse and Tyrian SPE one-step self-etch resin cements were evaluated [45]. The bond strength in the EDTA/NaOCl group with the etch-and-rinse system was higher than other groups; the bond strength in the EDTA with the self-etch system was the lowest. In addition, the bond strength in the etch-and-rinse system groups was higher than that in the self-etch system [45].

In another study by Gu et al, irrigation with 17% EDTA for one minute was compared with 5.25% NaOCl and normal saline [35]. The root canals were obturated with Panavia F self-etch adhesive cement and then cross-sections were prepared from the samples [35]. The bond strength of EDTA group in this study was significantly higher than the other two groups, which is contrary to the results of previous studies [46-47]. The bond strength in the NaOCl group was less than that of the normal saline group [35]. NaOCl can eliminate the organic components of dentin, consisting of collagen fibrils. In addition, it can alter the properties of collagen, making it prone to proteolysis. An increase in the duration of application of NaOCl resulted in a progressive decrease in bond strength [35]. The results from this section are summarized in table 4.

Table 3: Studies which have investigated the effect of Ethanol on bond strength

author	year	irrigant	Bonding agent	result
Ertas	**2014**	**Ethanol NaOCl CHX NaOCl/EDTA NaOCl/EDTA/CHX NaOCl/EDTA/Ethanol NaOCl/EDTA/PAD**	**BiFix SE Dual-Cure**	**The highest and lowest values pertain to ethanol and NaOCl/EDTA**
cecchin	**2011**	**CHX Ethanol CHX/Ethanol**	**Rely-X Clearfil SE Bond**	**CHX/Ethanol can preserve the bond strength after 12 months**
ceccin	**2011**	**CHX Ethanol Chx/ethanol**	**Scothch bond multi-purpose**	**Ethanol cannot preserve the bon strength in long term**
Bitter	**2013**	**99% Ethanol 2% CHX NaOCl**	**Rely-X Unicem XP Bond etch-rinse**	**Ethanol increase the bond strength significantly**

Table4: studies that have investigated the effect of EDTA on bond strength

author	year	irrigant	Bonding agent	result
hayashi	2005	17%EDTA 5% Ethanol NaOCl/EDTA	Unitech one-step Tyrian SPEonestep	EDTA/NaOCl with the etch-rinse system had the highest and EDTA with self-etch system had the lowest bond strength
Gu	2009	17% EDTA 5.25% NaOCl saline	Panavia F	Conterary to other studies EDTA showed the highest bond strength with a self-etch system

CONCLUSION

It can be concluded that the bond strength to root dentin is affected by different irrigation solutions, their concentrations and the type of the resin cement and the bonding agent used. Pretreatment with chlorhexidine often can preserve the bond strength to root dentin. When etch-and-rinse resin cements are used, demineralization and deproteination assist in bond durability. In contrast, when the resin-dentin interface is treated with a self-etch adhesive, widespread demineralization by endodontic irrigation solutions should be avoided

Conflict of Interest: None to declare.

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