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ORIGINAL ARTICLE

# Effect of Different Irrigant Activation Techniques on the Bond Strength of a Mineral Trioxide Aggregate-based Sealer: An *in vitro* Study

[1]Krishna P Prasad, [2]Aastha Tiwari, [3]Abhishek Sankhala, [4]Gagan Madan, [5]Shrikant Parakh, [6]Ankita Singh

## ABSTRACT

**Aim:** To evaluate the effect of conventional needles, CanalBrush, EndoVac, and ultrasonic irrigation activation systems on the pushout bond strength of a mineral trioxide aggregate (MTA)-based sealer to the root canal walls.

**Materials and methods:** A total of 80 single-rooted human teeth were prepared by using the ProTaper system to size F4. The specimens were randomly divided into four groups (n = 20) according to the final irrigation activation technique used as follows: No activation, ultrasonic activation (UA), CanalBrush, and EndoVac. The total working time for sodium hypochlorite and ethylenediaminetetraacetic acid was 2 minutes for all groups. Finally, the specimens were irrigated with 5 mL distilled water to prevent further irrigant action. All canals were obturated with an MTA-based sealer and F4 gutta-percha cones. A pushout test was used to measure the bond strength between the root canal dentin and the MTA-based sealer. The data obtained from the pushout test were analyzed using two-way analysis of variance, Krushkal–Wallis chi-square, and Tukey *post hoc* test.

**Results:** No statistical difference ($p > 0.05$) was observed between the four groups. Overall, group II showed better results.

**Conclusion:** The bond strength of the MTA-based sealer to the root canal dentin may improve with UA in the coronal and middle thirds and with EndoVac in the apical third.

**Clinical significance:** A combination of ultrasonic and EndoVac activation during the final irrigation of root canal may improve the bond strength of the sealer to root dentin.

**Keywords:** Bond strength, Canal Brush, Irrigation activation.

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[1]Professor and Head, [2,3,5]Postgraduate Student, [4]Consultant [6]Private Practitioner

[1-3,5]Department of Conservative Dentistry and Endodontics Chhattisgarh Dental College & Research Institute, Rajnandgaon Chhattisgarh, India

[4]Department of Endodontist, Family Dental Care, Nagpur Maharashtra, India

[6]Divine Smile Signatures Dental Clinic, Bhilai, Chhattisgarh, India

**Corresponding Author:** Aastha Tiwari, Postgraduate Student Department of Conservative Dentistry and Endodontics Chhattisgarh Dental College & Research Institute, Rajnandgaon Chhattisgarh, India, Phone: +919039179892, e-mail: aasthatiwari66@gmail.com

## INTRODUCTION

Endodontics is concerned with the biology, diagnosis, and pathology of the human dental pulp and periradicular tissues. The objective of endodontic therapy is to clean, shape, and fill the root canal system in order to remove all the organic materials and seal the canal three dimensionally.[1] Debridement of the root canal system is essential for endodontic success.[2] Irrigation is a vital part of root canal debridement. Unfortunately, many studies have shown that the currently used chemomechanical methods of root canal preparation do not effectively debride the entire root canal system. Ideally, root canal irrigants should flush out debris, dissolve organic tissue, kill microbes, destroy microbial byproducts, and remove the smear layer.[3,4]

The smear layer can inlet the residue of necrotic pulp tissues and bacterial biofilms. Residual biofilms can serve as a potential source of persistent infection and treatment failure.[5] Moreover, it has been indicated that the elimination of the smear layer may boost the bond strength of the filling material to canal walls.[6] The irrigation of the root canal is an essential procedure in the endodontic treatment for the elimination of the smear layer. Currently, the alternate use of sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) irrigants is recommended to remove both inorganic and organic components of the smear layer.[7] To accomplish these objectives, there must be an effective delivery system to working length.

The effectiveness of irrigants is associated with their direct association with the entire canal wall. However, this might not be achieved with conventional needle irrigation because of the complex nature of root canal anatomy.[8] During the last 2 decades, the field of endodontics as a specialty has shown noticeable improvements in the development of newer materials and techniques that have significantly altered the treatment modalities and enhanced the success. Different irrigation activation techniques have been proposed to improve the efficacy of irrigation solutions within the root canal system. These techniques consist of activation with gutta-percha cones, lasers, brushes, the negative pressure irrigation technique, and sonic and ultrasonic devices.[9] Because dentin surface treatment with different irrigation regimens causes shift in the chemical and structural architecture of the human dentin, the permeability and solubility characteristics of dentin may change[10,11] and hence, affect the adhesion of filling materials to dentin surfaces.[12]

CanalBrush (CB) (Coltene Whaledent, Langenau, Germany) is an endodontic microbrush molded entirely from polypropylene and can be used manually with a rotary action. However, it is more efficacious when attached to a contra-angle handpiece running at 600 rpm.[9,13]

Passive ultrasonic irrigation (PUI) was introduced to increase the effectiveness of canal disinfection by agitating the irrigant solution placed inside the canal. An ultrasonic tip is activated in the canal up to working length and is moved passively in an up-and-down motion to ensure it does not bind with the root canal walls. EndoVac is a negative pressure irrigation system that has been designed to safely deliver irrigant solutions into the apical portion of the canal. When using this system, the irrigant is delivered into the pulp chamber by the master delivery tip and is driven by negative pressure into the root canals with the aid of the macrocannula and microcannula.[8]

The most common root canal filling material used is gutta-percha in conjunction with sealers. Recently, calcium silicate-based materials, such as the mineral trioxide aggregate (MTA)-based sealer have been developed. The MTA Fillapex (Angelus, Londrina, PR, Brazil) is a two-paste resin sealer that consists of MTA, salicylate resin, natural resin, bismuth oxide, and silica.[2] The literature is scarce on the effect of various irrigants on the bond strength of the MTA Fillapex sealer to dentin; hence, this study was undertaken. The purpose of this study was to evaluate the effect of different final irrigation activation techniques on the bond strength of the MTA-based sealer (Angelus, Londrina, PR, Brazil).

## MATERIALS AND METHODS

A total of 80 freshly extracted human single-rooted teeth were obtained from the Department of Oral and Maxillofacial Surgery, Chhattisgarh Dental College & Research Institute, Rajnandgaon, Chhattisgarh, India. Teeth without any previous endodontic treatment, fractures, resorptive defects, calcifications, or open apices were selected for the study. They were cleaned of any residual tissue tags, rinsed under running water, and stored in 10% formalin solution. The length of the teeth was standardized to 20 mm from the apex using a diamond cutting saw. Access to the pulp chamber and the canal was made by using a cavity access set. After the removal of the pulp tissue by a barbed broach, a #10 K file was placed into each root canal and the working length was established using Radio Visio Graphy. The cervical bulge was removed by using #1 to #3 Gates Glidden drills.

The ProTaper rotary system comprising six nickel–titanium files were used in the Crown-Down Pressure-less technique. An X-Smart endomotor with a 16:1 reduction gear contra-angle handpiece was used. During instrumentation, the lubrication of canals was carried out using the EDTA gel. The recommended speed of rotation for the ProTaper system and torque was maintained throughout the procedure. Shaping of coronal two-thirds was done by using #10 and #15 K files followed by Sx and S1 with a firm brushing outstroke action. The working length was determined by a #15 K file using Radio Visio Graphy. After establishing patency with hand file, the ProTaper shaping file number S1 was first carried into the canal up to the working length, and then the Sx file was used with a brushstroke action again followed by S2. Sequentially, F1, F2, F3, and F4 were used up to the working length for finishing in "in and out" action. After each instrumentation, the canals were irrigated with 3% NaOCl solution. Specimens were randomly divided into four groups depending upon the types of irrigation system used with 20 specimens in each group.

- *Group I*: Control
- *Group II*: Ultrasonic activation
- *Group III*: Canal Brush activation
- *Group IV*: EndoVac activation

*Group I*: The final irrigation was performed with 5 mL of 3% NaOCl followed by 5 mL of 17% EDTA using a syringe and a 29-G needle placed 1 mm short of the working length. No additional activation of irrigants was performed.

*Group II*: In this group, 5 mL of 3% NaOCl and 5 mL of 17% EDTA were passively activated using an ultrasonic tip (EMS, Woodpacker) at a frequency of 32 KHz. The ultrasonic tip (e15d, Woodpacker) was placed into the canal to 1 mm short of the working length without touching the walls, enabling it to vibrate freely.

*Group III*: Activation of 5 mL of 3% NaOCl and 5 mL of 17% EDTA was performed using a CB with a tip diameter of 0.25 mm (Coltene Whaledent) in a contra-angle handpiece set at 600 rpm. The brush was used with a gentle up-and-down motion at 1 mm from the working length. One CB per root was used.

*Group IV*: The EndoVac delivery/evacuation tip was placed above the access opening to constantly deliver and evacuate 3% NaOCl, keeping the canal and pulp chamber full of irrigant at all times. The canals were macro- and microirrigated following manufacturer's instructions.

The macroirrigation of each canal with NaOCl was accomplished over a 30-second period. This was achieved using the EndoVac delivery/evacuation tip while the macrocannula was constantly moved up and down in the canal from a point where it started to bind to a point just beneath the orifice. The canal space was then left uninterrupted, full of irrigant for 60 seconds. Three cycles of microirrigation was followed. During the cycle of microirrigation, the pulp chamber was preserved full of irrigant, while the microcannula was placed at working length for 6 seconds. The microcannula was then positioned 2 mm from the working length for 6 seconds and then moved back to the working length for 6 seconds.

The first cycle used 3% NaOCl as the irrigant, the second cycle 17% EDTA, and the third cycle 3% NaOCl. At the end of the third microirrigation cycle, the microcannula was left at working length without replenishment to remove excess fluid. Paper points were inserted to working length to dry the canal.

The activation time for each irrigant was 1 minute. The total working time for NaOCl and EDTA was 2 minutes for all groups. Finally, the specimens were irrigated with 5 mL distilled water to inhibit further irrigant action. The total irrigation volume for the final irrigation procedure was 15 mL for all groups. Specimens in each group were dried with paper points (Dentsply Maillefer). All canals were obturated with the MTA-based sealer (MTA Fillapex) and F4 gutta-percha cones using the single-cone technique. Radiographs were taken to verify complete filling. In later root filling, the coronal 1 mm of the filling materials was removed from each specimen and restored with glass ionomer cement. Subsequently, all specimens were reserved at 37°C in 100% humidity for 2 weeks.

### Pushout Testing

Each root was cut horizontally at a slow speed using a water-cooled diamond saw (Isomet; Buehler, Lake Bluff, IL) at depths of 4, 7, and 10 mm to produce slices almost 1-mm thick from each root region (i.e., apical, middle, and coronal). The thickness of each slice was measured using a digital caliper. All slices were then scanned and the width of filling materials measured using an electronic scale in software (Adobe Photoshop) to determine the diameters of plungers to be used for the pushout test. The pushout test was achieved through a universal testing machine (Instron Corp, Canton, MA) by applying a continuous load to the apical side of each slice using 0.7, 0.8, and 0.9 mm diameter cylindrical plungers (Fig. 1), 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 till bond failure occurred. The maximum load applied to filling materials before failure was recorded in Newtons and converted to MPa according to the following formula:

**Fig. 1:** Universal testing machine

$$\text{Pushout bond strength ðMPaÞ} \frac{1}{4} N = A$$

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

The adhesion area of each section was calculated as: (pr1 + pr2) L, where L = O (r1 – r2)2 + h2, p is the constant 3.14, r1 is the smaller radius, r2 is the larger radius, and h is the thickness of the slice in millimeters. Data were collected and statistically analyzed using two-way analysis of variance test, the Krushkal–Wallis chi-square, and the Tukey *post hoc* test.

## RESULTS

There was a statistically significant interaction between final irrigant activation techniques and root canal thirds ($p < 0.05$). Table 1 shows coronal third had higher bond strength values than the middle third and the apical third ($p > 0.05$). In Table 2 the coronal third and the middle third, the bond strength of group II ultrasonic activation (UA) was higher than those of the others ($p < 0.05$). Table 3 shows bond strength of group IV EndoVac activation (EA) was higher than for other activation groups ($p > 0.05$).

## DISCUSSION

The main objective of root canal treatment is the adequate disinfection of the root canal system and the prevention of reinfection.[14] In root canal obturation procedures, sealers are used to secure an inaccessible 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 support

**Table 1:** Comparison of bond strength in the coronal third of four final irrigant activation techniques

*Descriptive statistics*

| | | | | | *95% confidence interval for mean* | | | |
|---|---|---|---|---|---|---|---|---|
| *Techniques* | *n* | *Mean* | *Std. deviation* | *Std. error* | *Lower bound* | *Upper bound* | *Minimum* | *Maximum* |
| Control | 20 | 0.708 | 0.445 | 0.099 | 0.499 | 0.916 | 0.04 | 1.36 |
| Ultrasonic activation | 20 | 0.848 | 0.186 | 0.041 | 0.761 | 0.936 | 0.51 | 1.21 |
| Canal Brush activation | 20 | 0.542 | 0.278 | 0.062 | 0.411 | 0.672 | 0.15 | 1.08 |
| EndoVac activation | 20 | 0.776 | 0.270 | 0.060 | 0.650 | 0.903 | 0.27 | 1.16 |

*Multiple comparison: Tukey test*

| | | | | | *95% confidence interval* | |
|---|---|---|---|---|---|---|
| *Techniques* | | *Mean difference (I−J)* | *Std. error* | *p-value* | *Lower bound* | *Upper bound* |
| Control | UA | –0.140 | 0.097 | 0.483, NS | –0.397 | 0.116 |
| | CB | 0.166 | 0.097 | 0.333, NS | –0.091 | 0.423 |
| | EA | –0.068 | 0.097 | 0.898, NS | –0.325 | 0.189 |
| UA | CB | 0.306 | 0.097 | 0.013, S | 0.049 | 0.564 |
| | EA | 0.072 | 0.097 | 0.882, NS | –0.185 | 0.329 |
| CB | EA | –0.234 | 0.097 | 0.087, NS | –0.491 | 0.022 |

S: Significant; NS: Nonsignificant

**Table 2:** Comparison of bond strength in the middle third of four final irrigant activation techniques

*Descriptive statistics*

| | | | | | *95% confidence interval for mean* | | | |
|---|---|---|---|---|---|---|---|---|
| *Techniques* | *n* | *Mean* | *Std. deviation* | *Std. error* | *Lower bound* | *Upper bound* | *Minimum* | *Maximum* |
| Control | 20 | 0.628 | 0.429 | 0.096 | 0.427 | 0.829 | 0.01 | 1.87 |
| Ultrasonic activation | 20 | 0.747 | 0.227 | 0.050 | 0.641 | 0.854 | 0.26 | 1.13 |
| Canal Brush activation | 20 | 0.583 | 0.321 | 0.071 | 0.432 | 0.733 | 0.06 | 0.99 |
| EndoVac activation | 20 | 0.738 | 0.403 | 0.090 | 0.550 | 0.927 | 0.10 | 1.95 |

*Multiple comparison: Tukey test*

| | | | | | *95% confidence interval* | |
|---|---|---|---|---|---|---|
| *Techniques* | | *Mean difference (I −J)* | *Std. error* | *p-value* | *Lower bound* | *Upper bound* |
| Control | UA | –0.119 | 0.112 | 0.713, NS | –0.413 | 0.175 |
| | CB | 0.045 | 0.112 | 0.977, NS | –0.249 | 0.340 |
| | EA | –0.110 | 0.112 | 0.759, NS | –0.404 | 0.184 |
| UA | CB | 0.164 | 0.112 | 0.462, NS | –0.129 | 0.459 |
| | EA | 0.008 | 0.112 | 1.000, NS | –0.285 | 0.303 |
| CB | EA | –0.155 | 0.112 | 0.510, NS | –0.450 | 0.138 |

NS: Nonsignificant

**Table 3:** Comparison of bond strength in the apical third of four final irrigant activation techniques

*Descriptive statistics*

| | | | | | *95% confidence interval for mean* | | | |
|---|---|---|---|---|---|---|---|---|
| *Techniques* | *n* | *Mean* | *Std. deviation* | *Std. error* | *Lower bound* | *Upper bound* | *Minimum* | *Maximum* |
| Control | 20 | 0.510 | 0.262 | 0.058 | 0.387 | 0.633 | 0.02 | 0.89 |
| Ultrasonic activation | 20 | 0.596 | 0.266 | 0.059 | 0.471 | 0.721 | 0.15 | 0.92 |
| Canal Brush activation | 20 | 0.499 | 0.258 | 0.057 | 0.378 | 0.620 | 0.13 | 0.91 |
| EndoVac activation | 20 | 0.628 | 0.393 | 0.087 | 0.444 | 0.812 | 0.08 | 1.88 |

*Multiple comparison: Tukey test*

| | | | | | *95% confidence interval* | |
|---|---|---|---|---|---|---|
| *Techniques* | | *Mean difference (I −J)* | *Std. error* | *p-value* | *Lower bound* | *Upper bound* |
| Control | CB | −0.086 | 0.095 | 0.802, NS | –0.335 | 0.163 |
| | UA | 0.010 | 0.095 | 0.999, NS | –0.238 | 0.260 |
| | EA | −0.118 | 0.095 | 0.602, NS | –0.367 | 0.131 |
| CB | UA | 0.096 | 0.095 | 0.739, NS | –0.152 | 0.346 |
| | EA | −0.031 | 0.095 | 0.987, NS | –0.281 | 0.217 |
| UA | EA | −0.128 | 0.095 | 0.532, NS | –0.378 | 0.120 |

NS: Nonsignificant

may be advantageous in preserving the integrity of the sealer–dentin interface.[15]

In dentin surface treatment, endodontic irrigants may affect the adhesion of sealers on root canal walls[16] because irrigants can alter the dentin surface composition.[10] The present study showed maximum bond strength in the coronal part, which gradually decreased apically. It may be due to altered dentinal tubule density.[17] In this sense, enhancing direct contact of the final irrigation solution with the entire canal wall can be helpful in improving the bond of the sealer. Therefore, the present study was focused in determining whether or not the bond strength of MTA Fillapex sealer improves with CB activation, UA, and EA devices.

The bond strength of endodontic sealers to dentin is an important property of filling materials because it minimizes the risk of filling detachment all along restorative procedures or the masticatory function, ensuring that sealing is maintained. The pushout bond strength test is a well-known evaluation method used in several other similar studies with great reliability.[18,19] Thus, its results can be useful for inferring the interfacial strength and dislocation resistance between different root filling materials and the root dentin.

The MTA Fillapex (Angelus, Londrina, PR, Brazil) has excellent radiopacity, easy handling, a good working time, and low solubility, providing sealing of the canal by expansion during setting. The above-mentioned advantages made us to select this material.

In the present study, the bond strength primarily decreased in the coronal-to-apical direction. This result is comparable with results from several studies exhibiting that the adhesion of root sealers generally declines in the coronal-to-apical direction. This can be explained by the decreasing tubule density from coronal to apical, which diminishes sealer penetration toward the smaller tubule diameter in the apical thirds.

Group I used the conventional needle irrigation without any final activation. A significantly lower bond strength was seen ($p < 0.05$) when compared with ultrasonic and EndoVac groups. This finding was in accordance with the studies done by Topçuoğlu et al[20] and da Costa Lima et al.[21] The conventional needle irrigation without activation may cause the formation of vapor lock due to gases present in the apical region into which fluid penetration is difficult. Therefore, various final irrigant activation techniques are helpful in breaking the vapor lock effect and moving the solutions apically.

Among all the groups tested, group II showed improved bond strength in coronal and middle thirds, which was statistically significant ($p < 0.05$). In our study, the tip of the ultrasonic needle was held at one position throughout irrigation. A larger volume of irrigant and the needle being held at one position were likely the reasons that the PUI showed a better penetration in the coronal and middle locations. Our findings simulate studies done by Topçuoğlu et al.[20] During ultrasonic irrigant activation, the file oscillation allows the irrigant to flow into the irregularities of the canal, accessing areas that were not touched by the instruments, and provides better cleanliness of the root canal system. The cavitation effect produced by PUI and increase in the irrigant temperature improves the effectiveness of NaOCl on tissue dissolution.

In group III, the CB activation did not show any improvement in adhesion of the sealer. A significant difference in bond strength was observed between the CB activation, UA, and EA groups ($p < 0.05$). These results coincide with the study performed by Plotino et al.[22] A nonsignificant difference ($p > 0.05$) in bond strength was seen between CB activation and control groups. Similar results were found by Narmatha and Thakur.[23] A CB was used with a circumferential and 2- to 3-mm up-and-down motion for 30 seconds in a slow-speed handpiece. Different results may be obtained if the brush was used for a longer course of time. Modifications to the brush may also boost its effectiveness in cleaning canal walls. The samples in the present study were all single rooted with straight canals, which is a limitation of this study. None of the brushes fractured, but deformity was detected similar to Plotino et al studies.[22]

In group IV, although the level of effectiveness that was expected from the EndoVac was not achieved entirely in the apical third, it did yield better results than the other methods. However, it did not show a statistical difference between other groups ($p > 0.05$). The EndoVac system achieved significantly better irrigant penetration results against the conventional needle. This could be explained by the negative pressure applied by the macrocannula and microcannula, which allowed the irrigant to penetrate close to the working length. It showed a better bond strength in the apical third portion of canals than in the other groups compared, but the difference was nonsignificant ($p > 0.05$).

The activation of irrigants provides a better penetration of sealers. The bond strength of the MTA Fillapex sealer increased after the activation of the final irrigant. The 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. No significant difference was seen between the PUI and EndoVac groups ($p = 0.06$). Further study is required to corroborate this preliminary data and to investigate the bond strength of different root canal sealers after final irrigant activation protocols.

Within the limitation of this *in vitro* study, the following conclusions were drawn:

- No statistically significant difference ($p > 0.05$) was observed between the four groups. However, in the coronal third, a statistically significant variation was found in the bond strength of the four groups ($p < 0.05$). Overall, group II UA showed better results.
- Among all the groups, group III (CB activation) had poor results irrespective of the technique and material used.

The bond strength of the MTA Fillapex sealer to root canal dentin was improved with UA in the coronal and middle thirds and with EA in the apical third.

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