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The Effects of Different Agitation Techniques of Canal Irrigant on Tubular Penetration of a Bioceramic Sealer

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ABSTRACT

Introduction: This study aimed to compare the effects of different agitation techniques of sodium hypochlorite (NaOCL) as the final irrigation with XP-Finisher file, passive ultrasonic irrigation (PUI), Er:YAG laser and irrigation with conventional syringes, on penetration of Sure Seal Root bioceramic sealer into dentinal tubules. **Methods and Materials:** Forty freshly extracted single-rooted human teeth were included in the present *in vitro* study. All the teeth were prepared up to #40 (4%) with Bio Race rotary file system, using crown-down technique. After chemomechanical preparation, the teeth were randomly assigned to 4 groups based on the agitation protocol: conventional needle irrigation (CNI) with a 30-G needle in a syringe, PUI, Er:YAG laser and XP-Finisher file, Subsequent to the agitation procedure, the root canals were obturated with tapered bioceramic-covered gutta-percha point and, bioceramic sealer, using the single-cone technique. The maximum penetration of the sealer into the dentinal tubules was determined in the coronal, middle and apical thirds using the scanning electron microscope (SEM) technique. After confirmation of the normal distribution of data with Shapiro-Wilk test, Data were analyzed using the one-way ANOVA and Tukey tests. **Results:** The mean penetration depth of the bioceramic sealer into the dentinal tubules in the PUI group was greater than that of other groups; however, the difference between the two PUI and Er:YAG laser groups in the apical third was not significant (P=0.078). Er:YAG laser, PUI and XP-Finisher file agitation techniques resulted in significantly greater penetration of the bioceramic sealer into the dentinal tubules compared to the CNI (P<0.001). The XP-Finisher file technique in the apical (P=0.752) and middle thirds (P=0.339) and the Er:YAG laser technique in the apical thirds (P=0.086) were not significantly different from the conventional irrigation technique. **Conclusion:** The PUI technique resulted in significantly deeper penetration of the Bioceramic sealer into the dentinal tubules compared to the three other techniques.

Keywords: Endodontics; Lasers; Root Canal Preparation; Ultrasonic; XP Endo Finisher

Introduction

Elimination of residual microorganisms, necrotic pulp, dentin debris and the smear layer is a prerequisite for the success of endodontic treatment [1]. During endodontic instrumentation, debris and the smear layer are found on the root canal walls [2]. The smear layer can prevent penetration of the disinfecting agents and sealer within the root canal into the dentinal tubules, resulting in microleakage between the root canal filling materials and the root canal walls [3]. Therefore, elimination of the smear layer results in an increase in the interfacial area between the root canal filling materials and root canal walls [4]. If the smear layer is properly eliminated, the sealer can penetrate into the dentinal tubules, attacking the remaining microorganisms, which gives rise to a proper seal [5].

It has been demonstrated that manual irrigation alone is not sufficient for elimination of debris and the smear layer [6] because the conventional manual irrigation technique of the root canal with the use of conventional syringes delivers the irrigation solutions to a maximum of 1 mm beyond the needle tip. The Vaper Lock system which provides deeper placement of needle into canal and with its sufficient flow rate makes air bubbles

entrapment in the apical part of a root canal, delivers the irrigation solution to the apical third of the root canal more efficiently [7, 8]. Therefore, root canal disinfection strategies should be able to deliver the irrigation and disinfecting solutions more actively into the root canal system [9]. Different active systems have been proposed to improve the effects of irrigation solutions. Some of these techniques include ultrasonic, sonic, negative apical pressure and laser techniques [10-13]. XP Endo Finisher file is a new file which has recently been introduced for use in the final stage of irrigation for the destruction and removal of bacterial biofilms [9]. In addition to chemomechanical preparation of the root canal, hermetic three-dimensional filling of the root canal is also considered a key factor in successful endodontic therapy. During root canal filling, penetration of root canal sealer into the dentinal tubule is necessary because it increases the connection between the core material and dentin, thereby helping to optimize the adaptability and sealing capability of the root canal filling [9].

Based on the available data, no study has ever evaluated the effect of XP-Finisher file on the penetration of sure seal root sealer (calcium silicate-based) into the dentinal tubules. Therefore, the present study was undertaken to compare the effects of final agitation of 5.25% sodium hypochlorite (NaOCl) with XP-Finisher file, passive ultrasonic irrigation (PUI), Er:YAG laser and conventional needle irrigation (CNI) (manual syringe) techniques on the penetration of a bioceramic sealer into the dentinal tubules.

Materials and Methods

A total of forty freshly extracted single-rooted human teeth were selected for 4 groups (n=10) in the present *in vitro* study which was conducted in Dental School, Department of Endodontics, Tabriz University of Medical Sciences. Teeth with caries, cracks, internal or external resorption, calcified root canals or root canal curvatures of >20° were excluded from the study.

After selecting the tooth samples and their final approval for inclusion in the study, the external surfaces of all the teeth were cleaned of PDL tissues with the use of scalers and an ultrasonic device. Then the samples were stored in chloramine T solution (Merck, Darmstadt, Germany) until they were prepared for the study.

All the teeth were cut from the coronal portion with a diamond disk to achieve a standard length of 12 mm in order to facilitate the preparation and drilling procedures [9].

After preparation of the access cavity, a 25 mm #10 K-file (FKG Dentaire, La Chaux-de-Fonds, Switzerland) was inserted into each root canal, so that it was visible at the apical foramen. The working length was determined at 1 mm short of the apical foramen. All the teeth underwent a filing procedure with BioRace files (FKG Dentaire, La Chaux-de Fonds, Switzerland) up to 40/0.04 file using the crown-down technique. The root canals were irrigated with 2 mL of 5.25% NaOCl (Cerkamed, Stalowa Wola, Poland) among each instrument alterations. A final wash was performed using 5 mL of 17% EDTA (Cerkamed, Stalowa Wola, Poland) for 1 min and 5 mL of 5.25% NaOCl for 1 min with the use of a 30-G needle (Cerkamed, Stalowa Wola, Poland) connected to a syringe and apico-coronal movements up to 1 mm from the apex.

Subsequent to the completion of chemomechanical preparation, the teeth were randomly assigned to 4 groups (n=10) in terms of the agitation protocol: Group 1; Root canal irrigation with a routine 30-G needle in a syringe, group 2; Agitation with passive ultrasonic irrigation, group 3; Agitation with Er:YAG laser and group 4; Agitation with XP-Finisher rotary file.

In group 1, irrigation was carried out with the use of 5 mL of 5.25% NaOCl continuously for 30 sec with the use of a 30-G needle in a syringe, using up-and-down movements.

In group 2, 5.25% NaOCl was delivered to the apical third with the use of #20 ultrasonic U file (Dentsply Maillefer, Ballaigues, Switzerland) for 30 sec. In addition, the power of the ultrasonic device (NSK, various 320, Japan; 30 kHz) was set at 3 to agitate this irrigation solution.

In group 3, 5.25% NaOCl was transferred to the apical area by use of 30-G needle connected to syringe and agitated using Er:YAG (Fidelis AT, Fotona, Ljubljana, Slovenia) laser beams at a power of 0.3 W, 20 mJ and a frequency of 15 Hz, according to manufacturer's instructions. In this technique, the laser beam was delivered to 3 mm from the apex with the use of a 200-μm flexible endodontic fiber tip and NaOCl was agitated in 4 cycles at 10-second intervals for 5 sec in each cycle with apico-coronal movements parallel to the long axis of each tooth [14].

In group 4, 5.25% NaOCl transferred to the apical area was agitated using apico-coronal movements of the Xp-Finisher (FKG Dentaire, Switzerland) for 1 min at a distance of 1 mm from the apical foramen (according to manufacturer's instruction).

After the agitation procedure, the root canals in all the groups were first dried with tapered paper cones (Ariadent, Asia Chemi Teb Co, Tehran, Iran) and The Sure Seal Root bioceramic sealer (SureDent Corporation, Seongnam, Korea) was delivered to the canal using its injecting tip and then the single matched bioceramic-coated cone (master cone) was inserted into canal. Then the cone was cut off at the level of the orifice and lightly condensed with a plugger (Single cone obturation technique).

Figure 1. Vertical dissection of the teeth can be seen

Figure 2. Covering of the samples with a layer of gold for SEM analysis was done

After completion of obturation, the coronal access was covered with utility wax and the teeth were incubated at 37°C and 100% relative humidity for 14 days to ensure sealer setting. In order to determine the depth of penetration of bioceramic sealer into the dentinal tubules, first two vertical notches were created on the teeth. Then the teeth were separated into two halves with the use of a non-cutting plier (Figure 1). Then the teeth were gently tried and covered with a layer of gold/palladium for SEM analysis (Figures 2) [14]. The maximum penetration of the sealer into the dentinal tubules was determined using the SEM technique (SEM 440 I, LEO Electron Microscopy, Cambridge, UK) in the coronal, middle and apical thirds. Each part of specimen (include both halves) was examined under low magnification 100× to obtain an overall view and an area with a maximum density of sealer penetration was selected. The maximum depth of sealer penetration in this area (in μm) was measured using the microscope's calibrated measuring tool under 1000× magnification (Figure 3).

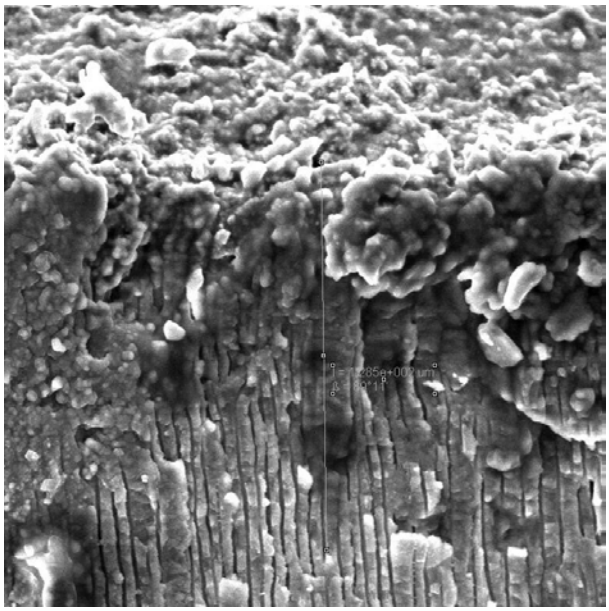

Figure 3. Measurement of sealer penetration into dentinal tubules was done by using the microscope's calibrated measuring tool under 1000× magnification

A calibrated and blinded specialist scored the presence and density of sealer tags using the following scale: absent, few sealer tags in tubules, sealer tags in the majority of tubules. After measurement, data were compared between the study groups.

Analysis of Data

Data were analyzed with SPSS version 17 (SPSS, Chicago, IL, USA). The normal distribution of data was confirmed with the Shapiro-Wilk test. Data were reported with the use of descriptive statistical methods (means of values in μm ± standard deviations). One-way ANOVA was used to compare the extent of penetration of the sealer between different techniques. Tukey tests were used for two-by-two comparisons of the groups. Statistical significance was set at $P<0.05$.

Results

The one-way ANOVA showed significant differences in the extent of penetration of bioceramic sealer into the dentinal tubules between the 4 study groups in the coronal, middle and apical thirds ($P<0.001$).

In the apical, middle and coronal thirds, the deepest penetration of bioceramic sealer into the dentinal tubules was observed in the passive ultrasonic irrigation (PUI) group (Table 1).

In the apical third there were no significant differences in the pentation of sealer into the dentinal tubules between the CNI and XP-Finisher file group ($P=0.752$), CNI and Er:YAG laser groups

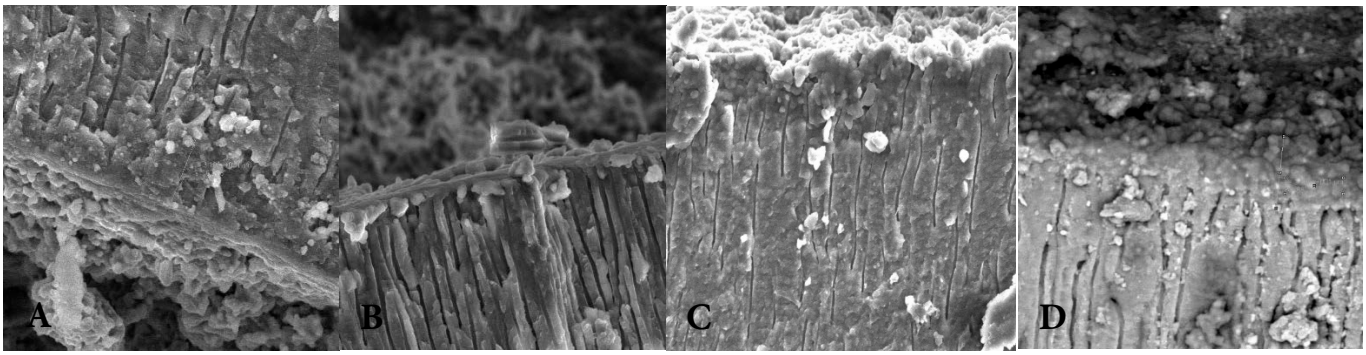

Figure 4. SEM analysis at 1000× magnification can be seen for the determination of the penetration of bioceramic sealer into the dentinal tubules in the apical third after agitation with *A*) Passive ultrasonic irrigation; *B*) 30-G needle in a syringe; *C*) XP-Finisher file; *D*) Er:YAG laser

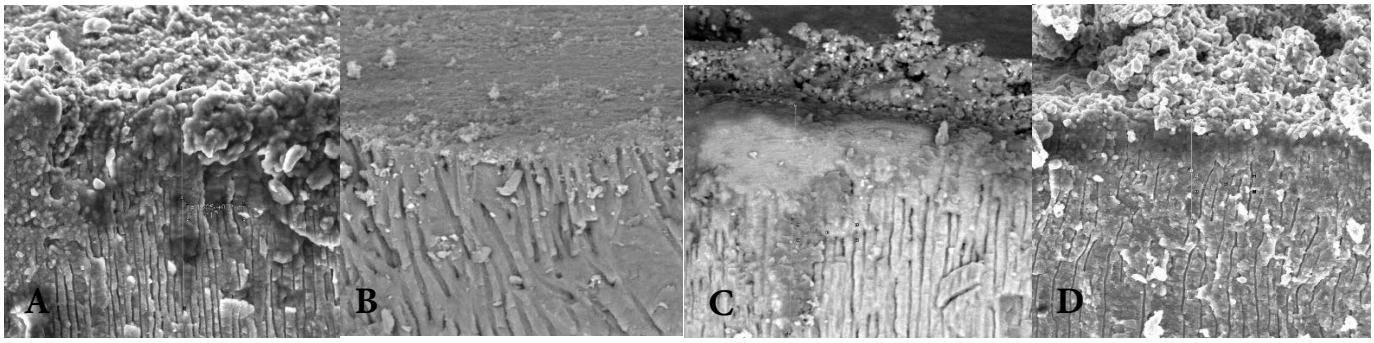

Figure 5. SEM analysis at 1000× magnification for the determination of penetration of bioceramic sealer into the dentinal tubules in the middle third after agitation with: *A*) Passive ultrasonic irrigation; *B*) 30-G needle in a syringe; *C*) XP-Finisher file; *D*) Er:YAG laser ,can be seen.

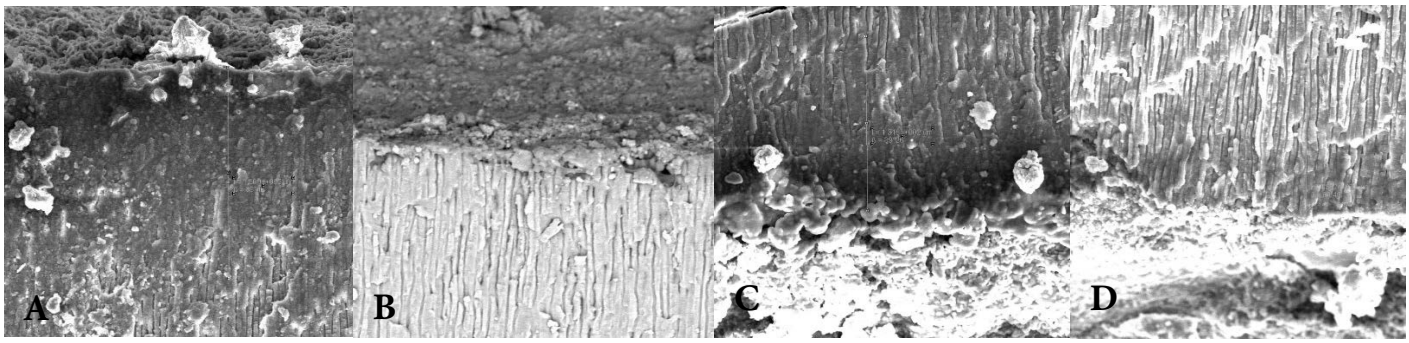

Figure 6. SEM analysis at 1000× magnification for the determination of pentation of bioceramic sealer into the dentinal tubules in the coronal third after agitation with: *A*) Passive ultrasonic irrigation; *B*) 30-G needle in a syringe; *C*) XP-Finisher file; *D*) Er:YAG laser can be seen.

(*P*=0.086), XP-Finisher file and Er:YAG laser groups (*P*=0.477), Er:YAG laser and PUI groups (*P*=0.078). The differences in the penetration of sealer into the dentinal tubules between the CNI and PUI groups (*P*<0.001), PUI and XP-Finisher file group were statistically significant (*P*=0.002) (Table 2).

In the middle third, there were no significant differences in the penetration of the sealer into the dental tubules between the CNI and XP-Finisher file groups (*P*=0.339), XP-Finisher file and Er:YAG laser groups (*P*=0.494). There were significant differences in the penetration of the sealer into the dentinal tubules between the CNI and Er:YAG laser groups (*P*=0.018), CNI and PUI groups (*P*<0.001), Er:YAG laser and PUI groups (*P*=0.003), PUI and XP-Finisher file groups (*P*<0.001) (Table 2).

In the coronal third there were significant differences in the penetration of the sealer into the dentinal tubules between the CNI and XP-Finisher file groups (*P*=0.022), CNI and Er:YAG laser groups (*P*=0.033), CNI and PUI groups (*P*<0.001), Er:YAG laser and PUI groups (*P*=0.001), PUI and XP-Finisher file groups (*P*=0.002).There was no significant difference in the penetration of the sealer into the dentinal tubules between the XP-Finisher file and Er:YAG laser groups (*P*=0.999) (Table 2).

Figures 4, 5 and 6 demonstrate the penetration of bioceramic sealer into the dentinal tubules in the 4 study groups in the apical, middle and coronal third respectively with the use of SEM analysis.

Discussion

In the present study, four different agitation techniques were compared in relation to their effect on the penetration of a bioceramic sealer into the dentinal tubules. These techniques consisted of agitation of the irrigation solution with a conventional syringe, PUI, XP-Finisher file and Er:YAG laser. Based on the results, the mean extent of penetration of the sealer into the dentinal tubules in the apical, coronal and middle thirds in the PUI group was greater than that of the other groups. In addition, PUI resulted in significantly more penetration of the sealer into the dentinal tubules in the coronal and middle thirds compared to the Er:YAG laser; however, the difference between the two techniques was not significant in the apical third.

The results of a study by Gu *et al.* [14] showed the highest penetration of sealer into the dentinal tubules in the Nd:YAP laser group compared to V-Clean endodontic, sonic and ultrasonic techniques and routine irrigation with a syringe. However, a significant difference was only observed at a distance of 8 mm from the apex, with no significant difference at 2- and 5-mm distances from the apex The results of the study above in the apical third are consistent with those of the present study; however, in the middle and coronal thirds, there are some differences between the results of these two studies, which might be attributed to the difference in the laser types used in the two studies. In this context, in the study by Gu *et al.* [14], Nd:YAP laser was applied and in the present study Er:YAG lase was used. Use of Er:YAG laser requires a water spray to prevent excessive heat production; this decreases the concentration of the irrigation solution Therefore, in the present study the effect of Er:YAG on the penetration of sealer was less than that of the ultrasound technique.

Study of Guimarães *et al.* [15] showed that dentinal tubule penetration of AH-plus, AH-26 and Acroseal sealers, were significantly higher in PUI group compared to conventional needle irrigation A study of Akcay *et al.* [16] comparing dentinal tubule penetration of different sealers including bioceramic and resin type, with different agitation protocols, showed that the iRootSP (bioceramic sealer) with the PUI and the Er:YAG Laser

Table 1. The means and standard deviations of the maximum penetration of bioceramic sealer into the dentinal tubules in the coronal, middle and apical thirds in the 4 study groups **(µm)**

Group	Apical	Middle	Coronal
Conventional irrigation	1.10 (1.29)	11.40 (8.00)	10.00 (7.09)
XP file	5.50 (4.97)	23.70 (11.88)	42.50 (25.02)
Er:YAG laser	11.90 (6.47)	34.00 (16.46)	40.80 (17.29)
Passive ultrasonic	22.90 (17.92)	61.10 (23.64)	84.20 (36.34)
***P*-value**	<0.001	<0.001	<0.001

Table2. *P*-Value of comparing of 4 study groups for apical, middle, coronal thirds in the terms of extent of penetration of bioceramic sealer

Dependent variables	Group (i)	Group (j)	*P*-value
Apical	Conventional	Xp-FInisher	0.752
		Laser Er:YAG	0.086
		PUI	<0.001
	Xp-FInisher	Conventional	0.752
		Laser Er:YAG	0.477
		PUI	0.002
	Laser Er:YAG	Conventional	0.086
		Xp-FInisher	0.477
		PUI	0.078
	PUI	Conventional	<0.001
		Xp-FInisher	0.002
		Laser Er:YAG	0.078
Middle	Conventional	Xp-FInisher	0.339
		Laser Er:YAG	0.018
		PUI	<0.001
	Xp-FInisher	Conventional	0.339
		Laser Er:YAG	0.494
		PUI	<0.001
	Laser Er:YAG	Conventional	0.018
		Xp-FInisher	0.494
		PUI	0.003
	PUI	Conventional	<0.001
		Xp-FInisher	<0.001
		Laser Er:YAG	0.003
Coronal	Conventional	Xp-FInisher	0.022
		Laser Er:YAG	0.033
		PUI	<0.001
	Xp-FInisher	Conventional	0.022
		Laser Er:YAG	0.999
		PUI	0.002
	Laser Er:YAG	Conventional	0.033
		Xp-FInisher	0.999
		PUI	0.001
	PUI	Conventional	<0.001
		Xp-FInisher	0.002
		Laser Er:YAG	0.001

agitation group had the highest penetration rate among the other agitation techniques The results of these studies are consistent with those of the present study; that agitation with PUI had higher penetration rate than other agitation group.

The smear layer produced by mechanical preparation can prevent penetration of the disinfecting agents and sealer within the root canal into the dentinal tubules, resulting in microleakage between the root canal filling materials and the root canal walls [17]. Therefore, elimination of the smear layer results in an increase in the interfacial area between the root canal filling materials and root canal walls [14]. Some studies have shown that the effects of irrigation solutions in terms of smear layer removal can be promoted by agitation techniques [3, 10, 14, 15] .One of the agitation techniques used in the present study was the XP-Finisher file technique, which has recently been introduced as an adjunctive technique to improve the efficacy of intracanal irrigation [18]. This instrument expands at body temperature and its winding motion within the root canal results in its contact with the residual debris within the root canal and its elimination [18]. In a study by Zand *et al.* [18], a combination of 2.5% NaOCl and 17% EDTA, agitated with XP-Finisher file exhibited the best efficacy in the removal of the smear layer in the coronal third. In addition a study by Elnaghy *et al.* [19] showed that irrigation of curved root canals with XP-Finisher file and Endo Activator techniques was more effective in the removal of the smear layer and debris in the positive control groups and groups with and without file agitation The results of a study by Azim *et al.* [9], too, showed a better effect of the XP Endo Finisher system compared to PIPS and Endo Activator techniques and irrigation with a standard syringe and needle on disinfecting the principal root canal and up to 5 mm into the dentinal tubules.

In the present study, the PUI technique resulted in a significant increase in the penetration depth of the sealer into the dentinal tubules compared to the XP-Finisher file technique. Several studies have evaluated the efficacy of these two systems in removing the smear layer, the bacterial biofilms and calcium hydroxide from the root canals witch can be effective in penetrating the sealer into the dentinal tubules and then reducing microleakage. For example, Xin *et al.* [20] reported a minor difference in the removal of the smear layer between these two techniques. Studies by Kfir *et al.* [21] and Wigler *et al.* [22] did not reveal any significant differences between these two techniques in the removal of calcium hydroxide from the root canals [22]. However, a study by Hamadan *et al.* [23] showed better efficacy of XP-Finisher file technique in removing calcium hydroxide from the apical third compared to the PUI technique. In contrast, Donnermeyer *et al.* [24] reported that he sonic and PUI techniques were significantly more effective in eliminating calcium hydroxide from the apical area compared to XP-Finisher file technique A study by Sasanakul *et al.* [25] showed that the XP-Finisher file technique resulted in the formation of fewer bacterial colonies compared to the PUI technique. In addition, Bao *et al.* [26], too, showed that the XP-Endo Finisher file and PUI techniques were the most effective in eliminating bacterial biofilms, respectively.

It can be concluded from the results of the studies above that the XP-Finisher file system is more effective than the PUI system in eliminating bacterial biofilms. However, only a number of studies have compared the ability of these two techniques to eliminate the smear layer and the ability of the sealer to penetrate into the dentinal tubules with application of these two techniques; therefore, it is advisable to carry out studies to compare these two technique and achieve conclusive results.

Apart from the importance of the agitation technique in cleaning the root canal system, the ability of the sealer to penetrate into the dentinal tubules is also important because this ability of the sealer results in a hermetic seal, preventing the penetration of microorganisms and their toxins [27-29]. In the present study a type of calcium silicate-based bioceramic sealer, Sure Seal Root, was used.

These bioceramic sealers, exhibit greater ability to penetrate into the dentinal tubules compared to AH-Plus sealer, which is attributed to their higher flowability and small particle sizes. These types of sealers has been designed to harden when exposed to humidity containing 20% water in dentinal tubules [30-33]. It is obvious that if a proper agitation technique and a sealer with a high capacity to penetrate into the dentinal tubules is used, it will be possible to minimize leakage and the incidence of infection in the root canal system.

The Limitation of the present study mostly attributed to complicated process of SEM evaluation technique, including difficulty in sample preparation, in observation of dentinal tubules and sealer tags, and precise measurement of penetration depth of sealer into dentinal tubules. Using Confocal Laser Scanning Microscope could have overcome these limitations.

Conclusion

The PUI technique resulted in significantly greater penetration of the bioceramic sealer into the dentinal tubules compared to the three other techniques. The XP-Finisher file irrigation technique in the apical and middle thirds and the Er:YAG laser technique in the coronal and middle thirds did not exhibit any significant differences from the conventional irrigation technique.

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Conflict of Interest: 'None declared'.

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