The Effect of Different Final Irrigant Activation Techniques on the Bond Strength of an MTA-Based Endodontic Sealer- An *in Vitro* Study

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Abstract. Aim: We aimed to evaluate and compare the effect of EndoVac™ irrigation, EndoActivator™ irrigation, Laser activated irrigation (LAI), Passive Ultrasonic Irrigation systems (PUI), and Manual irrigation system on push-out bond strength of endoseal Mineral trioxide aggregate (MTA) sealer.

Settings and Design: *In vitro* study.

Methods and Materials: Twenty five single rooted anterior teeth were prepared using ProTaper system to size F4, and using 5.25%sodium hypochlorite (NaOCl) and 17% Ethylenediamine tetraacetic acid (EDTA) a final irrigation regimen was done and then divided randomly into 5 groups: Conventional needle, Apical negative pressure using EndoVac™, Sonic Activation using EndoActivator™, PUI, and LAI. All the teeth were dried using paper point and obturated using single cone obturation using Endoseal MTA sealer. A push-out test was used to measure the bond strength.

Results: The push out bond strengths of the conventional needle were lower compared to the other groups wherein different irrigation systems were used. However, a substantial increase was noted in EndoVac, EndoActivator, and PUI groups compared to the conventional needle group. The LAI system group showed no significant increase to the conventional group.

Conclusion: Different irrigation activation systems increased the bond strength of MTA sealer.

Keywords: Bond strength · Endoseal MTA sealer · Irrigation activation

1 Introduction

Mechanical preparation with effective irrigation along with intracanal medicament and obturation of root canal (RC) space is the aid that can be used to attain endodontic success [1]. Sodium hypochlorite (NaOCl) and Ethylenediamine tetraacetic acid (EDTA) are

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used as an irritant for removal of organic as well as inorganic contents of smear layer. It was stated that irrigants are more effective when they are in direct contact with the entire RC wall. Although, it might be difficult using conventional needle irrigation as the anatomy of RC is complex [2].

Several irrigation activation systems had been introduced to improve action of irrigation solutions in the RC system. The systems increase the ability of smear layer removal efficiently, increase the contact time with RC dentine wall, and improve the penetration of irrigating solution in complex RC structures [2].

Mineral trioxide aggregate (MTA) is a portland cement–derived hydraulic material that has been widely used in a variety of endodontic applications. The crystalline deposits produced by the interaction of MTA and physiological fluids positively influence the push-out bond strength of MTA [3]. Endoseal MTA which was recently proposed, is a finely pulverized pozzolan-based MTA sealer. Sealer has a fast setting time (about 12min), higher resistance to washout compared to other MTA's, alongwith biological effects which include bio-mineralization, bio compatibility, and odontogenic activity which are some of the favorable properties [4]. In spite of having good properties, many studies have shown that MTA-based sealer did not have adequate push-out bond strength and hence we aimed to evaluate pushout bond strength of Endoseal MTA sealer after using different irrigation activation systems.

2 Materials and Methods

2.1 Sample Selection and Preparation

Twenty five freshly extracted human permanent single rooted teeth were taken for this study with 75 sections. Tooth was verified radiographically for the single patent canal of curvature less than 5 degrees, fully formed apices, intact root with no cracks, no calcification, no internal resorption, or earlier RC treatment. Specimens were stored in 3% hydrogen peroxide solution for 10 min to remove organic debris which was adhered to external root surface of tooth and to disinfect samples, which were further cleaned up with an ultrasonic scaler to remove remnants of tissue tags. The samples were stored in 0.2% thymol solution until further use. To standardize samples, they were decoronated with the diamond disc in low-speed straight handpiece under a water coolant just enough to protect crown portion as a reservoir for irrigation solution and length was standardized to 21 mm.

2.2 Root Canal Instrumentation and Preparation

A size 10 K file was passed 1mm beyond apical foramen ensuring canal patency. The file which snugly fit at the apical foramen was selected for individual tooth and working length was established by subtracting 1mm from this length. Cleaning and Shaping were performed using Protaper Universal rotary File system till F4. In between instrumentation 5.25% NaOCl and 17% EDTA gel was used for lubrication.

Teeth were divided randomly into 5 groups, 5 teeth in each group and routine irrigation protocol was applied to all groups with activation of irrigant with respective systems:
Group A: Conventional needle irrigation control group (n = 15).

Irrigation by conventional needle.

Group B: EndoVac™ (n = 15).

Irrigation by EndoVac irrigation activation system.

Group C: EndoActivator™ (n = 15).

Irrigation by EndoActivator irrigation activation system.

Group D: Passive Ultrasonic Irrigation (n = 15).

Irrigation by Ultrasonic irrigation activation system.

Group E: Laser activated Irrigation (n = 15).

Irrigation by Laser irrigation activation system.

After final irrigation activation canals were irrigated with saline. A master gutta-percha of size F4 was selected and apical tug back was checked radiographically. RCs were dried with paper points. Endoseal MTA sealer was used according to the manufactures instruction where it was injected into RC and master cone was positioned into the canal. The tug back was confirmed again. A heated instrument was employed to cut gutta-percha off at RC entrance. The access cavity was sealed using Intermediate Restorative Material (IRM).

The radiographs were taken for each tooth to assess the obturation for any voids. All teeth were stored in a humidor at 37°C for 24 h for complete setting of sealer. From each group, 15 samples were made by cutting the tooth perpendicular to their long axis to obtain slices from coronal, middle, and apical portions (2 mm each) with a slow-speed diamond saw. The exact dimension of each disk was measured by a digital calliper to be within the range of 2 ± 0.04 mm. Samples displaying physical deformation signs were discarded immediately.

Then sections underwent a push-out test using a universal testing machine, calculating diameter of the canal using image analysis software the plunger sizes of different diameter ranging from 1 mm to 0.6 mm were selected. The maximum load applied to each sample was noted down. The push-out bond strength in MPa was analysed.

3 Statistical Analysis

The data were analyzed with Statistical Package for Social Sciences (SPSS) for Windows, version 25.0 (IBM Corp., Armonk, N.Y., USA). Confidence intervals were set at 95% and values of $p < 0.05$ were interpreted as statistically significant. One way ANOVA was used to compare bond push-out strength for different irrigation activation systems. Tukey's Post Hoc test was computed to analyze in between-group differences of 5 different irrigating activation systems.

4 Results

EndoVac showed the highest bond strength (8.841 ± 1.79) followed by PUI (7.856 ± 1.95), EndoActivator (7.641 ± 1.89), and Laser activation of irrigation (6.016 ± 1.24) (Table 1). The push-out bond strengths of control (conventional needle) were lower than other groups where in different irrigation systems were used. However there was a significant increase in the pushout bond strength only in EndoVac, EndoActivator, and passive ultrasonic groups compared to the conventional needle group. The laser irrigation system group did not show any significant increase than the conventional group (Table 2).

5 Discussion

Adhesion of RC filling to dentinal walls has great significance in dynamic and static conditions. During dynamic conditions, resistance to dislodgement of this material during subsequent manipulation is needed. While in a static situation, it must eliminate any space allowing percolation of fluids between the filling and the wall [5]. During chemo-mechanical preparation, a smear layer is generated which can serve as a reservoir or source for microorganisms. Due to this, it can block progression of sealer tags into dentin tubules, such that micromechanical adhesion is decreased [1]. Cleaning and shaping are more effective for the central portion of RC system and not so for anatomical complexities like canal fins, cul-de-sacs, accessory, and lateral canals and isthmi [2]. Activating irrigants facilitates their contact with canal complexities will effectively cause smear layer removal, eventually helping with improvement of obturating material adhesion with dentine wall.

Conventional needle irrigation is widely employed and effective to deliver irrigant to root canal before introduction of the various other systems. Various modifications like side vented tip design and smaller gauge of the needle to improve efficacy without extrusion of irrigant are made with conventional needle irrigation. However, these modifications have been ineffective. Limited action achieved with increased risk of periapical extrusion of the irrigating solution are disadvantages that led to the development of new activation systems [2].

EndoVac™ is based on the principle of pressure alteration in which negative pressure is created into the root canal which allows the continuous flow of fresh irrigant till the working length. The EndoVac system is regarded as an apical negative pressure irrigation system composed of three basic components: a Master Delivery Tip (MDT), the Macrocannula, and the Microcannula. The MDT delivers irrigant to the pulp chamber and evacuates the irrigant concomitantly. Both the macrocannula and microcannula are connected via tubing to a syringe of irrigant and the highspeed suction of a dental unit [6]. EndoActivator™ is based on the principle of sonic activation of root canal irrigant. A specialized disposable polymer tip of small,medium,large having yellow, red and blue colors respectively are used which 2–3 vertical strokes creates sonic vibrations with a strong hydrodynamic phenomenon 10,000cycles /min are given to encourage debridement [7]. PUI activation is based on ultrasonic energy, which is transferred from an oscillating file or a smooth wire into RC irrigant through ultrasonic energy that encourage mechanism of acoustic streaming and cavitation of irrigating solution in RC 5 mL of 5.25% NaOCl, then 5 mL of 17% EDTA and 5 mL of distilled water was used for irrigation of root canals. Each irrigant was agitated with an ultrasonic system handpiece, irri safe (Satelac) equipped with a size 25 IRRI Ssmoothwire at 2 mm short of the working length. The irrigation was ultrasonically applied to the root canals for 3 min in total along with 5 mL of 17% EDTA, 5 mL of 5% NaOCl, and 5 mL of distilled water for 1 min (3 cycles of 10s) for each irrigant according to manufactures instructions [3]. In laser-activated disinfection, photomechanical actions like bubble formation and cavitation generate in the irrigation solutions inside root canals when a laser is applied in a pulsative manner in the irrigant filled canal. This photomechanical action induces an effect like a shockwave, which results in Laser activated disinfection for the better activity of the irrigant. 5 mL of 5.25% NaOCl, 5 mL of 17% EDTA and 5 mL of distlled water was used for irrigation of root canals. Each irrigant was fully activated for 1 min (3 cycles of 20 s) with 1064-nm wavelength Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) laser (Fotona)at 1 W/cm2 Power (20 Hz Frequency, 50 mj/cm2 Energy density) with a pulse duration of 50 µs by a non-cooled handpiece with 300 µm optical fiber [8].

Adhesion is tested using many tests in dentistry among which push-out bond test is the most popular as it has certain advantages like sample preparation is effective and reproducible and also it can be evaluated in low values of bond strengths. The push-out test depends upon shear stresses at junction between cement and dentin, similar to the stress occurring in clinical conditions [9]. Our study showed mean push-out bond strength values to be maximum for EndoVac™ group followed by EndoActivator™, passive ultrasonic irrigation, laser, and conventional needle irrigation. Also, all irrigation activation systems showed a statistically significant difference when compared with conventional syringe irrigation.

Table 1. Comparison of bond push-out strength for different irrigation activation systems

Groups irrigation activation system	Pushout bond strength (MPa)	F, df
	Mean ± SD	
Group A (Conventional needle irrigation control group)	4.860 ± 0.82	14.428,4
Group B (EndoVac™)	8.841 ± 1.79	
Group C (EndoActivator™)	7.641 ± 1.89	
Group D (Passive ultrasonic)	7.856 ± 1.95	
Group E (Laser)	6.016 ± 1.24	

Table 2. Pairwise comparison of bond push-out strength for different irrigation activation systems.

Irrigation activation systems	Conventional needle	EndoVac	EndoActivator	Passive ultrasonic	Laser
Conventional needle	–	0,001*	0,001*	0,001*	0,29
EndoVac	0,001*	–	0,21	0,45	0,001*
EndoActivator	0,001*	0,21	–	0,98	0,08
Passive ultrasonic	0,001*	0,45	0,98	–	0,02
Laser	0,29	0,001*	0,08	0,02	–

Tukey's Post Hoc* Significant.

EndoVac™ group has shown a statistically significant difference when compared with controls and in LAI. The mean value for EndoVac™ group being highest 8.841 ± 1.79, this could be because the negative pressure generated by the macrocannula and microcannula into the canal which effectively delivers irrigant to full working length as well as by suctioning effect pulls irrigant from the apex this establish a constant flow of the irrigant till working length. The continuous flow of irrigant on walls of RC along with apical suction effect creates a very quick turbulent cascade impact as the irrigant is forced to flow between the external surface of microcannula and RC walls. This position of microholes on the microcanula reverses the direction of the fast-flowing stream of irrigant from a full working length as close as 0.2 mm, generates turbulent action creating a current force, which effectively removes smear layer in all parts of RC [10]. The EndoActivator™ group has a mean push-out bond strength value of 7.641 ± 1.89. The greater push-out bond strength of EndoActivator could be attributed to the creation of acoustic streaming, cavitation by a combination of sonic vibration and vertical strokes of the tip. The production of single node and antinode could have increased the irrigant contact time with canal walls facilitating removal of smear layer [11]. For our study, the PUI group has to mean push-out values of 7.856 ± 1.95 and this is attributed to the formation of acoustic micro-streaming and cavitation effect generated by transmitting acoustic energy to an irrigant in the RC through oscillating file or smooth wire, this acoustic energy is in the form of ultrasonic waves.

The acoustic microstreaming generates shear flow and shear stresses which remove bacteria and debris from the RC wall. Acoustic cavitation creates new bubbles or contraction, expansion, and/or distortion of previous present bubbles in an irrigation solution which gets imploded on the root canal walls creating a force that helps in the removal of debris [12]. Another important factor in PUI is at the closest point of the tip of the instrument there is rise in temperature into RC from 37 °C to 45 °C and 37 °C distant from the tip when irrigant was continuously activated for 30s with no replenishment which is shown in a paper by Cameron *et al.* (1988) [13], Ahmed *et al.* (1990) [14], Cunnigham *et al.* (1980) [15].

Krishna Prasad *et al.* in their research concluded that PUI system and EndoVac negative pressure system are more effective than conventional endodontic needles in delivering the irrigant to the working length of root canals. They found no significant difference was seen between the PUI and EndoVac groups ($p = 0.06$). [16] Narmatha and Sophia in their study found that Passive Ultrasonic agitation produces the cleanest canal walls compared to Manual Dynamic activation and Canal Brush agitation. Canal Brush agitation and Manual Dynamic activation can be used effectively as irrigant agitation techniques compared to conventional syringe irrigation. Canal Brush agitation produced significantly cleaner canal walls compared to Manual Dynamic activation [17].

A systematic review carried out by Carla M. Augusto *et al.* inferred that most of the final irrigation protocols had a positive impact and promoted an improvement in the dislodgment resistance of root canal sealers to the root dentin [18].

6 Conclusion

In conclusion, using different irrigation activation system has increased the bond strength of Endoseal MTA sealer as compared to the conventional syringe irrigation. EndoVac™, EndoActivator™, PUI, laser activation have shown improved bond strength of this sealer.

Machine assisted irrigation protocol should be incorporated as routine irrigation protocol.

7 Conflict of Interest

None.

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