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EFFICACY OF ULTRASONICS VERSUS XP-ENDO FINISHER FOR REMOVAL OF INTRACANAL MEDICATIONS WITH TWO DIFFERENT VEHICLES (AN IN-VITRO STUDY)

Amany Suliman Abdelmalek[1], Dalia Mukhtar Fayyad[2], Nelly Mohamed Abdelsalam[3]

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KEYWORDS

Intracanal medication, Passive ultrasonic irrigation, Vehicles, XP-Endo Finisher

• E-mail address: amanysuliman@gmail.com

1. Postgraduate student, Endodontic Department, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.
2. Associate professor, Endodontic Department, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.
3. Associate professor, Endodontic Department, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt.

ABSTRACT

Introduction: The ultimate goal of endodontic treatment is to eliminate bacteria from infected root canals. Intracanal medications have been thought to be an important step in reducing microorganisms. Different means were introduced for the removal of intracanal medications, so there is a need to investigate which irrigation method should be used to remove the intracanal medication to achieve a complete coronal and apical seal of the disinfected canals. **Aim:** To compare the effectiveness of removal of Calcium hydroxide (Ca(OH)2) and Double antibiotic paste (DAP) with Propylene glycol (PG) and Glycerol vehicles using Passive Ultrasonic irrigation (PUI) and XP-Endo Finisher. **Material and methods:** 80 single-rooted extracted human teeth were categorized into 4 groups (n=20) based on the intracanal medicament used GroupA1; $Ca(OH)_2$ + PG GroupA2; $Ca(OH)_2$ + Glycerol. GroupA3; DAP + PG.GroupA4; DAP + Glycerol. Samples were stored in an incubator for 3 weeks and then subdivided into two groups Subgroup B1; PUI and Subgroup B2; XP-Endo Finisher. Irrigation protocol was NaOCl 2.5% followed by 17% EDTA. Each root half's picture was photographed using a USB digital microscope.The amount of medication still present in the canal was measured using the NIH image J V1.56 software program. One-way ANOVA and Duncan's Multiple Range Tests were used for the statistical analysis. **Results:** The difference between vehicles was not significant when all groups were compared as a total using the PUI method and XP-Endo Finisher ($p>0.05$). However, the differences in the percentage of remaining intracanal medication between vehicles were significant at apical, middle and coronal levels of PUI and also levels of XP-Endo Finisher. **Conclusion:** None of the irrigation activation methods used could eliminate any of the medications. Both vehicles did not improve the elimination of the medications used from the root canals. Removal of the medications from the apical level was more difficult than the other levels.

INTRODUCTION

Ideally, root canal instrumentation should contact the whole root canal system for optimal cleanliness and removal of microorganisms. Due to the intricate anatomy of the root canal system, this is, however, not possible. Modern dental technological breakthroughs have enabled new agitation devices and various ways to distribute the solution to the whole root canal to accomplish efficient disinfection and stimulate the removal of smear layer and debris from the walls of the root canal[(1)]. However, intracanal medication could contribute to the disinfection process. Different means were introduced for the removal of intracanal

medications, so there is a need to investigate which irrigation method should be used and which method should be used to eliminate the intracanal medication when used in the root canal preparation process to facilitate the complete seal of the root canal system[1-3]. The antimicrobial property of calcium hydroxide $Ca(OH)_2$ is debatable. Although several studies indicated the efficacy of $Ca(OH)_2$ against some bacterial species, other studies claimed its restrictions against fungal species. $Ca(OH)_2$ is a beneficial intracanal treatment in weeping canals, as well as for perforation control and resorption of roots. However, while employing $Ca(OH)_2$ as a dressing material in treatment for root canals, caution should be taken to avoid the paste being extended beyond the tooth apex and causing adverse side effects[4]. Double antibiotic paste DAP consists of ciprofloxacin and metronidazole and is widely utilized as an intracanal medication due to its bactericidal action and it does not cause discolouration of teeth when it is applied for weeks[5,6]. Vehicles were applied to $Ca(OH)_2$ as intracanal medication to improve its handling and delivery to the root canal. Examples of vehicles were water, saline, dental anaesthetics, Ringers solution, glycerin, polyethene glycol (PEG) and propylene glycol (PG)[7,8]. Remnants of intracanal medications may cause a gap between filling materials and the root canal wall. Thus, results in coronal or apical leakage which will cause a passage for the microorganisms and oral fluids to pass through the canal wall and filling materials failing the root canal treatment[9]. There are various techniques used for activation irrigants to facilitate removing of intracanal medications. Passive ultrasonic irrigation PUI considered being effective due to its flushing action[10]. XP-Endo Finisher is another method of activation which removed intracanal medications as well, especially from curved canals due to its free movement inside canals[11]. Efficiency of removal of intracanal medications is still a controversial issue with variable amount of remnants reported in different studies and the type of vechile that may affect the removal efficiency. This study was performed to held a comparison between PUI method and the XP-Endo Finisher activation method on irrigants to remove four different intracanal medications which are $Ca(OH)_2$+PG , $Ca(OH)_2$ with glycerol, DAP with PG and DAP with glycerol from the root canals. The null hypothesis of the present study is that there is no significant difference between the (i) intracanal medication type or (ii) activation methods regarding their effect on the amount of medication removed from the root canals.

MATERIALS AND METHODS

This research was achieved in alignment with the principles of the Declaration of Helsinki. Approval was given by the ethical committee of the Faculty of Dentistry, Suez Canal University (approval number: 163/2019).

1. Sample size calculation:

The sample size was calculated using G*Power software ver. 3.1.9.6 [12]. The effect size was 0.25 using an alpha (α) level of 0.05 and Beta (β) level of 0.05, i.e., Power= 95%; the approximate least sample size (n) was a sum of 80 samples.

2. Collection of samples:

This study was performed on extracted human mature, single-rooted teeth with a single canal. The single-rooted teeth were collected from the outpatient clinic of the Oral Surgery Department, Faculty of Dentistry, Suez Canal University with the following criteria: **Inclusion Criteria include:** Single rooted teeth with mature root apices. **Exclusion Criteria include:** Roots with cracks, Root caries, Teeth with external or internal resorption, Open Apices, Calcified root canals and Root curvatures.

3. Randomization, allocation concealment and blinding:

A. The samples were numbered from 1-80,

B. Then samples are distributed randomly by the allocator into four distinct groups, each with twenty samples and two subgroups, each with 10 samples using Microsoft Excel 365 (Microsoft, Redmond, WA, USA) and each irrigation activation technique was coded B1 or B2.**GroupA_1:** teeth received $Ca(OH)_2$ + PG (Metabiomed, Pennsylvania). **GroupA_2:** teeth received $Ca(OH)_2$ (JK Dental Vision, Cairo, Egypt) + Glycerol (OPTIKA, Italy). **Group A3:** teeth received DAP + PG (Shell global, Germany).**Group A4:** teeth received DAP + Glycerol (OPTIKA, Italy). **SubgroupB1:** Passive ultrasonic irrigation PUI with IrriSafe^R tips size 20 (Satelec, Acteon, France). **SubgroupB2:** XP-Endo Finisher size 25(FKG Dentaire, Swizterland).

C. The coded samples were sealed in an opaque envelope.

D. The operator was blinded for the coded samples but not for the irrigation technique used. The observer who measured the data using a Digital microscope (U500X, guandong, China) and the analyst who performed the statistical analysis were blinded.

4. Sample preparation:

Teeth were gathered and submerged in 5.25% NaOCl (Egyptian Company for household cleaners, Cairo, Egypt) for 10 minutes for disinfection. Using a periodontal curette (Helmut zepf, Germany), teeth were cleansed of calculus and soft tissue remains and then kept in distilled water at room temperature. A disc was used to decapitate teeth so that the remaining root length was about 15 mm to the end of the apex. Canal preparation was held out by one operator to maintain uniformity. First, in all samples, A #10 k file (DentsplyMaillefer, Ballaigues, Switzerland) was inserted to ensure canal patency. #10, #15 and #20 k-files (DentsplyMaillefer, Ballaigues, Switzerland) were used to prepare the root canals with 2mL NaOCl (Egyptian Company for household cleaners, Cairo, Egypt) irrigation to establish a glide path. Then, samples were mechanically prepared using ProTaper Next rotary (DentsplyMaillefer, Ballaigues, Switzerland) files on an X-smart motor (DentsplyMaillefer, Ballaigues, Switzerland) functioning at 300 rpm and a 200 gcm torque with a brushing motion and with light apical pressure by the following sequence X1 (017/04) file, X2 (025/06), X3 (030/07) and we stopped at X4 (040/06) at the full working length Between each rotary file, one ml of NaOCl (Egyptian Company for household cleaners, Cairo, Egypt) was utilised as an irrigant [13].

The 80 Samples were classified into four groups (n=20) according to the type of intracanal medications as follows:

GroupA1: teeth received $Ca(OH)_2$ + PG (ready-made, Metabiomed, Pennsylvania).

Group A2: $Ca(OH)_2$ powder (JK Dental Vision,Cairo, Egypt) combined with Glycerol (OPTIKA, Italy) was applied to the teeth as a vehicle. In a suitable container 8g weight $Ca(OH)_2$ is added to 20 g Glycerol portion wise while steering till homogenous paste is obtained.

Group A3: teeth received DAP mixed with PG as a vehicle. DAP with PG preparation: mixing 2.4g of ciprofloxacin (Pharco Pharmaceuticals, Cairo, Egypt) with 6 g metronidazole (Pfizer, USA) to obtain a homogenous DAP then in a suitable container 8.4g weight PG (Shell global, Germany) in a liquid form was added portion-wise while steering till the homogenous paste is obtained.

Group A4: teeth received DAP mixed with Glycerol (OPTIKA, Italy) as a vehicle. DAP with Glycerol preparation: mixing of DAP in the same

way as in group A_3, then in a homogenous container adding 20 g Glycerol portion-wise while steering till the homogenous paste is obtained. Medications were delivered to the canal by a lentulo spiral size 30 (DentsplyMaillefer, Ballaigues, Switzerland) on a low-speed handpiece.

Radiographic images were made to ensure that the canals had been filled and then the coronal part was sealed using cavity temporary filling (Cavit, 3M ESPE, Germany). Finally, all samples were stored in an incubator (PS.3A, Advanced Technology, Egypt) at room temperature for 3 weeks [13].

The temporary fillings (Cavit, 3M ESPE, Germany) were removed after the incubation period then manual K file size 40 (DentsplyMaillefer, Ballaigues, Switzerland) was inserted to the established working length to remove a gross amount of medications and to provide a pathway for the activating instruments.

Each group was divided into 2 subgroups based on the activation method:

SubgroupB1: Passive ultrasonic irrigation PUI with IrriSafe^R tips size 20 (Satelec, Acteon, France) To avoid contact with dentin walls, the Irrisafe tip was inserted one mm short of the working length and remained centered in the root canal. The activation started after the introducing of the irrisafe tip inside the root canal. Two cycles 30 seconds each were used to activate 10mL of 2.5% NaOCl (Egyptian Company for household cleaners, Cairo, Egypt) left in the root canals. The canal was cleaned with saline, and 5 mL 17% EDTA (DiaDent Group International, Canada) was activated for one cycle 30 seconds before a last rinse with 2.5 mL saline (Al Mottahedoon Pharma, Egypt) and drying with paper point size 40 (Metabiomed, Pennsylvania).

Subgroup B2: The XP-Endo Finisher size 25 (FKG Dentaire, Swizterland) was employed in a rotating motion with an X-smart endodontic motor (DentsplyMaillefer, Ballaigues, Switzerland). The engine speed was 800 rpm and the torque was 1 N.cm. In rotation mode, the A-phase form allows the file to access and clean parts that would otherwise be hard to reach with ordinary instruments. With slow and steady in-and-out movements, it was carried to its maximum working length. Two cycles 30 seconds each were used for activating 10 mL of 2.5% NaOCl (Egyptian Company for household cleaners, Cairo, Egypt). Then, after saline rinse, 5mL of 17% EDTA (DiaDent Group International, Canada) was activated for 30 seconds (one cycle) followed by a final rinse with 2.5mL saline (Al Mottahedoon Pharma, Egypt), and then canals were dried by paper point size 40 (Metabiomed, Pennsylvania) [14].

The total volume of irrigation was 20 mL: 10mL of 2.5% NaOCl, 5 mL of 17% EDTA and 5 mL of saline (2.5 mL for each rinse). The flow rate of irrigation was 5 mL/30 seconds. All samples were sectioned by making longitudinal grooves on each root's buccal and lingual surfaces with a diamond disc (kingsley North,USA) without penetrating the canal. A small chisel (Indosurgicals, New Delhi, India) was used to cut the roots in half.

5. Digital microscopic evaluation:

Under a digital microscope (U500X, guandong, China), the longitudinal two halves samples were inspected to calculate the percentage of the residual quantity of intracanal medications on the canal's walls in the coronal, middle, and apical thirds in proportion to the total surface area of the root canal. The best half with the apex shown was chosen for imaging [15]. A picture of each root half was obtained and the amount of leftover intracanal medications in the canal was calculated using the NIH image J V1.56 software program (Image J 1.43, National Institute of Health, USA). This program allows the transformation of the canal contents to black or white pixels which were then counted and compared.

Images were first, automatically, corrected for brightness and contrast. The picture with the cropped root canal third was duplicated, then the image was converted to 8-bit grayscale type, then thresholding was adjusted to select the whole root canal area and the total area was automatically calculated. In the duplicated image, conversion to an 8-bit grayscale type was also done. The thresholding of the root canal was adjusted to only select intracanal medications within the root canal. The total area of the selectively thresholded remnants of intracanal medication was automatically calculated. The residual intracanal medications were calculated as a percentage of the lumen area at each canal third, i.e. cervical, middle, and apical. Each third was determined by measuring the total root length using a digital caliper and dividing it by three [15].

Remaining medications (%)= (medication remaining area/area of radicular section lumen)*100[15].

Statistical analysis:

Statistical Package for Social Science (SPSS) IBM-SPSS ver. 23.0 for Mac OS was used to gather, check, edit, and organise data in tables and figures[12,16] and Microsoft Excel 2016. Outlier detection and a statistical test for normality were used to determine if the data were parametric or nonparametric. Data were analysed for both graphic and numeric descriptive statistics and the data were parametric. A one-way analysis of variation was applied to compare the difference across vehicles. Following that comes Duncan's Multiple Range (DMRTs) posthoc test at 0.05 level. An Independent t-test was applied to evaluate the difference between PUI and XP-Endo Finisher activation methods. A two-way analysis of variance was also performed to check the overall effect of medications, activation methods, and sections, in addition to the interaction between variables. Pearson correlation and simple linear regression were applied to assess the relationship between variables.

RESULTS

Comparisons between vehicles

The difference between vehicles was insignificant when all groups were compared as a total using the PUI method and the activation method of XP-Endo Finisher ($p>0.05$). However, according to one-way ANOVA, there were significant variations in the percentage of residual intracanal medicine (%) between vehicles at the apical, middle, and coronal levels of PUI and the same levels of XP-Endo Finisher. Duncan's multiple range tests (DMRTs) were also used to strengthen the comparison across groups (Table 1, Figures 1 and 2).

Comparison between methods of activation:

The difference between PUI Finisher and XP-Endo Finisher was insignificant as a total in the four groups (Table 1).

Comparisons between levels (apical, middle, coronal)

- ***PUI activation (Table 1 and Figure 1)***

The distinction between apical, middle and coronal levels was highly noteworthy, as revealed by one-way ANOVA in the four medications used. The highest % of remaining intracanal medication at the apical level was recorded in DAP+glycerol (84.6%), while in middle and coronal levels were recorded in $Ca(OH)_2$+glycerol (60.8%), (40.4%) respectively. In all groups, the apical level recorded the highest statistically significant mean value of % of remaining intracanal medication followed by the middle level, then the coronal level which recorded the lowest value.

- ***XP-Endo Finisher activation (Table 1 and Figure 2)***

Ca(OH)2+PG had the largest percentage of remaining intracanal medicine in the apical and intermediate levels (83.82%), and (66.65%), respectively, while DAP+Glycerol had the highest percentage in the coronal (47.2%). There was a statistically significant difference between apical, intermediate, and coronal levels in all treatment groups, except in DAP+Glycerol (A4), where there was no statistically significant distinction between various levels.

In groups A1, A2, and A3 apical levels recorded the highest statistically significant difference in the mean value of % of remaining intracanal medication than the middle and coronal levels which recorded the lowest one.

Table (1) *Percentage of remaining intracanal medication (%) at different vechile type (A; $Ca(OH)_2$ PG, $Ca(OH)_2$, DAP PG, and DAP glycerol), two activation methods (B) at three different levels (Apical, middle and coronal).*

Medication (A)	Level	Percentage of remaining intracanal medication					
		Activation method (B)					
		PUI		XP-endo		Independent t-test	
		Mean	SD	Mean	SD	t	Sign.
(A1) $Ca(OH)_2$ PG	Apical	**69.8**	8.5	**84.0**	14.7	-2.6	0.017*
	Middle	**48.4**	5.2	**66.8**	19.5	-2.9	0.010**
	Coronal	**40.4**	19.3	**29.3**	14.6	1.5	>0.05 ns
	Total	**52.9**	17.5	**60.0**	28.1	-1.2	>0.05 ns
(A2) Ca(OH)2 glycerol	Apical	**63.0**	14.9	**65.9**	18.6	-0.4	>0.05 ns
	Middle	**60.8**	9.2	**51.0**	15.3	1.7	>0.05 ns
	Coronal	**44.8**	19.3	**42.0**	16.6	0.3	>0.05 ns
	Total	**56.2**	16.7	**53.0**	19.1	0.7	>0.05 ns
(A3) DAP PG	Apical	**83.1**	17.6	**81.0**	19.9	0.3	>0.05 ns
	Middle	**50.5**	14.0	**27.1**	11.5	4.1	0.001***
	Coronal	**24.3**	15.9	**19.9**	9.2	0.8	>0.05 ns
	Total	**52.6**	28.9	**42.7**	31.0	0.2	>0.05 ns
A4 DAP Glycerol	Apical	**84.6**	11.0	**53.9**	12.9	5.7	<0.001***
	Middle	**44.5**	10.8	**49.8**	14.7	-0.9	>0.05 ns
	Coronal	**28.4**	10.1	**47.2**	9.3	-4.3	>0.05 ns
	Total	**52.5**	26.1	**50.3**	12.3	0.4	>0.05 ns

ANOVA-1 way			
Source	Df	F	Sig.
Corrected Model	23	18.2	<0.001***
Intercept	1	3177.1	<0.001***
Activation method (B)	1	1.2	>0.05 ns
Medication (A)	3	4.3	0.006**
Level	2	53.8	<0.001***
Activation method (B) * Medication (A)	3	3.6	0.015*
Activation method (B) * Level	2	1.2	>0.05 ns
Medication A * Level	6	8.3	<0.001***
Activation method B * Medication A * Level	6	8.6	<0.001***

NS; non-significant at p-value>0.05

** Significant at p<0.05; ** highly significant at p<0.01; *** very high significant at p<0.001*

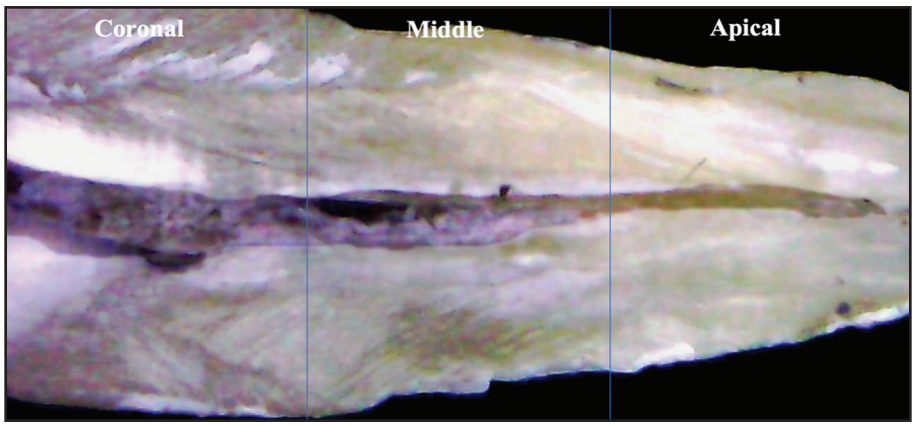

Fig. (1) Digital image showing 15mm remaining intracanal $Ca(OH)_2$+Glycerol after removal with PUI activation at different levels (apical, middle and coronal).

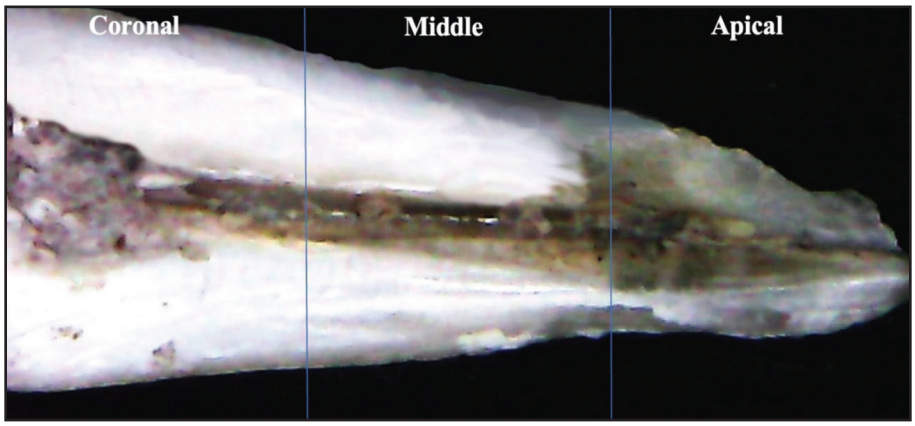

Fig. (2) Digital image showing 15mm remaining intracanal DAP+PG after removal with XP-Endo Finisher activation at different levels (apical, middle and coronal).

DISCUSSION

Removing intracanal medication is critical for optimal root canal system sealing by the obturating substance. Until now, however, no irrigation could entirely eliminate any of the most regularly used intracanal medications.This is due to the complexity of root canals and the stickiness of intracanal medications with their various carriers to root canal dentin walls[1,2,3]. The irregularities in the root canal system make it very difficult to clean completely. The main problem is that remnants of the intracanal medications would impede the proper sealing of the root canal system by the obturation material. This is due to the presence of gaps that prevents direct contact between the obturation material and the root canal dentin wall, which may lead to failure of root canal treatment[9]. The present research holds a comparison of the efficacy of two different irrigation activation methods, PUI and XP-Endo Finisher, in eliminating two intracanal medications with two different vehicles (PG and Glycerol), which were $Ca(OH)_2$ with PG as a vehicle, $Ca(OH)_2$ with Glycerol, DAP with PG and DAP with Glycerol

from root canals. $Ca(OH)_2$ with PG was chosen as it is very popular as an intracanal medication due to the antibacterial action of $Ca(OH)_2$[17,18]. $Ca(OH)_2$ with Glycerol as a vehicle was chosen as Glycerol enhances $Ca(OH)_2$ consistency and prevents its fast hardening [7]. DAP with PG was chosen because DAP is a broad-spectrum antibacterial agent that replaced TAP in cases to avoid minocycline-induced discoloration present in TAP [7]. The passive ultrasonic activation (PUI) method was chosen because it provides better irrigant distribution into root canal irregularities due to its characteristic acoustic microstreaming pattern. These actions provide mechanical flushing action which in combination with the chemical action of irrigant removes more intracanal medications from the root canals [10]. XP-Endo Finisher files were chosen for their flexibility and exceptional resistance to cyclic fatigue. Furthermore, the files make contact with and scrape the dentin surface and/or the root-filling material without affecting the canal's natural form[11]. Irrigation volume and solutions were standardized as 10mL of 2.5 % NaOCl and 5mL of 17% EDTA. Gokturk et al [19], used the same protocol and it was effective in removing intracanal medication from root canals. The root canals used in the present study were mechanically prepared by ProTaper Next files)20). The final preparation size selected was 40X to provide sufficient room for the intracanal medication to be placed. Also, this allows sufficient space for free movement of the activation means inside the root canal. Lentulo spiral size 30 was used at 5000 rpm, as it is considered safe and easy to deliver and properly distribute intracanal medications throughout the root canal[21]. The digital microscope was chosen because it allows for the capture of the root canal surface as a whole, more representative of the amount of medication remaining than previous studies that used scanning electron microscopes, which could only scan limited areas of a single section[22]. In this study, the different vehicles (PG and Glycerol) did not affect the total removal of intracanal medications regardless of the activation method applied, as there was no significant difference between different intracanal medications (with different vehicles). This could be attributed to the fact that both vehicles formed a homogenous paste with $Ca(OH)_2$ powder with an approximate molecular weight (PG: 76.09, Glycerol: 92.02) [17]. Due to its mechanical flushing action and chemical ability to dissolve Ca(OH)2 particles regardless of the vehicle used, the use of PUI suggests that the irrigant solution, in combination with ultrasonic vibration, was related to the removal of organic and inorganic debris from the root canal walls [23]. This was in agreement with Kirar et al [14], who compared water-based $Ca(OH)_2$ to oil-based $Ca(OH)_2$ removal from single rooted teeth by manual dynamic agitation, endoactivator agitation and PUI. The difference was insignificant between removing different Ca(OH)2 types with any activation mean. Removal of DAP was not affected by the vehicle used when PUI was applied and this is in agreement with Sariyilmaz et al [24] who compared a modified TAP mixture using cefaclor instead of minocycline to DAP, finding that neither TAP nor DAP influences the elimination efficacy of the tested activation systems. On the other hand, the present study was in disagreement with Berkhoff et al [25], who compared TAP to $Ca(OH)_2$ elimination using different irrigation techniques. They reported that 80 % of TAP was retained in the root canals but 80% of $Ca(OH)_2$ was removed from root canals. They referred to the reason for the TAP's high penetration, high diffusion and binding to the dentin that makes TAP very hard to be removed. In the present study when XP-Endo Finisher was applied, different intracanal medications showed significant difference which could be related to the type of the material used suggesting that $Ca(OH)_2$ has a small

particle size that easily penetrates dentin and be hard to remove but DAP large particle size makes it easier to be removed. DAP with PG showed the least amount of remaining intracanal medication compared to the other groups and it was significantly different than $Ca(OH)_2$ with the same vehicle PG. The vehicle used for both $Ca(OH)_2$ and DAP which were PG and Glycerol didn't affect the total amount of remaining percentage of intracanal medications left in the root canals when PUI or XP-Endo Finisher was applied. Hence, the first null hypothesis was accepted. Another point of comparison in this study was the comparison of XP-Endo Finisher and PUI as potential tool for improving the removal of intracanal medication. The results of the current research showed that the complete elimination of DAP and $Ca(OH)_2$ with different vehicles from the root canals was not obtained, and no significant difference was found between XP-Endo Finisher and PUI activation methods. This was in agreement with Keskin et al [26], who compared XP-Endo Finisher and PUI methods in removing $Ca(OH)_2$ from simulated internal resorption cavities and found no significant difference between them. They contributed their results to the physical flushing effect caused by the methods of activation to the irrigants used allowing them to interact with the $Ca(OH)_2$ particles and hence removing them. Non-significant differences between PUI and XP-Endo Finisher activation methods in the present study might be referred to as the straight wide canals that were used without curvatures that facilitate the instrument's work [27]. Lauritano et al [15], claimed that the PUI protocol is as effective as the XP-Endo Finisher instrument in removing root canal debris. Sariyilmaz et al [24], also found that XP-Endo Finisher and PUI were similarly effective in results in DAP/TAP removal. XP-Endo Finisher design as mentioned before being very flexible could enhance the effectiveness of irrigation even in the irregularities of the root canal system. The PUI and XP-Endo finisher activation methods both removed a gross amount of intracanal medication used in this study but no significant difference between them was spotted. This agreed with various studies which showed the same results [14,21,28-31]. Therefore, the second null hypothesis was accepted. Regarding the efficacy of medication removal from different root canal levels, the remaining % of intracanal medications in this study was higher in the apical area where it significantly decreased in the coronal area regardless of the method of activation used. This could be explained by the narrow diameter of the apical thirds which limits the removal of $Ca(OH)_2$ compared to the wide diameter of the middle and coronal parts respectively [29]. This was in agreement with Denna et al [29] where observed the complete removal of $Ca(OH)_2$ from the coronal and middle thirds of root canals when using the PUI or XP-Endo Finisher activation method. However, They noticed high remnants of $Ca(OH)_2$ in root canals in all tested groups in the apical thirds. The present study where XP-Endo Finisher showed a high remaining % of the $Ca(OH)_2$ groups in the apical area where it decreases significantly in the middle and coronal area, which was in disagreement with Gokturk et al who found that XP-Endo Finisher removed significantly more $Ca(OH)_2$ than the other groups tested in this study in the apical region (p0.05). They tested NaOCl activation with XP-Endo Finisher in different temperatures of solutions and environments. While the temperature of the NaOCl solution did not play a significant role in the $Ca(OH)_2$ removal. These contradictory results could be explained by the increased efficacy of the XP-Endo Finisher due to the elevated environmental temperature, as researchers paid attention that in-vitro testing of the XP-Endo Finisher needs an elevated temperature to transform from the M-phase which is soft and ductile to the A-phase which is

hard and strong, mimicking the actual clinical situation and rendering it more efficient in removing $Ca(OH)_2$ [19].

Micro Computerized Tomography(μct) image would have been more accurate than the digital microscope. This could be one of the limitations, unfortunately, μct is not available at the country. Although, XP-endo Finisher and PUI are appropriate methods for removal of intracanal medications but still more investigations should be done to figure out a protocol that could completely remove the intracanal medications.

CONCLUSION

None of the irrigation activation methods used could completely remove any of the intracanal medication despite the type of vehicle.

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