Evaluation of Effects of Irrigation Protocols on Push-out Bond Strength of Glass Fiber Posts

Nomjit Vidhyaphum* and Chalermpol Leevailoj

Esthetic Restorative and Implant Dentistry, Faculty of Dentistry, Chulalongkorn University, Thailand
*Corresponding author, E-mail: nj_nuch@hotmail.com

Abstract

The purpose of this study was to compare the bond strength of glass fiber post to intra-radicular dentin of maxillary anterior teeth with different irrigation methods and different irrigant solutions accomplished by push-out bond strength test and to evaluate the bond strength in different regions of the root. A hundred human anterior maxillary teeth were randomly divided into ten groups (n=10). After root canal fillings and post space preparation has been done then different final irrigation were performed in each group; groups 1 to 3: syringe irrigation, groups 4 to 6: ultrasonic instrumentation and groups 7 to 9: passive ultrasonic irrigation. Different irrigant solutions were performed in each group; 2.5%NaOCl (groups1, 4,7), 17%EDTA (groups 2,5,8) and 2.5%NaOCl followed by 10% sodium ascorbate (groups 3, 6 & 9). Group 10 was negative control which used syringes irrigation with distilled water. Then fiber post luting has been done with Panavia SA cement Plus (Kuraray). Slices with thickness of 1 mm were prepared by using a low-speed saw, which was divided into cervical and apical parts. Push-out bond strength tests were performed at a crosshead speed of 0.5mm/min by using universal testing machine. Mode of failure was evaluated with Stereo Microscope. Bond strengths were significantly affected by different irrigants ($p<0.05$; 2-way ANOVA). It has been found higher bond strength in group 3, 6 and 9 with irrigated with NaOCl followed by Sodium ascorbate. Only group 6 had significant difference between cervical and apical region of root. Adhesive failure between post and cement were observed in group 3, 6 & 9 and apical part in group 2, while the other groups were found adhesive failure between intra-radicular dentin and cement. Bond strengths of fiber post to intra-radicular dentin in maxillary anterior teeth were significantly affected by different irrigant solutions. Irrigant solution group with NaOCl followed by Sodium ascorbate resulted in high bond strength values.

Keywords**:** *bond strength test, push-out bond strength, glass fiber post, irrigation, ultrasonic, sodium ascorbate*

1. Introduction

Post is necessary to retain cores in case of coronal excessive loss of previously treated teeth (Peroz, Blankenstein, Lange, & Naumann, 2005; Schwartz & Robbins, 2004). Proper elastic modulus and esthetically preferred are benefits of glass fiber post, which has been widely used nowadays. However, clinical failure is still observed which is mainly caused by de-cementation of glass fiber post to intra-radicular dentin, which can lead to post fracture (Heling et al., 2002; Pegoretti, Fambri, Zappini, & Bianchetti, 2002).

Irrigation is an important step to provide better cleaning of intra-radicular dentin in root canal treatment. Mechanical instrumentation only cannot sufficiently disinfect root canal walls (Sen, Wesselink & Turkun, 1995). Ultrasonic irrigation has been introduced in endodontics by using ultrasonically activated files. Two methods of ultrasonic irrigation have been introduced in literature; UI (ultrasonic instrumentation) operated with simultaneous instrumentation and PUI (passive ultrasonic irrigation), operated without simultaneous instrumentation (Walmsley, 1987; Van der Sluis, Versluis, Wu, & Wesselink, 2007). Ultrasonic irrigation provides higher velocity and volume of irrigant flow in the root canal with enhanced cleaning of intra-radicular dentin. Two mechanisms of ultrasonic irrigation are acoustic microstreaming and cavitation. Ahmad, Ford, Crum and Walton (1988) demonstrated that the shear flow caused by acoustic microstreaming produces shear stresses along the root canal wall, which assist in the removal of debris and bacteria. Studies shown that when PUI was used with different concentration of NaOCl, complete removal of smear layer was shown. On the other hand, Cheung and Stock (1993) had shown that it could not completely remove the smear layer by using PUI with 1% NaOCl for 10 seconds. Moreover, Gu, Kim, Ling, Choi, Pashley and Tay (2009) demonstrated that PUI with EDTA (ethylenediaminetetraacetic acid) or a combination of EDTA and NaOCl (Sodium hypochlorite) did not completely remove smear layers from the apical third of the canal walls. However, higher temperatures in

RANGSIT UNIVERSITY

the root canal system and uncontrolled cutting of the root canal wall could be found as a downside of this method.

Together with mechanical preparation, the use of irrigant provides a further antibacterial effect. EDTA and NaOCl solutions are used to remove the inorganic and organic portion of smear layer (Teixeira, Felippe, & Felippe, 2005). It has been shown to enhance bacterial removal significantly. Gu et al. (2009) had shown that EDTA could effectively improve the bond strength of the self-etching adhesive resin cement compared to NaOCl. Marques, Bueno, Veloso, Almeida and Pinheiro (2014) had shown that NaOCl alone may have an oxidizing affect that might decrease bond strength. Sodium ascorbate is a sodium salt of ascorbic acid. It is well known as an efficient antioxidant that could reverse the compromising effect of NaOCl on bond strength to enamel and dentin. Celik, Erkut, Gulsahi, Yamanel and Kucukesmen (2010) claimed that Sodium ascorbate application after NaOCl conventional syringe irrigation improved the bond strength value.

2. Objectives

As a result, to minimized post de-cementation problem the researchers conduct this research to compare the bond strength of fiber post to intra-radicular dentin which is using different irrigation methods and different irrigant solutions by performing push-out bond strength test and to evaluate the bond strength in different regions of the root.

3. Materials and Methods

This study was approved by the ethical committee of the faculty of dentistry, Chulalongkorn University, Thailand (approval number: HREC-DCU 2016-058.)

One hundred maxillary human anterior teeth were collected with inclusion criteria as followed; straight or slightly curved canals, no sign of crack and fracture, no root caries, fully developed apices with complete root length. The teeth were cleaned of soft tissue and calculus and stored in 0.1% Thymol solution at 4°c not more than 6 months. Then the crowns were cut above cento-enamel junction 2 mm with diamond disks and slow speed saw under water-cooling. The teeth with an initial apical file (IAF) 25-30 and root length 13-15mm were included in the study. Then the length of the root canal was determined by No.10 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) until present at the point of apical foramen. The working length was obtained by deduct 1 mm from the tooth length.

Root canal preparation was done by Protaper Next X3-X5 (Dentsply, Maillefer, Ballaigues, Switzerland) with ATR Motor (ATR Technika Digital motor, Pistoia, Italy) at 300 RPM, 4 Ncm torque. Then 2.5% NaOCl was used to irrigate 3 ml in each change of instrument, then recapitulated and re-irrigated again. Each instrument was used to enlarge eight canals only. Apical patency was done by No.10 K-file. Final irrigation was done by 1 ml of 17% EDTA and 3 ml of distilled water, then evacuated out by Luer Vac Adapter (Ultradent Products, South Jordan, Utah, USA) and dried with 3 absorbent paper points 3 second each (Dentsply, Maillefer, Ballaigues, Switzerland). Master apical file was No.50. Root canal obturation was done by using lateral condensation technique with AH Plus sealer and gutta percha cone (Dentsply, Maillefer, Ballaigues, Switzerland). Temporary filling was done by Cavit (3M,ESPE, St. Paul, MN, USA). Digital x-ray was done randomly to check the quality of canal obturation. Then teeth were stored in distilled water for 48 hours at 37°c.

After storage, gutta percha was removed until 4mm left behind for preserve apical seal. The post space was prepared by D.T. Finishing drill No.2 (RTD, France) as recommended by the manufacturer in a low speed hand-piece (rotation speed 1000-2000 rpm).

One hundred maxillary anterior teeth were randomly divided in to 10 groups (n=10) : group 1: syringe irrigation with 2.5% NaOCl; group 2: syringe irrigation with 17% EDTA; group 3: syringe irrigation with 2.5% NaOCl then 10% Sodium ascorbate; group 4: ultrasonic irrigation with 2.5% NaOCl; group 5: ultrasonic irrigation with 17% EDTA; group 6: ultrasonic irrigation with 2.5% NaOCl then 10% Sodium ascorbate; group 7: passive ultrasonic irrigation with 2.5% NaOCl; group 8: passive ultrasonic irrigation with 17% EDTA; group 9: passive ultrasonic irrigation with 2.5% NaOCl then 10% Sodium ascorbate; group 10 : syringe irrigation with distilled water (Negative control).

RANGSIT UNIVERSITY

Syringe irrigation group (Positive control) was performed with 10ml syringe and ProRinse Endo Irrigation Needles (Dentsply, Maillefer, Ballaigues, Switzerland) by placing 1mm above gutta percha. Irrigant solution were injected into canal by in and out motion 10ml for 1 minute then evacuated out by Luer Vac Adapter (Ultradent Products, South Jordan, Utah, USA) then re-applied irrigant several times with a total of 3ml in 3 minutes in each group.

Ultrasonic irrigation group was performed with an Ultrasonic unit (Acteon P5 Newtron XS) power setting of 7 along with a tip (EndoTip ; ET20D, Acteon) placing 1mm above gutta percha with simultaneous instrumentation the root canal wall using push-pull circumferential motion. During irrigation, intermittent flush were used with irrigant injected into canal by syringe 1 minute then evacuated out by Luer Vac Adapter (Ultradent Products, South Jordan, Utah, USA) then re-applied irrigant several times with total of 3ml in 3 minutes in each group.

Passive ultrasonic irrigation group was performed with an Ultrasonic unit (Acteon P5 Newtron XS) power setting of 9 along with a special file (Irrisafe ,Acteon) 25-diameter and 21 mm-long placing 1mm above gutta percha at the center of canal avoided contact of root canal surface. During irrigation, intermittent flush were used which irrigant is injected into canal by syringe 1 minute then evacuated out by Luer Vac Adapter (Ultradent Products, South Jordan, Utah, USA) then re-applied irrigant several times with total of 3ml in 3 minutes in each group.

Then, group 1 to group 9 were irrigated with distilled water and evacuated out by Luer Vac Adapter then 3 absorbent paper points were used 3 second each.

Negative control group was performed with 10ml syringe and ProRinse Endo Irrigation Needles (Dentsply, Maillefer, Ballaigues, Switzerland) by placing 1mm above gutta percha and irrigate with distilled water total of 3 ml in 3 minutes.

The D.T. Light-Post Illusion X-RO No.2 (RTD, France) were prepared and cleaned with alcohol as recommended by manufacturers. Panavia SA Cement Plus, a dual-cure, self-adhesive resin cement was used in all groups by applying it in the post space from bottom to the top using a root canal tip. The posts were seated in to canal by finger pressure and excess cement were immediatly removed. It was polymerized using LED for 10 seconds which tip of light cure unit place direct to the post, stabilized without pushing it. Digital x-ray was done randomly to check the quality of post placement.

After cementation, specimens were stored in distilled water for 48 hours at 37°c. and then sectioned with a Low speed cutting machine (ISOMET 1000, USA) divided into 2 pieces which identified into cervical and apical sections. The thickness of each root sections were verified by Digital caliper (Mitutoyo, Japan) and the radius of the post was measured by Stereo Microscope (ML9300, Meiji Techno, Japan). Push-out bond strength was tested with a universal testing machine (SHIMADZU, Japan) with push-out jig 0.5 mm at a crosshead speed 0.5 mm/min until post dislodgment (Figure1).

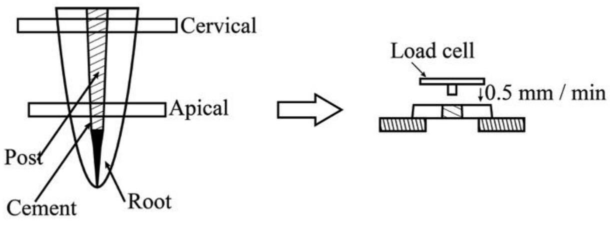

Figure 1. Preparation of specimens: Low speed cutting machine was used to prepare two sections; one mm cut below cement-enamel junction for cervical part and one mm cut above gutta purcha for apical part, each one mm thick (*left*). Push-out bond strength was tested with universal testing machine (*right*)

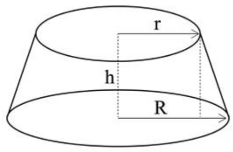

Figure 2. Bonded surface area was calculated using formula: $A = \pi(R + r) \sqrt{(R - r)^2 + h^2}$; where r is the apical side of post radius, R is the cervical side of post radius, and h is the thickness of the post in mm

The peak force at the point of extrusion of the post segment from root was taken as point of bond failure. The value was recorded in Newton (N). To get the bond strength in MPa, the load value was recorded in Newton was divided by the area of the bonded interface (Figure 2).

After push-out testing, specimens were analyzed under Stereo Microscope (ML 9300, MEIJI) to determine failure mode at apical side of post radius at magnification of *45. The types of failure was classified into the following 5 categories:

1. adhesive failure between post and cement
2. adhesive failure between intra-radicular dentin and cement
3. cohesive failure of post
4. cohesive failure of cement
5. mixed failure

Five categories were examined by one operator with decision of more than 50% of that failure fall into that category. Mixed failure was determined by more than one failure that has been shown in equally amount.

Statistical analysis was performed applying two-way analysis of variance (ANOVA) followed by Tukey's test as post-hoc comparison at a significance level set at $p<0.05$.

4. Results and Discussion

Irrigant solutions were found significantly effective on push-out bond strength ($p<0.05$; Table I). The group that irrigated with NaOCl followed by Sodium ascorbate had shown higher bond strength than NaOCl and EDTA group (Group 3, 6 and 9). Only group 6 had significant difference between cervical and apical region of root ($p<0.05$; Table II). The failure modes of the groups and root levels are presented in Table III. No cohesive failure in the post and cement (type 3 and 4) was observed. A higher incidence of type 1 failure was observed in group 2 (55%), group 3 (80%), group 6 (70%) and group 9 (80%). The other groups had shown high incidence in type 2 failure mode. Noted that the result had been transformed into Log 10 before analysis to get a better bell-shaped, normal distribution curve.

Irrigation is an essential step to provide better cleaning of intra-radicular dentin before cementation. Different irrigation methods and irrigant solutions can directly affect bond strength. Ultrasonic irrigation provides higher velocity and volume of irrigant flow in the root canal with enhanced cleaning of intra-radicular dentin. Goracci, Sadek, Fabianelli, Tay and Ferrari (2005) showed that irrigation efficacy relies on the working mechanism of the irrigant, which must come into contact with intra-radicular dentin. Two mechanisms of ultrasonic irrigation are acoustic microstreaming and cavitation. Acoustic microstreaming refers to the rapid movement of fluid in a circular or vortex-like motion around a vibrating file in the root canal (Plotino, Pameijer, Grande, & Somma, 2007; Lea, Walmsley, & Lumley, 2010). Leighton (1994) defined cavitation as the impulsive formation of cavities in a liquid through tensile forces induced by high-speed flows or flow gradients. These cavities expand as bubbles and then rapidly collapse producing a focus of energy leading to intense sound and damage, and resulting in better irrigant flow (Roy, Ahmad & Crum, 1994). However, here, no statistically significant difference was observed between syringe irrigation and ultrasonic irrigation. The samples were maxillary anterior teeth with large straight root canals, in comparison with previous studies that used premolar or molar teeth. The distance of the file from the root

RANGSIT UNIVERSITY

canal wall affects passive ultrasonic irrigation, and increasing the file diameter may improve efficiency (Van der Sluis et al., 2007). The results showed no statistically significant difference in ultrasonic instrumentation from varying the distance between the ultrasonic tip and root canal wall. Ultrasonic instrumentation has been reported as less effective than passive ultrasonic irrigation for the removal of the smear layer in the root canal. Reduction of acoustic microstreaming and cavitation can be explained for this reason (Walmsley, 1987; Van der Sluis et al., 2007). Moreover, ultrasonic instrumentation could result in higher temperatures in the root canal system and uncontrolled cutting of the root canal wall. Recently, Boutsioukis and Tzimpoulas (2016) demonstrated that passive ultrasonic irrigation might also result in uncontrolled removal of dentin in straight root canals.

A final irrigation with chemicals such as EDTA and NaOCl is recommended to remove inorganic and organic components of debris and the smear layer (Torabinejad, Handysides, Khademi, & Bakland, 2002). NaOCl and EDTA irrigation groups have been reported as similar; however, statistically significant differences ($p<0.05$) have been recorded for NaOCl followed by Sodium ascorbate irrigation, even for diverse irrigation methods. NaOCl has antimicrobial action, with an ability to reduce endotoxic load and capacity to dissolve organic tissue. It also has a deproteinization effect and acts as a biological oxidant, which breaks down, to Sodium chloride and oxygen (Naenni, Thoma & Zehnder, 2004). However, oxygen demonstrated a negative effect on polymerization of the adhesive system, which caused lower bond strength. Reactive residual free radicals in Sodium hypochlorite-treated dentin may hamper the propagation of free radicals during light activation of the adhesive, creating premature chain termination and incomplete polymerization (Morris, Lee, Agee, Bouillaguet, & Pashley, 2001). Many authors demonstrated that NaOCl application decreased dentin bond strength, and if this results from its oxidizing effect, it may be possible to reverse the reaction using a biocompatible antioxidant such as Sodium ascorbate. This could reverse the compromising effect of NaOCl on enamel-dentin bond strength by restoring the altered redox potential of the oxidized bonding substrate. Sodium ascorbate allows free radical polymerization of the adhesive to proceed without premature termination (Lai et al., 2001; Celik et al., 2010). The results demonstrated that different irrigant solutions (NaOCl, EDTA, NaOCl followed by Sodium ascorbate) affected the bond strength of the post and intra-radicular dentin, while different irrigation methods (syringe irrigation, ultrasonic instrumentation, passive ultrasonic irrigation) recorded no significant difference. Therefore, the first null hypothesis is accepted for irrigation methods but rejected for irrigation solutions.

Diverse regions of the post in the root canal (cervical third and apical third) recorded statistically significant differences in only one group out of ten (group 6). Therefore, overall results were not significantly different, consistent with previous studies (Aksornmuang, Foxton, Nakajima, & Tagami, 2004; Gaston, West, Liewehr, Fernandes, & Pashley, 2001). However, some authors reported that the apical third region recorded poor bond strength due to incomplete polymerization from insufficient light in the lower region of the canal or insufficient moisture control (Topcu, Erdemir, Sahinkesen, Mumcu, Yildiz, & Uslan, 2010). The adhesive used was Panavia SA Cement Plus (Kuraray, Tokyo, Japan) as one-step self-adhesive resin cement, which was not technique sensitive, compared with three- or two-step adhesives. Dual cure mode was provided to diminish insufficient light activation in the apical third of the canal wall (Ferracane, Stansbury, & Burke, 2011; Jang, Ferracane, Pfeifer, Park, Shin, & Roh, 2017). Cement thickness in the cervical third was thicker than in the apical third because of the oval shape of the cervical area. After root canal preparation, there was more room to fit in the apical area; nonetheless, no difference in bond strength of these two areas was recorded. A low-speed hand-piece finishing drill was recommended by the manufacturer for a well-prepared root canal. Moisture control was performed after the final irrigation by 3 absorbent paper points for 3 seconds each. Resin cement was transported into the canal by an endo tip applicator with a small and long shape to allow injection of cement into the canal easily and effectively.

Among the different irrigation groups, NaOCl followed by Sodium ascorbate recorded the highest bond strength (38.09 ± 19.28 MPa), which presented as an adhesive failure between post and cement. In contrast, other groups showed adhesive failure between intra-radicular dentin and cement. (NaOCl 13.55 ± 13.17 MPa, EDTA 13.71 ± 13.54 MPa). Findings confirmed that the group irrigated with NaOCl followed by Sodium ascorbate showed enhanced bond strength of intra-radicular dentin and cement, with failure presented between the post and cement interface.

RANGSIT UNIVERSITY

During the course of a hundred specimen preparations, human error was found. An oval shaped canal causes problems for complete gutta percha removal before cementation. The edge of the oval tip is always a problematic area for instrumentation access to clear gutta percha remnants, which can influence lower bond strength by impeding the polymerization of resin-based material to intra-radicular dentin. The study recorded gutta percha remnants in 10% of all specimens distributed in many groups (Figure 3). The researcher did not exclude any of these specimens to portray a real clinical situation. Moreover, this *in-vitro* study presented a wide range of standard deviations, possibly due to the diverse anatomy of each root section, with varying tubule density and diameter. However, well-controlled specimens were properly presented following stringent criteria of specimen selection, allocation and preparation.

5. Conclusion

Within the limitations of the study, the following conclusion has been drawn:

1. Ultrasonic instrumentation and passive ultrasonic irrigation does not affect bond strength of fiber post to intra-radicular dentin in maxillary anterior teeth when using with self-adhesive cement.
2. Irrigant solution group with NaOCl followed by Sodium ascorbate resulted in higher bond strength values compared to NaOCl ,EDTA and distilled water group.
3. Region of root does not affect bond strength.

6. Acknowledgements

The researcher would like to give sincere thank to advisor Prof. Chalermpol leevailoj for the continuous support of this research, for his patience, inspired motivation, and valuable knowledge. His guidance helped in all the time of research and writing of this thesis.

Table 1. ANOVA models

Source of variation	Sum of squares	*df*	Mean square	F	*P*
Irrigation method	.438	2	.219	1.189	.307
Irrigant solution	14.174	2	7.087	38.474	.000
Irrigation method*Irrigant solution	.418	4	.105	.568	.686
Error	31.498	171			
Total	267.782	180			

Table 2. Mean bond strength values (SDs) of original data to different regions of the post in root canal *

Group No.	Groups	Bond strength of cervical third (MPa)	Bond strength of apical third (MPa)
1	Syringe + NaOCl	12.18(10.56)^{Bb}	21.59(14.34)^{Bb}
2	Syringe + EDTA	11.27(8.23)^{Bb}	17.33(21.50)^{Bb}
3	Syringe + NaOCl + Sodium ascorbate	39.30(17.86)^{Ab}	35.96(18.90)^{Ab}
4	UI + NaOCl	13.47(13.18)^{Bb}	7.78(9.35)^{Bb}
5	UI + EDTA	15.25(10.54)^{Bb}	9.44(6.36)^{Bb}
6	UI + NaOCl + Sodium ascorbate	27.97(12.48)^{Aa}	43.18(20.99)^{Ab}
7	PUI + NaOCl	19.84(18.08)^{Bb}	6.49(4.71)^{Bb}
8	PUI + EDTA	12.89(14.13)^{Bb}	16.14(16.44)^{Bb}
9	PUI + NaOCl + Sodium ascorbate	39.30(21.49)^{Ab}	42.85(22.98)^{Ab}
10	Syringe + distilled water	18.68(19.81)^{Bb}	13.47(13.13)^{Bb}

*Within the same column, different capital letter means statistically significant different ;within the same row, different lower case means statistically significant different (p<0.05).

RANGSIT UNIVERSITY

Table 3. Distribution of the failure mode following push-out bond strength test (Each group presented cervical followed by apical part)

Failure mode	Group1		Group2		Group3		Group4		Group5		Group6		Group7		Group8		Group9		Group10	
1.adhesive failure between post and cement	2	4	3	8	8	8	1	2	4	2	6	8	4	3	2	0	8	8	3	0
2.adhesive failure between intra-radicular dentin and cement	7	6	5	2	2	2	8	8	6	8	4	2	5	6	8	9	1	2	7	9
3.cohesive failure of post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.cohesive failure of cement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.mixed failure	1	-	2	-	-	-	1	-	-	-	-	-	1	1	-	1	1	-	-	1

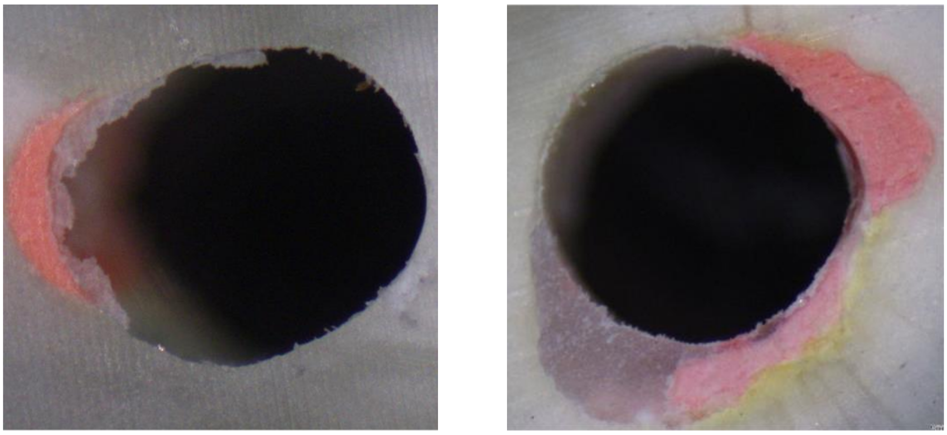

Figure 3. Gutta percha remnant has been shown in approximately 10% of all case, which influence bond strength

7. References

Ahmad, M., Ford, T. P., Crum, L. A., & Walton, A. J. (1988). Ultrasonic debridement of root canals: acoustic cavitation and its relevance. *Journal of Endodontics*, *14*(10), 486-493.

Aksornmuang, J., Foxton, R. M., Nakajima, M., & Tagami, J. (2004). Microtensile bond strength of a dual-cure resin core material to glass and quartz fibre posts. *Journal of Dentistry*, *32*(6), 443-450.

Boutsioukis, C., & Tzimpoulas, N. (2016). Uncontrolled removal of dentin during in vitro ultrasonic irrigant activation. *Journal of endodontics*, *42*(2), 289-293.

Celik, C., Erkut, S., Gulsahi, K., Yamanel, K., & Kucukesmen, C. (2010). Effect of sodium ascorbate on bond strength of different adhesive systems to NaOCl-treated dentin. *Australian Endodontic Journal*, *36*(1), 12-18.

Cheung, G. S. P., & Stock, C. J. R. (1993). In vitro cleaning ability of root canal irrigants with and without endosonics. *International Endodontic Journal*, *26*(6), 334-343.

Ferracane, J. L., Stansbury, J. W., & Burke, F. J. T. (2011). Self-adhesive resin cements–chemistry, properties and clinical considerations. *Journal of Oral Rehabilitation*, *38*(4), 295-314.

Gaston, B. A., West, L. A., Liewehr, F. R., Fernandes, C., & Pashley, D. H. (2001). Evaluation of regional bond strength of resin cement to endodontic surfaces. *Journal of Endodontics*, *27*(5), 321-324.

Goracci, C., Sadek, F. T., Fabianelli, A., Tay, F. R., & Ferrari, M. (2005). Evaluation of the adhesion of fiber posts to intraradicular dentin. *OPERATIVE DENTISTRY-UNIVERSITY OF WASHINGTON-*, *30*(5), 627-635.

Gu, L. S., Kim, J. R., Ling, J., Choi, K. K., Pashley, D. H., & Tay, F. R. (2009). Review of contemporary irrigant agitation techniques and devices. *Journal of Endodontics*, *35*(6), 791-804.

Heling, I., Gorfil, C., Slutzky, H., Kopolovic, K., Zalkind, M., & Slutzky-Goldberg, I. (2002). Endodontic failure caused by inadequate restorative procedures: review and treatment recommendations. *Journal of Prosthetic Dentistry*, *87*(6), 674-678.

Jang, Y., Ferracane, J. L., Pfeifer, C. S., Park, J. W., Shin, Y., & Roh, B. D. (2017). Effect of insufficient light exposure on polymerization kinetics of conventional and self-adhesive dual-cure resin cements. *Operative Dentistry*, *42*(1), E1-E9.

Lai, S. C. N., Mak, Y. F., Cheung, G. S. P., Osorio, R., Toledano, M., Carvalho, R. M., ... & Pashley, D. H. (2001). Reversal of compromised bonding to oxidized etched dentin. *Journal of Dental Research*, *80*(10), 1919-1924.

Lea, S. C., Walmsley, A. D., & Lumley, P. J. (2010). Analyzing endosonic root canal file oscillations: an in vitro evaluation. *Journal of Endodontics*, *36*(5), 880-883.

Leighton, T.G. (1994). The Acoustic Bubble, Chapter 1 and 2. New York: Academic Press.

Marques, E. F., Bueno, C. E., Veloso, H. H., Almeida, G., & Pinheiro, S. L. (2014). Influence of instrumentation techniques and irrigating solutions on bond strength of glass fiber posts to root dentin. *General Dentistry*, *62*(2), 50-53.

Morris, M. D., Lee, K. W., Agee, K. A., Bouillaguet, S., & Pashley, D. H. (2001). Effects of sodium hypochlorite and RC-prep on bond strengths of resin cement to endodontic surfaces. *Journal of Endodontics*, *27*(12), 753-757.

Naenni, N., Thoma, K., & Zehnder, M. (2004). Soft tissue dissolution capacity of currently used and potential endodontic irrigants. *Journal of Endodontics*, *30*(11), 785-787.

Pegoretti, A., Fambri, L., Zappini, G., & Bianchetti, M. (2002). Finite element analysis of a glass fibre reinforced composite endodontic post. *Biomaterials*, *23*(13), 2667-2682.

Peroz, I., Blankenstein, F., Lange, K. P., & Naumann, M. (2005). Restoring endodontically treated teeth with posts and cores--a review. *Quintessence International*, *36*(9) ,737-46.

Plotino, G., Pameijer, C. H., Grande, N. M., & Somma, F. (2007). Ultrasonics in endodontics: a review of the literature. *Journal of endodontics*, *33*(2), 81-95.

Roy, R. A., Ahmad, M, Crum, L. A. (1994). Physical mechanisms governing the hydrodynamic response of an oscillating ultrasonic file. *International Endodontic Journal,27(4),*197-207.

Schwartz, R. S., & Robbins, J. W. (2004). Post placement and restoration of endodontically treated teeth: a literature review. *Journal of Endodontics*, *30*(5), 289-301.

Şen, B. H., Wesselink, P. R., & Türkün, M. (1995). The smear layer: a phenomenon in root canal therapy. *International Endodontic Journal*, *28*(3), 141-148.

Teixeira, C. S., Felippe, M. C. S., & Felippe, W. T. (2005). The effect of application time of EDTA and NaOCl on intracanal smear layer removal: an SEM analysis. *International Endodontic Journal*, *38*(5), 285-290.

Topcu, F. T., Erdemir, U., Sahinkesen, G., Mumcu, E., Yildiz, E., & Uslan, I. (2010). Retracted: Push-out bond strengths of two fiber post types bonded with different dentin bonding agents. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*, *93*(2), 359-366.

Torabinejad, M., Handysides, R., Khademi, A. A., & Bakland, L. K. (2002). Clinical implications of the smear layer in endodontics: a review. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics*, *94*(6), 658-666.

Van der Sluis, L. W. M., Versluis, M., Wu, M. K., & Wesselink, P. R. (2007). Passive ultrasonic irrigation of the root canal: a review of the literature. *International Endodontic Journal*, *40*(6), 415-426.

Walmsley, A. D. (1987). Ultrasound and root canal treatment: the need for scientific evaluation. *International Endodontic Journal*, *20*(3), 105-111.