Effect of advanced irrigation protocols on self-expanding Smart-Seal obturation system: A scanning electron microscopic push-out bond strength study

Vibha Hegde, Shashank Arora

Abstract

Introduction: The aim of this study was to evaluate the effect of different final irrigation activation techniques affect the bond strength of self-expanding Smart-Seal obturation at the different thirds of root canal space. **Materials and Methods:** One hundred single-rooted human teeth were prepared using the Pro-Taper system to size F3, and a final irrigation regimen using 3% sodium hypochlorite and 17% EDTA was performed. The specimens were randomly divided into five groups (n = 20) according to the final irrigation activation technique used as follows: No activation (control), manual dynamic activation (MDA), CanalBrush activation, ultrasonic activation (UA) and EndoActivator. Five specimens from each group were subjected to scanning electron microscopic observation for assessment of the smear layer removal after the final irrigation procedures. All remaining roots were then obturated with Smart-Seal obturation system. A push-out test was used to measure the bond strength between the root canal dentin and Smart-Seal paste. The data obtained from the push-out test were analyzed using two-way analysis of variance and Tukey *post-hoc* tests. **Conclusions:** It was observed that UA improved the bond strength of Smart-Seal obturation in the coronal and middle third and MDA/EndoActivator in the apical third of the root canal space.

Keywords: Push-out bond strength, self-expanding, Smart-Seal system

Introduction

The ultimate goal of root canal treatment is the efficient disinfection of the root canal system and the aversion of reinfection.[1] A cumulation of mechanical preparation with an efficacious irrigating regimen, the utilization of intracanal medicaments between appointments and obturation of the root canal system are implements that can be habituated to procure this goal.[2,3] Following chemomechanical preparation, a smear layer 1- to 2-mm-thick is composed on the root canal walls. It consists of inorganic dentin debris and organic substances containing fragments of odontoblastic processes, microorganisms, their byproducts, and necrotic pulp tissues.[4] This smear layer is responsible for harboring remnants of necrotic pulp tissues along with biofilms. Residual biofilms can accommodate as a potential source of sedulously assiduous infection and treatment failure.[5] In additament, the smear layer could inhibit penetration of the root canal irrigation solutions and medicaments into dentinal tubules.[6] Moreover, it has been betokened that abstraction of the smear layer may increase the bond strength of filling material to canal walls.[7] However, Saleh *et al*.[8] verbalized that the penetration of the endodontic sealers into the dentinal tubules when the smear layer was abstracted was not associated with higher bond strength. The irrigation of the root canal is an essential procedure in the endodontic treatment for the abstraction of the smear layer. Currently, the alternate utilization of sodium hypochlorite and EDTA irrigants is recommended to abstract both the inorganic and organic components of the smear layer.[9] It was verbally expressed that the efficacy of irrigants is associated with their direct contact with the entire canal wall. However, this might not be achieved with conventional needle irrigation because of the intricate nature of root canal anatomy.[10] Different irrigation activation techniques have been proposed to amend the efficacy of irrigation solutions within the root canal system. These techniques include activation with Gutta-percha cones, lasers, brushes, negative pressure irrigation technique, and sonic and ultrasonic contrivances.[11] Because dentin surface treatment with different irrigation regimens causes alteration in the chemical and structural composition of human dentin, the permeability and solubility

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Access this article online	
Quick Response Code:	Website: www.contempclindent.org
	DOI: 10.4103/0976-237X.149287

characteristics of dentin may change[12,13] and hence affect the adhesion of filling materials to dentin surfaces.[14] Various studies have been performed regarding the effect of different final irrigation regimens on the bond strength of canal filling materials. According to the results of the studies, authors claim that final irrigating protocols impact the adhesion of sealers to root dentin.[15-18] The bond strength of on obturation system on setting in the root canal space depends on the opening of the dentinal tubules present, which in-turn would allow penetration of the sealer deeper into the root canal. Greater the penetration of the sealer into the dentinal tubules better would be the bond strength of the obturation system. Hydrophilic obturation systems have shown to bond better to the root canal dentin. Thus, in the wake of this concept, the most recent advancement in endodontic obturating materials uses a hydrophilic polymer in the root canal, The Smart-Seal system (Prosmart-DRFP Ltd., Stamford, UK). The system consists of obturation points (Pro-points) containing a polyamide core with an outer bonded hydrophilic polymer coating and an accompanying sealer, which is further provided with polymer powder to be incorporated during the manipulation of the sealer. The endodontic points are designed to expand laterally without expanding axially by absorbing residual water from the instrumented root canal space and the naturally present moisture in the dentinal tubules.[19] Currently, there is no literature addressing the effect of various irrigation protocols on the bond strength of novel Smart-Seal system. Smart-Seal system having advantageous properties of hydrophilicity and self-expanding nature.

Materials and Methods

Tooth selection and specimen preparation

Totally, 100 extracted single-rooted human teeth with fully formed apices and similar root length from the cement-enamel junction to the root apex were selected for this study and were stored at 4°C in a saline solution. Preoperative mesio-distal and bucco-lingual radiographs were taken to verify the presence of a single canal. Criteria for tooth selection included a completely formed apex and the absence of previous root filling, resorption, or calcifications. The length of the teeth was standardized at 20 mm by trimming the crowns of teeth with silicon carbide abrasive paper. The teeth were completely not de-coronated, and the crowns served as a reservoir for the irrigation solution. Endodontic access cavities were prepared using diamond burs (Diatech; Coltene Whaledent, Altststten, Switzerland) with a high-speed hand piece under water cooling. A #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into each canal until its tip was just visible at the apical foramen, and the length was measured. The working length (WL) was established by subtracting 1 mm from this measurement. To prevent the escape of irrigants from the root apex by simulating a clinical situation, the apex was sealed with melted wax (Modeling Wax; Dentsply DeTrey, Weybridge, UK). The root canals were prepared using the Pro-Taper rotary instruments (Dentsply Maillefer) to a size 30, 0.06 taper (F3) to the WL. Between the use of each instrument, the canals were irrigated with 2 mL 3% NaOCl solution using a syringe and 29-G needle (NaviTip; Ultradent, South Jordan, UT, USA).

After completion of the chemomechanical preparation, specimens were randomly divided into 1 control group and 4 experimental groups ($n = 20$). A description of the treatment of each group follows:

No-activation group (control) ($n = 20$) – A final irrigation was performed with 5 mL 3% NaOCl followed by 5 mL 17% EDTA using a syringe and a 27-G needle placed 1 mm short of the WL. No additional activation of irrigants was performed.

Manual dynamic activation (MDA) group ($n = 20$) – The canals were flooded with 5 mL 3% NaOCl followed by 5 mL 17% EDTA, and each irrigant was activated manually to the WL using a size F4 (Dentsply Maillefer) Gutta-percha cone. The frequency of activation used was 100 push-pull strokes per minute. Four Gutta-percha cones per root canal were used.

CanalBrush (CB) group ($n = 20$) – Activation of 5 mL 3% NaOCl and 5 mL 17% EDTA was performed using a CB with a tip diameter of 0.25 mm (Coltene Whaledent) in a hand piece set at 600 rpm. The brush was used with a gentle up-and-down motion at 1 mm from the WL. One CB per root canal was used.

Ultrasonic activation (UA) group ($n = 20$) – In this group, 5 mL 3% NaOCl and 5 mL 17% EDTA were each passively activated using an ultrasonic device. A smooth ultrasonic file (size 15, 0.02 taper) (ESI Instrument, EMS) was placed into the canal to 1 mm short of the WL without touching the walls, enabling it to vibrate freely. The ultrasonic file was activated at a power setting of 5. One ultrasonic tip was used for 5 root canals.

EndoActivator group ($n = 20$) – In this group, 5 mL 3% NaOCl and 5 ml 17% EDTA were each passively activated using EndoActivator. The activator tip was inserted till 1 mm of the WL without touching the walls, enabling it to vibrate freely.

The activation time for each irrigant was 1 min. The total working time for NaOCl and EDTA was 2 min for all groups. Finally, the specimens were irrigated with 5 mL distilled water to prevent further irrigant action. The total irrigation volume for final irrigation procedures was 15 mL for all groups.

Scanning electron microscopy examination after final irrigation activation procedures

Five specimens from each group were left for scanning electron microscopic (SEM) (Leo-440; Leo Electron Microscopy, Cambridge, England) observation of the smear layer removal after final activation procedures. Grooves were prepared with a water-cooled diamond bur on the buccal and lingual surfaces of the teeth, and the teeth were split along their long axis in a buccolingual direction using a diamond disk. For SEM analysis, the samples were dehydrated and coated with gold-palladium particles (20 nm). Three photomicrographs were taken from the coronal, middle, and apical thirds of the root canals at 2000x magnification to evaluate the cleanliness of the canal walls [Figure 1].

Root canal obturation

Twenty specimens in every group, the canals were dried with paper points (Dentsply Maillefer). All canals were then obturated with a smart paste sealer which was mixed with the polymer powder provided, and F3 propoint obturating cones using the single-cone technique. Mesiodistal and buccolingual radiographs were taken to confirm complete filling. After root filling, the coronal 1 mm of the filling materials was removed from each specimen, and the space in each was filled with a temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). Subsequently, all specimens were stored at 37°C in 100% humidity for 2 weeks.

Push-out testing

Each root was cut horizontally at a slow-speed using a water-cooled diamond saw (Isomet; Buehler, Lake Bluff, IL, USA) at depths of 4, 7, and 10 mm to produce slices approximately 1-mm thick rom each root region (i.e. apical, middle, and coronal). The thickness of each slice was measured using a digital caliper (Teknikel, Istanbul, Turkey) to an accuracy of 0.001 mm. Both the apical and coronal aspects of the specimens were then microscopically examined to confirm a circular canal shape.[19] All slices were then scanned, and the diameters of filling materials measured using an electronic scale in software (Adobe Photoshop) to determine the diameters of plungers to be used for the push-out test. The push-out test was performed in a universal testing machine (Instron Corp., Canton, MA, USA) by applying a continuous load to the apical side of each slice using 0.7-, 0.8-, and 0.9-mm diameter cylindrical plungers, respectively, matching the diameter of each canal third. The diameter of plungers was approximately 80% of the canal diameters. Loading was applied at a crosshead speed of 1 mm/min from the apical to the coronal direction until bond failure occurred. The maximum load applied to filling material before failure was recorded in newton and converted to megapascal (MPa) according to the following formula:

Push-out bond strength MPa = N/A

Where N = maximum load (N) and A = adhesion area of root canal filling (mm^2).

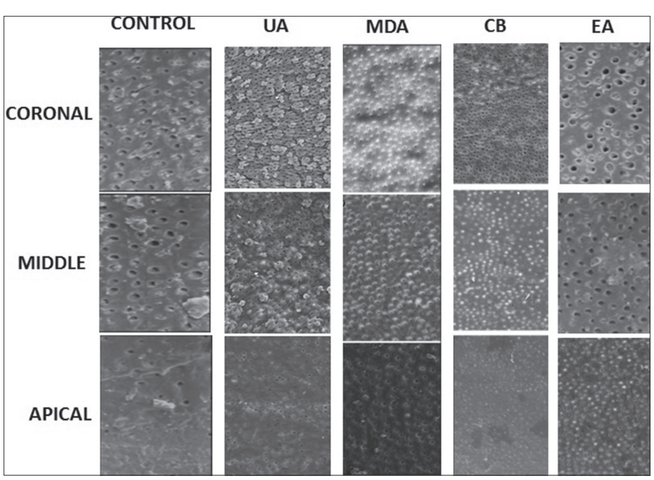

Figure 1: Scanning electron microscopic image analysis at ×2000

Statistical analysis

The Kruskal–Wallis test was used to detect the effect of final irrigation activation techniques in the removal of the smear layer. Multiple comparisons were performed using the Mann–Whitney U-test. Two-way analysis of variance was used to detect the effect of the independent variables, final irrigant activation techniques (control, UA, CB, and MDA) and root canal thirds (coronal, middle, and apical), and their interaction on push-out bond strength. The Tukey *post-hoc* test was performed for multiple comparisons. The significance level was set at $P < 0.05$. All statistical analyses were performed using SPSS 16.0 software (SPSS Inc., Chicago, IL, USA) [Table 1].

Results

The removal of smear layer

The Kruskal–Wallis statistic showed a significant difference among the groups with respect to the smear layer ($P < 0.05$). The Mann–Whitney statistic showed that the UA group had a higher number of open dentinal tubules in the coronal and middle thirds when compared with the other groups ($P < 0.05$). Also, the MDA group had a higher number of open dentinal tubules in the apical third than the other groups ($P < 0.05$).

Push-out bond strength test

Mean bond strength values (MPa) after the push-out tests are shown in Figure 2. Two-way analysis of variance indicated that push-out bond strength values were significantly affected by both final irrigant activation techniques ($P < 0.05$) and root

Table 1: Push-out bond strengths of all groups in Coronal, Middle and Apical Third

	MPa		
	Coronal	Middle	Apical
Control	6.38	5.43	2.12
UA	8.93	7.12	3.76
MDA	7.78	6.23	4.96
CB	6.54	4.33	3.34
EA	7.56	5.43	4.52

MPa: Megapascal; MDA: Manual dynamic activation; UA: Ultrasonic activation; CB: Canal brush; EA: Endo activator

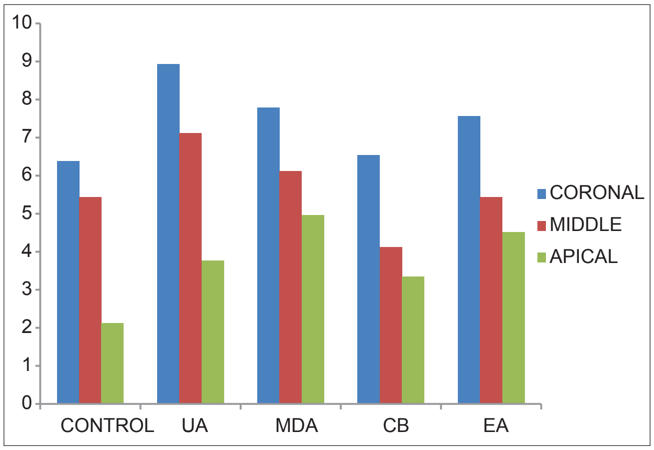

Figure 2: Graph comparing the push-out bond strengths of all groups in Coronal, Middle and Apical Third

canal thirds ($P < 0.001$). There was a statistically significant interaction between final irrigant activation techniques and root canal thirds ($P < 0.05$). The coronal third had higher bond strength values than the middle third and the apical third ($P < 0.001$). The middle third had higher bond strength values than the apical third ($P < 0.001$). In the coronal third, the bond strength in the UA group was higher than those in the control group ($P = 0.010$), CB ($P = 0.007$), and MDA groups ($P = 0.002$). In the middle third, the bond strength in the UA group was higher than those of the others ($P < 0.001$). In the apical third, the bond strength in the MDA group was higher than those in the control ($P < 0.001$), UA ($P = 0.002$), and CB groups ($P < 0.001$).

Discussion

In root canal obturation procedures, sealers are used to attain an impervious seal between the core materials and root canal walls. The high bond strength of a root canal sealer to intraradicular dentin through micromechanical retention or frictional resistance may be advantageous in maintaining the integrity of the sealer-dentin interface.[20] Chemical adhesion between the dentin and sealer (with the exception of glass ionomer sealers) cannot be achieved. Therefore, it has been suggested that the mechanical interlocking of the sealer plug inside the dentinal tubules after smear layer removal may improve the dislocation resistance of root filling materials.[21] Dentin surface treatment with endodontic irrigants may affect the adhesion of sealers on root canal walls[22] because irrigants can alter the dentin surface composition.[12] The null hypothesis was accepted based on the results of the present study. In the present study, the bond strength primarily decreased in the coronal to apical direction. This result is comparable with results from several studies showing that the adhesion of root sealers generally decreased in the coronal to apical direction.[23,24] This can be explained by the decreasing tubule density from coronal to apical, which reduces sealer penetration into the smaller tubule diameter in the apical thirds.[25,26] The lack of access to the apical region of irrigation solutions and the consequent incomplete removal of the smear layer may decrease the penetration of the sealer into dentinal tubules and may thereby affect adhesion in the apical region.[27] In this sense, enhancing direct contact of the final irrigation solution with the entire canal wall can be helpful in improving the adhesion of sealer. Therefore, the present study focused on determining whether or not the bond strength of Smart-Seal system improves after different final irrigant activation techniques, especially in the apical region.

Smart-Seal system (Prosmart-DRFP Ltd., Stamford, UK) consists of polyamide polymer cones (Propoints) and a resin sealer with additional polymer powder to be mixed during manipulation of the sealer. The white points consist of a radiopaque core, coated with a radiopaque hydrophilic polymer which can expand laterally upon absorbing water from the tooth, adopting the shape of the canal. The points can expand up to around 17% and will still give the same X-ray appearance as with conventional root filling materials.[28] A correlation between the bond strength and penetration of the sealer has been unproven, the effective removal of the smear layer may improve the adhesion of AH Plus sealer with increased penetration of AH Plus sealer into dentinal tubules. It has been stated that good penetration, adaptation, and adhesion properties will have a positive effect on sealing because of the increased surface contact between the sealer and dentin.[29] McGill *et al*.[30] stated that the push-pull motion of a well-fitting Gutta-percha point in the canal space might generate higher intracanal pressure changes during pushing movements, leading to more effective delivery of the irrigant to the “untouched” canal surfaces. Effective cleaning of the apical region can thereby be accomplished. The superior bond strength values of the MDA group in the apical region may be caused by increased sealer penetration depending on effective removal of the smear layer in the apical region. In the present study, bond strength values were higher in the apical third with the application of MDA or using UA as a final irrigation protocol. Higher bond strength values can also be attributed to the expansion mechanism seen with the Smart-Seal system which allows better sealer penetration into the surface treated dentinal tubules.

Conclusion

Under the conditions of this study, it can be concluded that the bond strength of Smart-Seal system to root canal dentin may improve with UA in the coronal and middle thirds and MDA/EndoActivator in the apical third. Further study is required to confirm this data and to investigate the bond strength of different root canal sealers after final irrigant activation protocols.

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How to cite this article: Hegde V, Arora S. Effect of advanced irrigation protocols on self-expanding Smart-Seal obturation system: A scanning electron microscopic push-out bond strength study. Contemp Clin Dent 2015;6:26-30.

Source of Support: Nil. **Conflict of Interest:** None declared.