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Effectiveness of Combination Irrigant Technique for Debris Removal in Simulated Canal Irregularities: An *in vitro* Study

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Abstract

Aim: To evaluate the debridement efficacy of different irrigation systems in simulated canal irregularities. **Study Design and Setting:** About sixty maxillary central incisors were selected and after chemomechanical preparation were split longitudinally into two halves. Each groove and depression were filled with dentine debris mixed with 2.5 % NaOCl to simulate a situation where dentine debris accumulates in the un-instrumented extensions of the root canal. **Materials and Methods:** The specimens were randomly divided into 4 experimental groups as follows: Group I - Conventional Needle Irrigation, Group II - Apical Negative Pressure Irrigation (EndoVac), Group III - Passive Ultrasonic Irrigation and Group IV - Combination Irrigation (EV+PUI). 9 ml of 2.5 % NaOCl, 9 ml of 17 % EDTA and 9 ml of saline was used for the final irrigation protocol. Images were taken before and after irrigation using PRIMA DNT surgical microscope with digital camera. **Statistical Analysis:** The intergroup and individual comparison of percentage reduction of debris in groove and depressions were carried out by using Kruskal-Wallis and Mann-Whitney U tests respectively. The intergroup comparison for different scoring criteria was compared using Pearson's chi-square tests. Differences were considered statistically significant at P value < 0.05. **Results:** The combination group, EV group and PUI group showed better removal of debris in Groove and Depressions than Conventional needle irrigation group. The Combination group had significant reduction of debris at 2 mm level when compared to all the other groups. **Conclusion:** The effectiveness of this combination irrigant delivery system for smear layer removal and antibacterial efficacy have to be evaluated further in future clinical studies.

Keywords: Apical Negative Pressure; Conventional Needle Irrigation; EndoVac; Irrigant Technique; Passive Ultrasonic Irrigation.

INTRODUCTION

Effective debridement of the root canal system is essential for endodontic success. However, the aberrations within the root canal anatomy has limited our ability to clean and disinfect it thoroughly [1]. Even with the advent of Ni Ti rotary instrumentation multiple areas in the root canal remain untouched. Peters *et al*. compared micro computed tomography scans before and after mechanical instrumentation and found that, regardless of the instrumentation technique, 35% or more of the root canal surfaces remained un-instrumented [2]. Hence the role of irrigants become essential for complete debridement of the root canal. A bigger challenge during irrigation may be the areas untouched by the files, such as fins, isthmuses, large lateral canals and large areas in the oval and flat canals [3]. These areas contain tissue remnants and biofilms that can be removed only by irrigation. The apical root canal poses a special challenge to irrigation as the balance between safety and effectiveness is particularly important in this area [4].

Various irrigating methods have been introduced till date, but the conventional method of irrigating the root canal has been performed with a syringe and needle. However, this system becomes ineffective in cleaning the apical portions of the root canal, as the irrigant can progress only 1 mm beyond from the tip of the needle [5]. Greater positive pressure and placing the needle near the working length could extrude the solution to the periapical region. Furthermore, in clinical condition, the root canal may behave as a closed-end channel, which results in gas entrapment creating a "vapour lock" effect thereby preventing the irrigant from reaching the full working length [6]. Passive ultrasonic irrigation (PUI) was introduced to increase the effectiveness of irrigants to remove the smear layer and debris from inaccessible areas of the root canal. PUI was introduced to increase the effectiveness of irrigants to remove the smear layer and debris from inaccessible areas of the root canal. An ultrasonic tip is activated in the canal 2 mm short of

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working length and is moved passively in an up-and-down motion to ensure it did not bind with the root canal walls. It has been shown that PUI is significantly more effective in removing debris in simulated un-instrumented extensions and irregularities in straight and wide canals [7-8]. EndoVac is a negative pressure irrigation system that has been designed to safely deliver irrigant solutions to the apical portion of the canal. This device consists of a master delivery tip, a macrocannula, and a microcannula that are connected to a vacuum line. When using this system, the irrigant is delivered in to the pulp chamber by the master delivery tip and is driven by negative pressure in to the root canals with the aid of the macrocannula and microcannula.

A study by Nielsen and Baumgartner showed that volume of irrigant delivered with apical negative pressure system (ANP) EndoVac was approximately 42 ml which was significantly more than volume delivered with needle irrigation which was 15 ml over the same amount of time [9]. The volume of irrigant delivered by this method may be more and its effect on debris removal is not known. Few years ago, Spoorthy *et al*. reported that the combination of ANP and passive ultrasonic irrigation (PUI) allows irrigants to penetrate to working length and also into lateral canals [10]. But to date, the debridement efficacy of this combination irrigant technique has not been evaluated. Hence, the aim of the present study is to evaluate the effect of combination irrigant technique (ANP and PUI) for debris removal in simulated canal irregularities. Hypothesis of this study is that the combination of ANP and PUI irrigation system will be able to three dimensionally clean the root canal system.

MATERIALS AND METHODS

After obtaining ethical clearance from the "Institute's Review Board" about sixty samples of freshly extracted human maxillary central incisors with single canal were selected and stored in 0.1 % thymol solution (Figure 1). External debris was removed using an ultrasonic scaler and examined under 10x magnification to verify the absence of micro cracks, craze lines etc. Following the recommendation and guidelines of Occupational Safety and Health Administration (OSHA) as well as Centers for Disease Control and Prevention (CDC), collection, storage, sterilization and handling of extracted teeth were performed accordingly [11]. All crowns were removed with a double-sided diamond disc using a low-speed straight hand piece. The root size of each specimen was standardized to a length of 17 mm (Figure 2), following which 2 longitudinal grooves were created along the mesial and distal external root without reaching the root canal. Utility wax was placed at the apex of each sample. Then, each sample was moulded with condensation silicone and embedded in a metallic jig to prevent leakage of irrigant during chemo mechanical preparation simulating a closed irrigation system.

Root Canal Instrumentation

The root canals were instrumented in a crown down technique using protaper rotary system in the sequence of S1, S2, F1, F2, F3 and F4. Irrigation was done with 5.25 % NaOCl and saline where 3 ml of 17 % EDTA acted as a lubricant during instrumentation.

Groove and Depression

After chemomechanical preparation, the samples were removed from the metallic jig and cleaved longitudinally using a chisel (Figure 3). A longitudinal groove (4 mm long, 0.2 mm wide and 0.5 mm deep) was created with a double-sided diamond disc on one half of the internal surface of the root canal at 2 mm from the apex. The diameter of a 1/4 round bur was reduced to 0.3 mm by grinding it on Sic-paper. Using this modified round bur, three standard saucer shaped depressions (0.3 mm in diameter and 0.5 mm deep) were created on the other half of the root canal at 2, 4 and 6 mm from the apex (Figure 4).

Preparation of Debris

Debris was produced from the wear of the root dentin from extracted tooth using double sided diamond disc at low speed. Debris was weighed on an analytical balance, separated into 0.005 g portions. This was mixed with 0.1 ml of 2.5 % NaOCl to achieve a wet sand like consistency. The dentin debris was packed into the grooves following which depressions were created using a dental explorer to simulate a clinical situation wherein dentin debris accumulates in un-instrumented extensions of the root canal. The root halves were approximated together with ligature wire and the apices were sealed using utility wax. The roots were then reassembled back into the metallic jig and the samples were randomly divided into four groups as follows. In Group I, using Conventional Needle Irrigation (CNI, n = 15) samples were irrigated with 9 ml of 2.5 % NaOCl followed by 9 ml of 17 % EDTA solution and 9 ml of saline. In Group II, using Apical Negative Pressure – EndoVac (EV, n = 15) approach 3 cycles of microirrigation were performed. The first cycle was irrigated using 9 ml of 2.5 % NaOCl, the second cycle was irrigated using 9 ml of 17 % EDTA and the third microirrigation cycle were irrigated using 9 ml of saline. For Group III, by following the Passive Ultrasonic Irrigation (PUI, n = 15) method irrigation was done using an Irrisafe tip (Satelec, France) set at a power setting of 5 at 1 mm from the apex moved in an up and down motion. PUI were performed in 3 cycles (1 cycle of NaOCl + 1 cycle of EDTA + 1 cycle of saline) with 9 mL irrigant per cycle. In group IV, by using the combination of Apical Negative Pressure and Passive Ultrasonic Irrigation (EV + PUI, n = 15) samples of this group were irrigated with 9 ml of 2.5 % NaOCl (4.5 ml EV + 4.5 ml PUI) followed by 9 ml (4.5 ml EV + 4.5 ml PUI) of 17 % EDTA and 9 ml (4.5 ml EV + 4.5 ml PUI) of saline. Images of the two halves of the canal wall were taken before and after irrigation (provided in the Appendix 1) using a prima DNT Surgical Microscope with digital SLR camera at 5 step magnification.

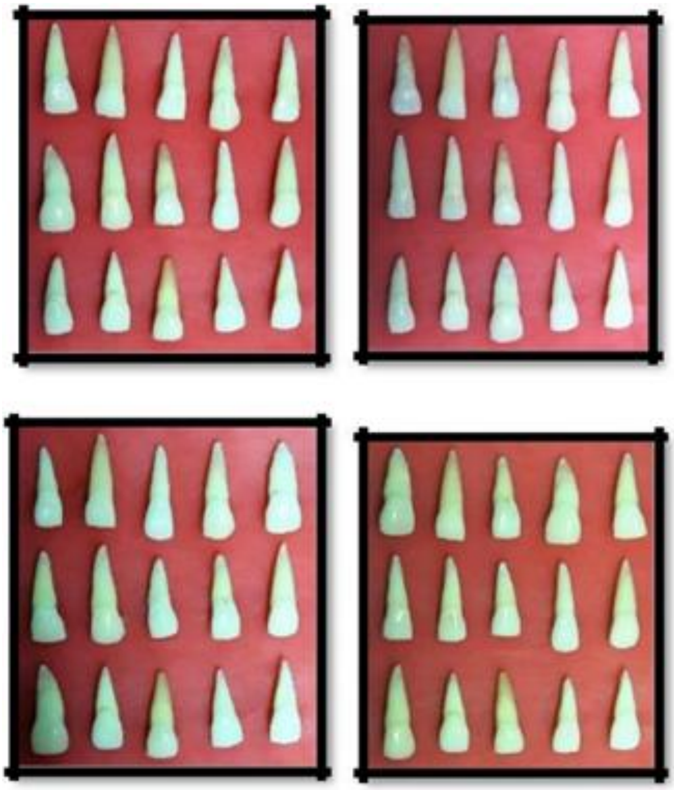

Figure 1: Maxillary Central Incisors

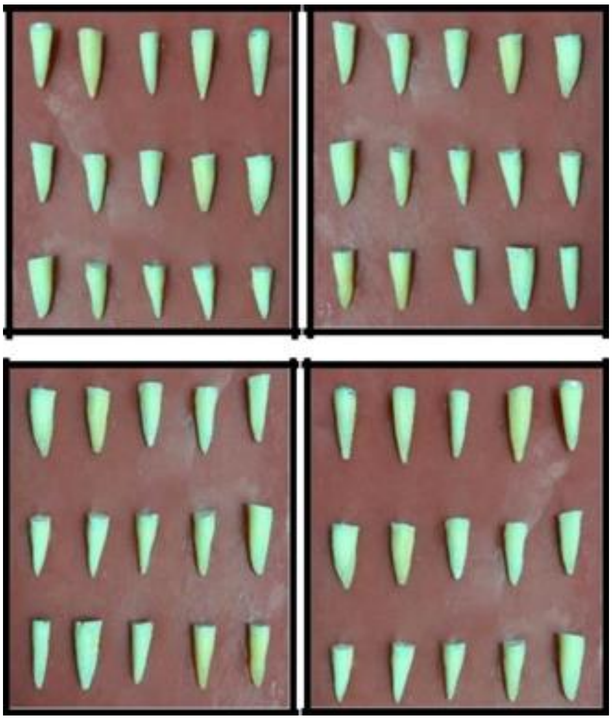

Figure 2: Crowns Removed with Double Sided Diamond Disc

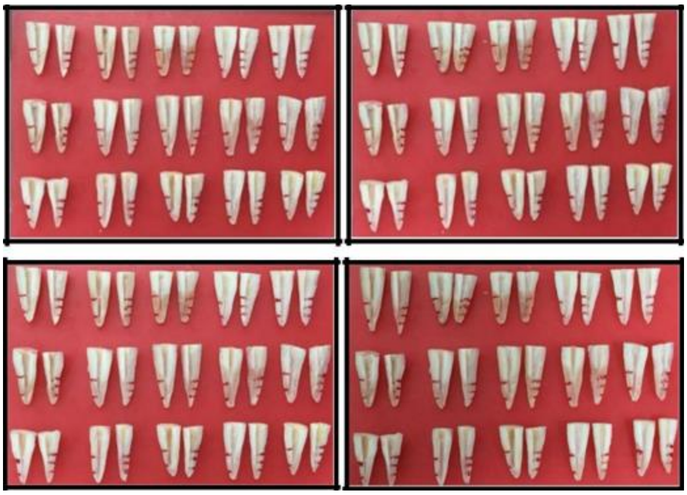

Figure 3: Measurement Points for Groove and Depressions

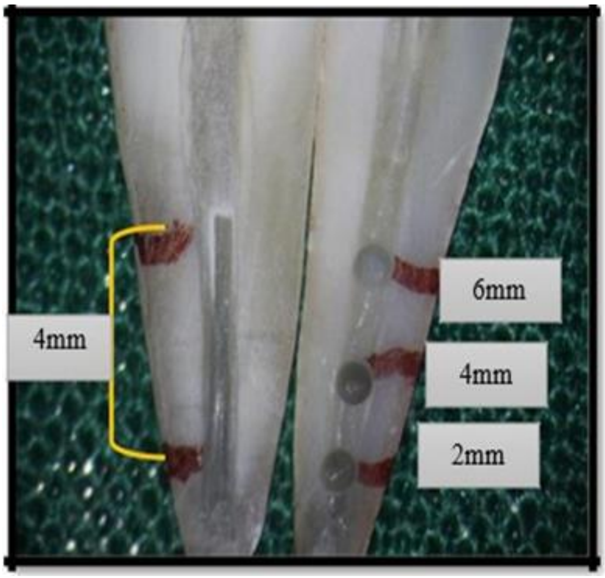

Figure 4: Microscopic Image of Groove and Depression

Evaluation Criteria

Samples were evaluated based on the scoring criteria according to Lee *et al*. (10). Score 0 – debris free groove or depression, Score 1 - Less than half of the groove or depression filled with debris, Score 2 - Half or greater than half of the grove or depression filled with debris and Score 3 - Entire groove or depression were filled with debris. The average score of the three depressions was used as the depression score for each specimen. The amount of dentine debris in the groove and depressions was then scored by 2 calibrated examiners blinded to the experimental groups. The first score (before irrigation) was used to assess whether the canals in all the groups contained a comparable amount of debris before irrigation. Each specimen was finally re-examined by a second investigator.

Statistical Analysis

The collected data were analyzed using the software Statistical Package for Social Sciences (SPSS version 16.0). While the intergroup comparison of percentage reduction of debris in groove and depressions was carried out by Kruskal-Wallis test, the individual comparison was performed by using Mann-Whitney U tests. The intergroup comparison for different scoring criteria was compared using Pearson's chi-square tests. P value < 0.05 was considered to be statistically significant in the present study.

RESULTS

From the results, while the percentage reduction of debris (groove) for the combination group (EV+PUI) was found to be 95.5 %, for PUI, EV and CNI group it was found to be 82.2 %, 73.3 % and 31.1 % respectively (Table 1). Though the combination group (EV+PUI) along with PUI and EV were found to be superior to CNI, still no statistically significant difference was observed between combination group (EV+PUI) and PUI as well as EV and PUI group (Table 2). Similarly, the percentage reduction of debris (depression) in combination group (EV+PUI), PUI, EV and CNI group were found to be 91.5 %, 74.4 %, 49.3 % and 21.8 % respectively (Table 3). On contrary to the results obtained for grooves (Table 2), the differences obtained in the intergroup comparison involving the groups (depressions) were found to be statistically significant (Table 4). The combination group (EV + PUI) and PUI performed better at 6 mm level than EV and CNI. However, there was no statistically significant difference observed between CNI and EV group (Table 5). The combination group (EV + PUI) along with PUI and EV performed not only better than CNI but also performed better than EV at 4 mm level. However, there was no statistically significant difference was observed between EV and PUI group as well as PUI and Combination group (Table 6). The combination group (EV + PUI) along with PUI and EV performed not only better than CNI but also performed better than PUI and EV at 2 mm level. However, there was no statistically significant difference was observed between EV and PUI group (Table 7).

Table 1: Mean Percentage Reduction of Debris in Groove

Groups	Groove (Mean ± SD)
CNI	31.11 ± 29.45
EV	73.33 ± 28.72
PUI	82.22 ± 30.51
EV + PUI	95.55 ± 11.72
P Value	0.0001

Table 2: Intergroup Comparison of the Groups (Groove)

Groups	P Value
CNI Vs EV	0.001
CNI Vs PUI	0.000
CNI Vs EV + PUI	0.000
EV Vs PUI	0.297
EV Vs EV + PUI	0.015
PUI Vs EV + PUI	0.169

Table 3: Mean Percentage Reduction of Debris in Depression

Groups	Groove (Mean ± SD)
CNI	21.77 ± 20.62
EV	49.33 ± 31.47
PUI	74.44 ± 22.56
EV + PUI	91.55 ± 14.19
P Value	0.0001

Table 4: Intergroup Comparison of the Groups (Depressions)

Groups	P Value
CNI Vs EV	0.016
CNI Vs PUI	0.000
CNI Vs EV + PUI	0.000
EV Vs PUI	0.020
EV Vs EV + PUI	0.000
PUI Vs EV + PUI	0.021

Table 5: Intragroup Comparison of the Groups at 6 mm Level

Groups	P Value
CNI Vs EV	0.252
CNI Vs PUI	0.002
CNI Vs EV + PUI	0.001
EV Vs PUI	0.008
EV Vs EV + PUI	0.006**
PUI Vs EV + PUI	1.000**

** Fisher Exact test

Table 6: Intragroup Comparison of the Groups at 4 mm Level

Groups	P Value
CNI Vs EV	0.049
CNI Vs PUI	0.001
CNI Vs EV + PUI	0.000
EV Vs PUI	0.250
EV Vs EV + PUI	0.012
PUI Vs EV + PUI	0.159

Table 7: Intragroup Comparison of the Groups at 2 mm Level

Groups	P Value
CNI Vs EV	0.023
CNI Vs PUI	0.032
CNI Vs EV + PUI	0.000
EV Vs PUI	0.343
EV Vs EV + PUI	0.013
PUI Vs EV + PUI	0.010

DISCUSSION

The present study was performed to assess the debris removal in simulated canal irregularities in the apical third of the root canal using various irrigation techniques. The un-instrumented extensions of the root canal may include isthmus, fins, irregularities, lateral canals and extensions of oval and flat canals [3, 12] which may harbour necrotic debris thereby leading to failure of endodontic treatment [13]. Recently, Spoorthy *et al*. showed that the combination of apical negative pressure irrigation and passive ultrasonic irrigation allows irrigant to penetrate to full working length and also into lateral canals. Three dimensional irrigant penetration was achieved with this technique [10]. But to date no studies have evaluated the debridement efficacy of EndoVac irrigation and combination technique in simulated canal irregularities. Hence in this study we have comparatively evaluated the debridement efficacy of Conventional needle irrigation, Apical negative pressure irrigation (EndoVac), Passive ultrasonic irrigation and Combination of both (ANP & PUI).

The metallic jig used in this study helps to reapproximate the sectioned half of the tooth to prevent leakage from the irrigant and simulated a closed irrigation system. The debris was preweighed as 0.005 g portions mixed with 0.1 ml of 2.5 % NaOCl, a method which is similar to the one suggested by Aline Martins *et al*. [14]. Previous studies have stated that the volume of irrigant affects root canal cleaning [15]. In our study the overall volume of irrigant was standardized to 27 ml (9 ml of NaOCl, 9 ml of EDTA and 9 ml of saline). This was similar to a study done by Abarajithan *et al*. [16]. For the combination group, 27 ml of irrigant has been used (13.5 ml for EV + 13.5 ml for PUI). The results of conventional needle irrigation showed only 31 % debris reduction in Grooves and 21 % reduction in Depression. This could be because of the creation of vapour lock [6] and placement of irrigating needle which was 2 mm short of the apex [17-18] resulting in the poor performance of this group. EndoVac group performed better in Groove and Depression (4 mm & 2 mm level) when compared to conventional needle irrigation. The reason might be that EndoVac irrigation safely delivers irrigant up to the full working length and the negative pressure pulls the irrigant upto the critical apical third thereby eliminating vapour lock [6]. But in comparison with the combination group, the EndoVac group performed inferior in Groove and Depressions at all levels. This may be because of the lower shear wall stress [19] exerted by the EndoVac which prevents it from penetrating into the irregularities. Currently, Passive ultrasonic irrigation is considered to be the gold standard among irrigant delivery systems [7-8, 20]. Overall, PUI has performed better than CNI for debris removal from Groove and Depressions at all levels. PUI has also performed similar to the combination group (EV+PUI) in the Groove and Depressions except at the 2 mm level. PUI exhibits high shear wall stress resulting in turbulence which could have facilitated debris removal.

According to Al-Jadaa *et al*., the transient cavitation and streaming around the activated ultrasonic file could have produced a pressure vacuum effect which would suck the debris from the canal irregularities into the main canal [20]. At 2 mm level the combination group (EV+PUI) alone has proved to be effective in debris removal (73.3 %) when compared to PUI (33.3 %) and EV (20 %). The probable reason might be that the Apical negative pressure allows penetration of irrigant to full working length, it eliminates the vapour lock and ensures sufficient irrigant penetrating up to the root apex [6]. When PUI was used subsequently, acoustic streaming and cavitation, would have enhanced the irrigant to flow in to the canal irregularities [8]. The combination group, EV and PUI group showed better removal of debris in Groove and Depressions than conventional needle irrigation group. The Combination group had significant reduction of debris at 2 mm level when compared to all the other groups.

CONCLUSION

The aim of the present study was to evaluate the debridement efficacy of conventional needle irrigation, Apical negative pressure irrigation (EndoVac), Passive ultrasonic irrigation and combination of Apical Negative Pressure irrigation and Passive ultrasonic irrigation in simulated canal irregularities. Sixty maxillary central incisors were chosen for which crowns were removed and standardized to a length of 17 mm. After dividing the specimens randomly into 4 groups 9 ml of 2.5 % NaOCl, 9 ml of 17 % EDTA and 9 ml of saline were used as the final irrigation protocol. Using Pearson's chi-square tests the intergroup comparison for different scoring criteria was compared. Differences were considered statistically significant at P value < 0.05. Within the limitations of this study it can be concluded that: 1) Combination group (EV+PUI), EV, PUI showed better removal of debris in Groove and Depressions when compared to CNI group. 2) Combination group (EV+PUI) showed better removal of debris in Groove than EV, but no difference was observed when it was compared with PUI group. 3) Overall, the combination group (EV+PUI) showed better debris removal in Depressions when compared to all other groups, this was followed by PUI group and then by EV. 4) Similarly, combination group (EV+PUI) and PUI showed better debris removal in Depressions at 6 mm level when compared to EV group. 5) In case of debris removal in Depressions at 4 mm level there was no differences among the groups. 6) The combination group (EV+PUI) was the only group that had better debris removal at 2 mm level. Further studies are needed to evaluate the effectiveness of this combination irrigant delivery system for smear layer removal and antibacterial efficacy.

Conflicts of interest:

Declared none.

Acknowledgement:

Nil.

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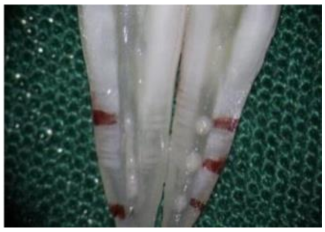
APPENDIX 1: REPRESENTATIVE SAMPLE OF EACH GROUP

GROUP I: Conventional Needle Irrigation

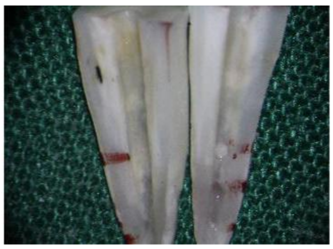
Before Irrigation



After Irrigation

GROUP II: Endovac Irrigation

Before Irrigation

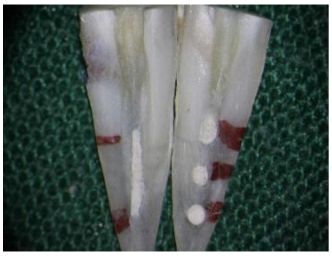


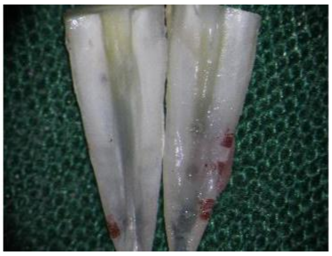
After Irrigation

GROUP III: Passive Ultrasonic Irrigation

Before Irrigation **After Irrigation**

GROUP IV: Combination Irrigation (Ev+Pui)





Before Irrigation **After Irrigation**