Effect of temperature and activation techniques of irrigating solutions on push-out bond strength of fiber post

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Abstract
AIM: This study evaluated the effect of preheated irrigants (EDTA, QMix), then use of various activation techniques such as ultrasonic system and laser on push-out bond strength (POBS) of fiber posts to root dentin.

Methodology: One hundred and twenty extracted human teeth were decoronated below the cementoenamel junction. All the root canals were instrumented, irrigated using sodium hypochlorite and normal saline, dried with paper points, and filled with gutta-percha and AH Plus sealer. Post spaces were prepared. The irrigating solutions QMix and EDTA were heated to 60°C. Normal QMix and EDTA served as control. The irrigants were activated with Laser and Ultrasound system. Then, the fiber posts were cemented, roots were sliced to thickness of 2 mm and mounted for measurement of POBS.

Results: Preheated irrigants group showed maximum POBS as compared to Normal irrigants. QMix group showed better results as compared to EDTA. Irrigants when activated with laser and ultrasonics showed comparable results.

Conclusion: Within the limitations of the study, it can be concluded that preheated irrigants (QMix, EDTA) increase the POBS of fiber post to root dentin. Both laser and ultrasonic are equally effective for increasing the POBS.

Keywords: EDTA; fiber post; preheating; QMix

INTRODUCTION
Endodontically treated teeth with massive loss of coronal tooth structure requires the use of an intraradicular post for improving the retention of additional restoration. Compared to the traditional cast metal and core systems, fiber posts have superior mechanical properties, such as high flexural strength and elasticity modulus, similar to those of dentin, does not corrode, and transfers loads to the root in order to protect the tooth against root fracture.[1]

The most common failure associated with fiber posts is their debonding at the adhesive resin–dentin interface caused by difficulties regarding dentin hybridization.[2] Dentin hybridization can be affected by modifications in the dentin substrate caused by irrigants, obstruction of the dentin tubules during instrumentation, post space preparation, and type of adhesive system.[3] Root canal dentin surfaces were always covered with a thick smear layer and debris after post space preparation, which might be much more difficult to remove with normal saline irrigation.
EDTA is effective at dissolving inorganic material, including hydroxyapatite without any effect on organic tissue. QMix (Dentsply Tulsa Dental, USA) is a novel endodontic irrigant designed as a final irrigant effective for post space preparation. This one-step final rinse is supposed to combine the antimicrobial and substantivity properties of chlorhexidine (CHX) with the smear layer removing properties of EDTA.\[^4,5\]

According to studies, preheating the irrigating solutions may reduce the surface tension of the dentinal tubules which may lead to better penetration into the dentinal tubules and which lead to effective smear layer removal.\[^6\]

Ideal root canal irrigants should be brought into direct contact with the entire canal wall surfaces for effective action. Ultrasonic system enhances the smear layer dissolving capability of irrigating solutions as they create both cavitation and acoustic streaming. Cavitation is limited to the tip but Acoustic streaming is more significant.\[^7\]

The interaction between laser and the irrigant in the root canal outlines a new area of interest in the field of endodontic disinfection. Diode laser has shown promising results in smear layer removal and root canal disinfection in endodontics to achieve reduced permeability and microleakage.\[^8\]

There has been no such study in literature evaluating the effect the various preheated irrigants along with the use of various activation techniques and evaluating the push-out bond strength (POBS) of fiber posts to dentin. This study involves evaluating the effect of preheating the irrigants (EDTA, QMix) and then use of various activation techniques like ultrasonic system and Laser and then measure the POBS of fiber posts to root dentin.

**METHODOLOGY**

**Preparation of the samples**

One hundred and twenty teeth were decoronated below the cementoenamel junction perpendicularly to the longitudinal axis by using a slow-speed, water-cooled diamond saw at low rotation to get a uniform length of 16 mm from the apical end for each root. The apices of the teeth were sealed with Cavit (3M, ESPE).

All root canals were instrumented up to 60K file size (Sybron Endo). Irrigation was done using sodium hypochlorite (Parcan, Septodont healthcare) and normal saline to remove the remaining debris, dried with paper points, and filled with gutta-percha by lateral condensation and AH Plus sealer (DENTSPLY). The specimens were kept at 37°C and relative humidity for 7 days for setting of full cement. Then, the roots were embedded in acrylic resin. The post spaces were prepared using Peeso reamers (DENTSPLY) no 3 leaving 5 mm of gutta-percha in the apex.

**Irrigation**

The specimens were divided into two groups (n = 60) depending on the irrigating solution. The irrigating solutions used were QMix (Dentsply Tulsa dental, USA) and EDTA (Largal Ultra, Septodont). Samples were further divided depending on temperature of irrigating solution. The irrigants (QMix and EDTA) (n = 30) were pre heated to the temperature 60°C using water bath. Normal QMIX and EDTA served as control.

In both the groups, post spaces were irrigated with the mentioned irrigating solutions and was activated with the two auxiliary techniques. For the ultrasonic subgroups, the ultrasonic D\(_1\) tip (Acteon, Merignac, France) was used, running all 10 laps around them, with 10% of power. For the laser subgroups, the diode laser (Biolase, EpicX, USA) was irradiated in the root canal with the following parameters: 1.5 W output power, 20 Hz frequency, 238.85 J/cm\(^2\), and light in continuous mode. A 200 µm fiber optic tip was introduced into the post space. All the samples were irrigated with normal saline as a final irrigant. The canals were dried with paper points. The fiberglass posts were (Selfpost, Medicept dental) cemented to the root canal by using Dual cure Resin cement (Maxcem Elite, Kerr Corporation). The specimens were kept at 37°C and relative humidity for 7 days.

**Push-out test**

For the POBS test, each bonded post was sectioned horizontally into slices of 2.0 mm in thickness. The apical aspect of the slice was loaded with a cylindrical plunger of 1.2 mm diameter that was mounted on a Universal Testing Machine (INSTRON 3369, USA). The load was applied in apico-coronal direction at a cross-head speed of 0.5 mm/min until the post segment was dislodged from the root slice. The results were expressed in Newtons (N). POBS in MPa was calculated by dividing load at debonding (N) by the area (A) of the bonded interface. The surface area of the bonded interface was calculated by the formula: A = π × k (r\(_1\) + r\(_2\)), in which π is the constant 3.14, r\(_1\) represents the coronal post radius, r\(_2\) represents apical post radius and k can be calculated using formula \((h^2 + [r_1−r_2]^2)^{0.5}\) where h is the thickness of the slice in millimeter.

**RESULTS**

The POBS data were analyzed by Mann–Whitney test using SPSS version 17.0 software (IBM, Chicago, IL, USA). The mean and standard deviations of POBS values are presented in Tables 1-3.
The groups irrigated with QMix showed higher POBS [Table 1] of 12.24 ± 2.07 MPa as compared to EDTA (8.81 ± 1.24 MPa). Comparison was statistically significant as $P < 0.001$. Mean POBS of preheated irrigants (EDTA + QMix) was more (11.97) [Table 2] as compared to normal irrigants (9.77). Comparison was statistically significant as $P < 0.001$.

There was no statistical significant difference of Mean POBS of samples activated with laser and ultrasonic [Table 3] as $P = 0.25$. They showed comparable results.

**DISCUSSION**

Achieving clean dentinal surfaces after mechanical post space preparation seems to be a critical step for optimal post retention when resin cement is used. To enable satisfactory adhesion of posts to root dentin, the smear layer has to be removed as it will hinder penetration of self-adhesive resin cement which may affect bond strength of fiber post.

Chemical agents, such as NaOCl, $H_2O_2$, EDTA, CHX digluconate, citric acid (10%, 20%, and 50%), orthophosphoric acid ($H_3PO_4$), and combinations of these, have been proposed for the removal of the smear layer.

As a mild chelating agent, EDTA acts by removing the hydroxyapatite and noncollagenous protein selectively, avoiding major alterations of the native collagen fibrillar structure. As the unaltered collagen fibrils are thought to preserve most of their intrafibrillar mineral, they are more stable and less affected by dehydration, which subsequently improves the infiltration of the resin materials and resulted in better bond strength.

Results demonstrated that the overall Mean POBS of QMix samples were more (12.24 MPa) as compared to EDTA (8.81 MPa) which was statistically significant ($P < 0.05$) [Table 1]. It is attributed to EDTA along with CHX and surfactant present in QMix. As mentioned above, EDTA had enhanced the bond strength of fiber posts to root dentin. CHX increases the surface energy of dentin and decreases the contact angle while detergents have an ability to lower the surface tension of solutions and improve their wettability. Another reason to use QMix for post space irrigation is that inhibition of the enzyme matrix metalloproteinase by CHX which prevents decomposition of the hybrid layer and decalcification of the root canal dentin. This finding is in agreement with the general findings and other studies but in contrast to study conducted by Barreto et al. He stated that the reduced bond strength of QMix may be due to the inefficiency of surfactant in removing smear layer.

It has been reported that at 60°C, the 1% NaOCl solution is more effective in pulp tissue dissolution when compared to 1% NaOCl at 45°C. At 60°C using 3% NaOCl and 17% EDTA, the smear layer was removed effectively. Cunningham and Balekjian also showed that increasing the temperature of irrigant significantly increases its dissolving ability of smear layer. According to a study by Çiçek and Keskin, it was concluded that using EDTA and MTAD at 25°C and 37°C was found more effective than using the solutions at 4°C temperature even in apical level of the root canal for the removal of smear layer. So, in this study the irrigants were preheated to 60°C and then subjected to various supplementary activation techniques i.e., Laser and ultrasonics. The mean POBS value of preheated irrigants (EDTA + QMix) samples were higher (10.97) as compared to normal irrigants (EDTA + QMix) as mentioned in Table 2. There was significant difference between the two groups as $P < 0.001$. This may be attributed to the fact that using heat, or a surfactant, may reduce surface tension, increase the surface energy which leads to increased wetting of dentinal tubules and smear layer removal.

Increasing the temperature of the irrigants may also reduce the viscosity which improves its penetrability in root dentin which results in effective smear layer removal and increased the POBS.

The use of 17% EDTA for 5 min alone could cause a severe erosion of the dentin root surface due to excessive demineralization of the canal walls. Saito et al. claim that reducing the irrigation time with EDTA below 1 min can significantly reduce smear layer removal. Hence, in this study, preheating was done along with various activation techniques to increase the efficiency of the irrigants.

Results showed that the mean POBS of irrigants when activated with laser (10.78 MPa) was more but not statistically significant as compared to activation with ultrasonic (10.27) [Table 3]. The reason for equal performance of laser with ultrasonic could be due to the fact that diode laser modifies the smear layer.

| Group         | Mean±SD | Mean rank | Sum of ranks | Mann-Whitney U-test | $P$  |
|---------------|---------|-----------|--------------|---------------------|------|
| QMix          | 12.24±2.07 | 66.22     | 3046.00      | 151.000             | <0.001 |
| EDTA          | 8.81±1.24  | 26.78     | 1232.00      |                      |      |

SD: Standard deviation, EDTA: Ethylene diaminetetraacetic acid

| Group         | Mean±SD | Mean rank | Sum of ranks | Mann-Whitney U-test | $P$  |
|---------------|---------|-----------|--------------|---------------------|------|
| Preheated     | 11.97±2.24 | 57.59     | 2764.50      | 523.50              | <0.001 |
| Normal        | 9.77±1.14  | 34.40     | 1513.50      |                      |      |

SD: Standard deviation

| Group         | Mean±SD | Mean rank | Sum of ranks | Mann-Whitney U-test | $P$  |
|---------------|---------|-----------|--------------|---------------------|------|
| Laser         | 10.78±2.33 | 51.48     | 2368.00      | 829.00              | 0.25 |
| Ultrasonic    | 10.27±2.5  | 41.52     | 1910.00      |                      |      |

SD: Standard deviation
without opening the dentinal tubules of the canal walls.[19] Adhesive penetration may be obstructed due to the presence of smear layer and closed dentinal tubules. This study was in agreement with study conducted by Mathew et al. proving that Diode laser along with EDTA does not enhance bond strength.[20] In contrast according to Arslan et al., agitation of 15% EDTA with an 808-nm diode laser for 20 s was effective in removing the smear layer in the apical thirds of root canals.[8] This was further supported by Borges et al.,[21] whose study showed that diode laser enhanced the bonding of fiber post to root dentin. Diode lasers offer thin optical fibers that can fit into root canals, thus promoting enhanced penetration to the less accessible areas of the tubular network.[22] They increase the dentin permeability by removing the smear layer and potentially increasing the cement penetration in dentinal tubules. Reason for better performance of diode laser in previous studies[8,21] may be due to its mode of delivery and its fiber optic tip of length 14 mm. Ultrasonic system showed comparatively lower performance and it may be due to the fact that ultrasonic file has a shorter contact time with the root canal.

Macedo et al. affirmed that dual-cured resin cements combine favorable properties of both types of resin cements, light cure and self-cured for glass fiber posts cementation.[22] They have high potential to chemically react with dentin. Dual-cure self-adhesive resin cement was selected as it requires the use of fewest clinical steps. In addition, dual cure resin cement is capable of ensuring sufficient polymerization in deep areas of root canals.

The efficacy of the bonds between fiber posts and root dentin can be evaluated by micro leakage testing, bond strength tests and Scanning electron microscope (SEM) evaluations. The push-out test is a more reliable method for determining bond strengths between fiber posts and dentine as push-out tests result in a shear stress at the interface between dentine and cement as well as between post and cement, and are comparable with the stress under clinical conditions.[23] Mechanical testing of bonded interfaces can provide insights into material selection and outcome prediction.

CONCLUSION

Under the limitations of the present study, the results showed that preheating of irrigants along with laser and ultrasonic activation techniques are effective measure to increase the bond strength of fiber post. Further studies need to be conducted to evaluate the effect of both preheating and activation technique on POBS of fiber post.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Victorino KR, Kuga MC, Duarte MA, Cavenago BC, Só MV, Pereira JR. The effects of chlorhexidine and ethanol on push-out bond strength of fiber posts. J Conserv Dent 2016;19:96-100.
2. Pasley DH. Smear layer: Physiological considerations. Oper Dent Suppl 1984;3:13-29.
3. Cecchin D, de Almeida JF, Gomes BP, Zaia AA, Ferraz CC. Effect of chlorhexidine and ethanol on the durability of the adhesion of the fiber post relined with resin composite to the root canal. J Endod 2011;37:678-83.
4. Elmaghy AM. Effect of QMix irrigant on bond strength of glass fibre posts to root dentine. Int Endod J 2014;47:280-9.
5. Stojicic S, Shen Y, Qian W, Johnson B, Haapasalo M. Antibacterial and smear layer removal ability of a novel irrigant, QMix. Int Endod J 2012;45:369-71.
6. Çiçek E, Keskin Ö. The effect of the temperature changes of EDTA and MTAD on the removal of the smear layer: A scanning electron microscopy study. Scanning 2015;37:193-6.
7. Plotino G, Pameijer CH, Grande NM, Somma F. Ultrasonics in endodontics: A review of the literature. J Endod 2007;33:81-95.
8. Arslan H, Ayrancı LB, Karatas E, Topçuolu HS, Yayuz MS, Kesimal B. Effect of agitation of EDTA and 808-nm diode laser on removal of smear layer. J Endod 2013;39:1589-92.
9. Cunningham WT, Baleykin YA. Effects of temperature on collagen-dissolving ability of sodium hypochlorite endodontic irrigant. Oral Surg Oral Med Oral Pathol Oral Radiol 1980;49:175-7.
10. Lo Giudice G, Luzio A, Giudice RL, Centofanti F, Rizzo G, Runci M, et al. The Effect of Different Cleaning Protocols on Post Space: A SEM Study. Int J Dent. 2016;2016:1907124. doi:10.1155/2016/1907124.
11. Barreto MS, Rosa RA, Seballos VG, Machado E, Vlandaro LF, Kaizer OB, et al. Effect of intracanal irrigants on bond strength of fiber posts cemented with a self-adhesive resin cement. Oper Dent 2016;41:159-67.
12. Léon BL, Franco VL, Silva EV, Muniz L, Ribeiro FC. Push-out bond strength of glass fiber posts luted with two resin cements. Braz Dent Sci 2017;18, 20:78-84.
13. Uzunoglu E, Turkar SA, Karahan S. The effect of increased temperatures of QMix and EDTA on the push-out bond strength of an epoxy-resin based sealer. J Clin Diagn Res 2015;9:ZC98-101.
14. Brichko J, Burrow MF, Parashos P. Design variability of the push-out bond test in endodontic research: A systematic review. J Endod 2018;44:1237-45.
15. Elliot C, Hatton JF, Stewart GP, Hildebolt CF, Jane Gillespie M, Gutmann JL. The effect of the irrigant QMix on removal of canal wall smear layer: An ex vivo study. Odontology 2014;102:232-40.
16. Poggio C, Ceci M, Beltrami R, Colombo M, Dagna A. Viscosity of endodontic irrigants: Influence of temperature. Dent Res J (Isfahan) 2015;12:425-30.
17. Faría-e-Silva AL, Menezes Mde S, Silva FP, Reis GR, Moraes RR. Intra-radicular dentin treatments and retention of fiber posts with self-adhesive resin cements. Braz Oral Res 2013;27:14-9.
18. Saito K, Webb TD, Imamura GM, Goodell GG. Effect of shortened irrigation times with 17% ethylene diamine tetra-acetic acid on smear layer removal after rotary canal instrumentation. J Endod 2008;34:1011-4.
19. Zafar QA, Malik WJ, Azam S. Comparison of 980 nm Diode Laser and Q-Mix solution alone and in combination on removal of smear layer from root canal surface; a scanning electron microscope study. Oral Health Dent Manag 2019;30, 18:64-9.
20. Mathew S, Rau IR, Sreedev CP, Karthick K, Boopathi T, Deepa NT. Evaluation of push-out bond strength of fiber post after treating the intra radicular post space with different postspace treatment techniques: A randomized controlled intravitro trial. J Pharm Bioallied Sci 2017;9:5197-200.
21. Borges GC, Palma-Dibb RG, Rodrigues FC, Plotegher F, Rossi-Fedele G, de Sousa-Neto MD, et al. The effect of diode and Er:Cr:YSGG lasers on the bond strength of fiber posts. Photobiomodul Photomed Laser Surg 2020;38:66-74.
22. Macedo VC, Faría e Silva AL, Martins LR. Effect of cement type, relining procedure, and length of cementation on pull-out bond strength of fiber posts. J Endod 2010;36:1543-6.
23. Kadam A, Pujar M, Patil C. Evaluation of push-out bond strength of two fiber-reinforced composite posts systems using two luting cements in vitro. J Conserv Dent 2013;16:444-8.