Efficacy of XP-endo Finisher, XP-endo Finisher R, CanalBrush and EndoActivator in the removal of Intracanal Medicament (An in Vitro Study)

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Abstract: ***The aim of this study was to evaluate and compare the efficacy of XP-endo Finisher, XP-endo Finisher R, CanalBrush and EndoActivator in the removal of Intracanal medicament. Sixty freshly extracted upper molar teeth with straight palatal roots were used in this study; all roots were shortened to a length of 12 mm. Canals were prepared with RECIPROC blue file R40 and irrigated with 10 ml of 2.5% NaOCl. Then the roots were split longitudinally. Two of the three standard grooves were created in the coronal and apical parts of one of root halves, and the other in the middle part of the second halves then each of the root halves and grooves was irrigated with 5 ml 17% EDTA for 60 sec. and 5 ml 2.5% NaOCl for 60 sec. The standardized grooves were filled with $Ca(OH)_2$ and the root halves were reassembled. After 7 days, R40 file at WL was used to get a space for irrigation needle and instruments.After thatspecimens were randomly divided into 4 experimental groups (n=15/group). $Ca(OH)_2$ was removed with different instruments as follow: Group (I): CanalBrush, Group (Π): EndoActivator, Group (III): XP-endo Finisher, and Group (IV): XP-endo Finisher R. 5 ml 2.5% NaOCl irrigation was used before and after every cleaning procedure with each instrument.The amount of remaining $Ca(OH)_2$ in the grooves was scored under a Stereomicroscope at 30X magnification. Statistical evaluation was performed using Kruskal–Wallis and Wilcoxon Sum rank test. The results showed that cleaning with XP-endo Finisher R (IV) resulted in significantly cleaner canals ($P \leq 0.05$) than CanalBrush (I), EndoActivator (Π), and XP-endo Finisher (III) at all canal levels. XP-endo Finisher resulted in cleaner canals than CanalBrush, EndoActivator at all levels, but with insignificant statistical difference ($P>0.05$). Apical level of all canals showed greater amountof$Ca(OH)_2$ remnants in compared to middle and coronal levels, whatever instruments were used. Apical groove was significantly difference from coronal groove ($P\leq0.05$) in all groups.None of the investigated instruments were able to completely removed all $Ca(OH)_2$ from the three root regions.*** ***Keywords: EndoActivator; XP-endo Finisher; XP-endo Finisher R; CanalBrush; $Ca(OH)_2$.***

1. Introduction

The primary aims of endodontic treatment are the removal of microorganisms and prevention of reinfection inside the root canal system. Even after mechanical instrumentation and irrigation procedures, resistant microorganisms can stay within the root canal system as a result of its complex anatomy **[1].**

Many studies **[2; 3; 4]** established the efficiency of intracanal medications in fighting the antimicrobial resistant microorganisms.In endodontics, calcium hydroxide ($Ca(OH)_2$)is utilized as an intracanal medication, owing to its antimicrobial efficacy and biological properties. The antimicrobial properties of $Ca(OH)_2$medicamentwere owing to its ability in releasing of hydroxyl ions and providing a highly alkaline environment with a pH value is about 12.5 **[5].** It is well recognized that $Ca(OH)_2$ residual must be eliminated due to its effect on the sealing and bonding of endodontic materials. Moreover, the residual of $Ca(OH)_2$ may result in an adverse chemical reactions with root canal sealer, leading to unpredictable prognosis by reducing its flow and working time**[6].**

Remaining medicament also has been established to impact negatively the accuracy of electronic working length (WL) measurement **[7].** Therefore, complete elimination of $Ca(OH)_2$ medicament prior to root filling is necessary. Since irrigation using sodium hypochlorite (NaOCl) only was not effective in the elimination of the medication **[8; 9]**, for that reason a combination of chemical and mechanical removal would be essential. Root canal instrumentation using a master apical file (MAF) and copious irrigation is the most commonly described removal technique **[10; 11].**

Several instruments and devices have been introduced for root canal cleaning. Some of these instruments, for instance CanalBrush **[12],** laser systems **[13]**, EndoActivator **[14] [15; 7],** EndoVac and XP-endo Finisher **[16][17]** have been utilized for the elimination of intracanal medicaments. XP-endo Finisher R recently introduced to the market for retreatment case. The results regarding the efficacy of these instruments and devices in removal of intracanal medicaments are controversial. Therefore, the cleaning ability of these instruments require further investigation.

2. Materials and Methods

2.1 Methods

2.1.1 Sample Collection and Selection

Palatal roots of sixty freshly extracted maxillary molars human teeth were selected. The criteria for root selection:
1) Straight root canal.
2) Mature centrally located apical foramen.
3) Patent apical foramen.
4) Root devoid of any resorption (internal and external resorption), crack or fracture.

Immediately after the extraction, calculus, stains and soft tissues on the tooth surface were removed manually by the use of a cumine**,** disinfected with 3.0 % NaOCl solution for 30 minutes **[18]**, followed by washing with tap water. The teeth were then stored in container containing thymol solution.

2.1.2. Sample Preparation

The length of the palatal root was standardized to 12mm from the anatomic apex by using a digital caliper and a permanent red marker. The tooth was then fixed on a bench vice, a double-faced diamond disc with straight handpiece**,** under water coolant, was utilized for cutting off the palatal root perpendicular to the long axis of the root in accordance with the drawn line**.** Then all root were measured using digital veneer**.** The pulpal tissues were extirpated by using barbed broaches, and the location of the apical foramen and the patency of the canals were verified by the insertion of a #15 stainless steel K-file and introduced slowly till it is visualized at the apical foramen Then the silicon stopper was set on the file, then the file was withdraw and measured by using an endodontic ruler, after that the correct WL was measured by subtracting 1mm from that measurement **[19].**

The samples were embedded, except for the coronal 3 millimeters, in an Eppendorf vial containing silicon rubber base impression material (putty consistency) to aid handling of the samples throughout the following steps**.** A straight fissure bur fixed on a low speed straight handpiece was used to make a hole in the base of the plastic vial to permit for the air in the tube to release during silicon putty insertion. According to the manufacturer's instructions the putty was mixed with the catalyst gel and inserted in the plastic vial then the sample was embedded in the silicon putty. Then the silicon material was left for complete setting and forming a block. After that the plastic vials were fixed using a bench vice in order to achieve a standardized position during the entire procedure.

2.1.3. Root Canal Instrumentation

The root canals were irrigatedwith 10 ml of 2.5% NaOCl solution during the preparation delivered by a 5.0 ml disposable syringe witha 30-gauge side-vented needle. During all irrigation phases, the needle was placedshort 2 mm from the WL.

The root canals were prepared with RECIPROC blue **(**40/06) NiTi file usingVDW.SILVER®RECIPROC® endomotors**.** According to the manufacturer 's instructions,the silicone stopper was set on the Reciproc® blue instrument at two thirds of WL. After that, the Reciproc® blue file was advanced in the canal by a slow pecking motion (in- and out- movements) without withdrawing the instrument totally out of the canal. The amplitude of pecking motions must not be surpass 3–4 mm. The instrument introduced easily in the canal in an apical direction. After 3 pecks, or if resistance was felt before the 3 pecks were completed, the instrument was withdrawn out of the canal to clean it. For the purpose of checking the patency of the canal a #15 hand file was utilized.

Then the canal was copiously irrigated and Reciproc® blue instrument was then re-used in the same way till it reached the two thirds of the estimated WL. The canal was irrigated and a #15 file was used to check patency up to the WL. The Reciproc® blue instrument was re-used as previously-mentioned till it reached the WL. Once the WL was reached, the Reciproc® blue instrument was pulled out of the canal for the aim of avoiding an unnecessary over-enlargement **[20].** For standardization purposes, one rotary file was used to prepare three canals and then discarded.

2.1.4. Root Sectioning

After complete root canal instrumentation, the roots were removed from their vials and a marker was utilized to draw guiding lines longitudinally on the buccal and palatal sides. Then the roots were fixed on the bench vice and longitudinally grooved buccopalatally on the previously-mentioned lines by using a diamond disc fixed on a low speed straight handpiece with water cooling, conserving the inner shelf of dentin surrounding the canal. The grooves were then cleaned from any remaining dust and debris by a short blast of air. Then the roots were cleaved by placing a surgical blade #15 in the groove and striking the blade gently with a small mallet **[21].** The longitudinal section of each root with ≤180° of the canal circumference was selected for the study since the sections with >180 of canal circumference would possibly hinder the total canal visualization thru photography **[22].** If teeth showing that the canals had been penetrated, the tooth was then discarded and replaced **[23].**

2.1.5. Artificial Standard Grooves

The specimens were positioned in silicone on Microscope slide. A graphite mark was made 2 mm apart from the apex to indicate the apical end of the apical groove. A second graphite mark was made 3 mm away from the first mark to indicate the other end of the apical groove. This maneuver was achieved by using an Electronic digital caliper with graded ends that were fixed 3 mm from one another in order to standardize the groove size and location**.** A similar graphite marks were made 8-11 mm from the apex for the coronal groove in the same half of the apical groove and 5-8 mm from the apex for the middle groove.

Then an ultrasonic tip P1 (0.3mm)was used to create artificial standard grooves inside the canal in each half which were 3 mm in length, 0.3 mm in width and 0.5 mm in depth and were located 2–5 mm from the apex for apical sections, 8-11 mm from the apex for coronal sections, and 5-8 mm from the apex in the opposite half for middle sections**[24].** Then the dimension of grooves was checked under a Stereomicroscope at 30X magnification**[11; 29, 30].**

The root halves and grooves were irrigated with 5 ml 17% EDTA for 60 sec. and 5 mL 2.5% NaOCl for 60 sec . Then, the root canal was dried with paper points **[25].** The root halves were dried with gauze.

2.1.6 Calcium Hydroxide Paste Insertion

Each groove was filled with $Ca(OH)_2$ by inserting the needle tip of $Ca(OH]_2$ paste on the groove and adapted by paper point **[26; 17]**and the Stereomicroscope was used to confirm that the groove was fully filled with $Ca(OH)_2$ paste **[25].**

After that a ligature wire 0.3 mm in diameter was used for the fixation of root halves and interlocked using orthodontic plier and then the root halves was reassembled by using a thin layer of cyanoacrylate glue and was remounted in Eppendorf vials **[19].**

Next, the roots were filled with $Ca(OH)_2$ paste starting from the apical aspect with the needle slowly advancing coronally until the paste was visualized at the canal orifice then using lentulo spiralin a slow speed handpiece**.**

Radiographs were taken to ensure that canals were completely filled with $Ca(OH)_2$ paste**.** Excess material was wiped off with moist cotton.

For all samples in the four groups the root canal was sealed coronally with a temporary filling material. Then the samples were stored in an incubator at 37°C with 100% relative humidity for 1 week.

2.1.7. Sample grouping

After this period, the temporary filling material was removed. For the removal of $Ca(OH)_2$, an R40 file at WL and 1 ml 2.5 % NaOCL was utilized to get a space for irrigation needle and instruments **[19].** After removal of R40 file, all specimens were randomly divided into four experimental groups (n=15) according to the instrument was used for removal of $Ca(OH)_2$

2.1.8 $Ca(OH)_2$ Removal

Group (I): CanalBrush

The root canals were irrigated with 5 ml 2.5% NaOCl and then were brushed with a Canal Brush (medium size). A 2–3 mm up and down motion was made by the Canal Brush at 600 rpm for 1min; according to manufacturer's instructions. The Canal Brush was introduced 1 mm short of the WL. After that, Canal Brush was moved around in small vertical movementsfollowed by a final flush of the root canal with 5 ml 2.5% NaOCland was dried with RECIPROC paper points. For standardization purpose one canal brush was used for cleaning a single canal, and then was discarded **[25; 24; 19].**

Group (II): EndoActivator

After irrigation of the root canals with 5 ml 2.5% NaOCl. The medium size polymer tip was used to remove the paste. The tip was fit passively inside the canal, 2mm shorter than the WL. EndoActivator was activated at 10,000 cpm for 1min with pumping action in short 2-3mm vertical strokes with the amplitude of 2mm for 1minaccording to the manufacture's instruction. Then the root canal was underwent a final flush with 5 ml 2.5% NaOCl and was dried with RECIPROC paper points. For standardization purposes the activator tip was used for cleaning a single canal then discarded **[25; 24; 19].**

Group (III): XP-endo Finisher

The XP-endo Finisher (25/00)was used according to the instruction of the manufacture, at 800 rpm for the speed and 1.0 Ncm for the torque.The stopper was set 1 mm short of the WL with the provided tube, the XP-endo- Finisher was cooled down with cold spray while it is inside the tube **.** After irrigating the canal with 5.0 ml 2.5% NaOCl, the XP-endo Finisher was removed from the tube and activated while its tip was inside the canal. The Finisher was activated for 1 min inside the canal using gentle 7-8mm lengthwise movements to contact the full length of the canal**.** Then the root canal underwent a final rinse (5.0 ml 2.5% NaOCl) and drying of the canal with RECIPROC paper points. For standardization purposes, each file was used for cleaning a single canal, and then discarded **[25;24].**

Group (IV): XP-endo Finisher R

The XP-endo Finisher R (30/00) was used according to the instruction of the manufacture, at 800 rpm for the speed and 1.0 Ncm for the torque**.** The stopper was set 1 mm short of the WL with the provided tube; the XP-endo Finisher R was cooled down with cold spray while it is inside the tube. So after irrigating the canal with 5.0 ml 2.5% NaOCl, the XP-endoFinisher R was removed from the tube and activated while its tip was inside the canal. The XP-endo Finisher R was activated for 1 min inside the canal using gentle 7-8mm lengthwise movements to contact the full length of the canal **,** followed by the final rinse (5.0 ml 2.5% NaOCl) and drying of the canal with RECIPROC paper points.

For standardization purposes, each file was used for cleaning a single canal, and then discarded**[25; 24].**

Both XP-Endo Finisher and XP-endo Finisher Rfiles were used under 35 °C by using heater **[27; 28].**

After finished all roots were removed and each half was separated, then all grooves in both half were evaluated under Stereomicroscope. The photographs were taken using a Stereomicroscope equipping with a digital camera at 30X magnification **[11; 29; 30; 33].**

2.1.9. Stereomicroscope Evaluation

The amount of remaining $Ca(OH)_2$ in the grooves was assessed under a Stereomicroscope at 30× magnification and equipped with a digital camera by using an numeric evaluation scale as described by[**31;26;30].**

Score 0: the cavity is free of $Ca(OH)_2$ remnants.

Score 1: less than the half of the cavity is filled with $Ca(OH)_2$ remnants.

Score 2: more than the half of the cavity is filled with $Ca(OH)_2$ remnants.

Score 3: the cavity is filled with $Ca(OH]_2$ remnants completely.

The remnants in each groove were traced by using specific software tool magnetic lasso tool and the total number of pixels occupied by the remnants were reported using the histogram function in the software **[32; 33].**

The 4 experimental groups were analyzed using Kruskal-Wallis and Wilcoxon Sum rank test at a significance level of $P \leq 0.05$. All statistical Analyses were performed using IBM SPSS Statistics 21 software.

3. Results

Kruskal–Wallis test and Wilcoxon Sum rank test were used due to the ordinal nature of the scores **[25; 24]**

Table (3-1): Kruskal-Wallis Test for the scores of $Ca(OH)_2$ remaining for four instruments groups at three different sites

Site	Groups	Min.	Max.	Median	MR	Kruskal-Wallis test	
						Chi-square	P-value
Coronal	CB	1.00	3.00	2.00	41.70	30.318	0.000
	EA	1.00	3.00	2.00	37.10		
	XP	1.00	2.00	2.00	30.80		
	XP-R	.00	2.00	1.00	12.40		
	Total	.00	3.00	2.00			
Middle	CB	1.00	3.00	2.00	35.40	15.526	0.001
	EA	1.00	3.00	2.00	37.33		
	XP	1.00	3.00	2.00	32.53		
	XP-R	.00	2.00	1.00	16.73		
	Total	.00	3.00	2.00			
Apical	CB	1.00	3.00	2.00	34.40	19.424	0.000
	EA	2.00	3.00	2.00	39.17		
	XP	1.00	3.00	2.00	32.73		
	XP-R	.00	2.00	1.00	15.70		
	Total	.00	3.00	2.00			

$P \leq 0.05$ significant(S), P>0.05 non-significant(NS)

The mean rank values for $Ca(OH)_2$ remnants for all groups at three levels shown in **(Figure3-1)**.

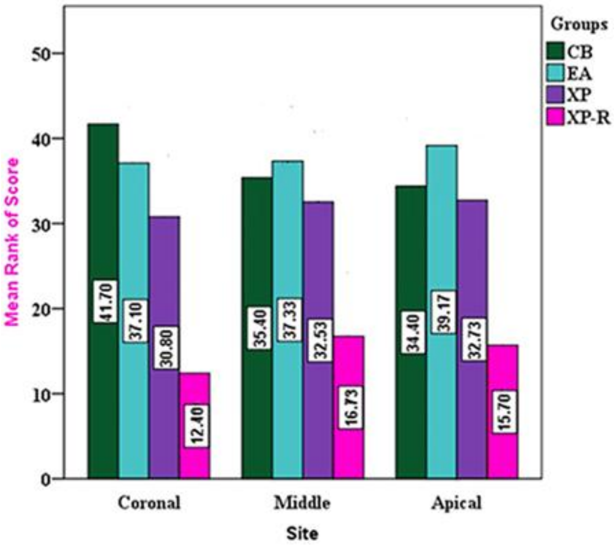

Figure (3-1): Bar chart showing mean rank of scores of $Ca(OH)_2$ remnants for four instruments groups at three different sites

From **Table (3-1)**and **(Fig. 3-1)**

At coronal level the highest mean rank was shown in Canal Brush (41.70) followed by Endoactivator (37.10) then the XP-endo Finisher (30.80)while the lowest mean rank at coronal groove was showed by XP-endo Finisher R (12.40)

At middle level the highest mean rank was shown in EndoActivator (37.33) followed by Canal Brush (35.40) then the XP-endo Finisher (32.53) while the lowest mean rank at middle groove was showed by XP-endo Finisher R (16.73).

At apical level the highest mean rank was shown in EndoActivator (39.17) followed by Canal Brush (34.40) then theXP-endo Finisher (32.73) while the lowest mean rank at apical groove was showed by XP-endo Finisher R (15.70). Wilcoxon Sum rank test was done for intergroups comparison was shown in **Table (3-2).**

Table (3-2): Wilcoxon Sum rank test for the scores of $Ca(OH)_2$ remnants between groups at three different sites (Coronal, Middle, Apical)

Site	*Group*	*Group*	*Wilcoxon Sum rank test*	
			Z	*P-value*
Coronal	CB	EA	0.804	1.00
	CB	XP	1.904	0.314
	CB	XP-R	5.119	**0.000**
	EA	XP	1.101	1.00
	EA	XP-R	4.315	**0.000**
	XP	XP-R	3.214	**0.008**
Middle	CB	EA	0.331	1.00
	CB	XP	0.491	1.00
	CB	XP-R	3.199	**0.008**
	EA	XP	0.823	1.00
	EA	XP-R	3.530	**0.002**
	XP	XP-R	2.708	**0.041**
Apical	CB	EA	0.838	1.00
	CB	XP	0.293	1.00
	CB	XP-R	3.287	**0.006**
	EA	XP	1.131	1.00
	EA	XP-R	4.125	**0.000**
	XP	XP-R	2.994	**0.017**

$P \leq 0.05$ significant(S), P>0.05 non-significant(NS)

From table (3-2) there were a significance differences $P \leq 0.05$ between XP-endo Finisher R and all other groups at the three different site levels. While a non-significance differences P>0.05 were found between XP-endo Finisher, EndoActivator groups and Canal Brush at the three different site levels.

3.1 The comparison of the remaining $Ca(OH)_2$ among three different sites (Coronal, Middle, Apical) at the same group

Kruskal-Wallis Test was done for the scores of $Ca(OH)_2$ to see if there was any significance difference among the three different site **Table (3-3)** and **(Figure3-2).**

Table (3-3): Kruskal-Wallis Test for the scores of $Ca(OH)_2$ remnants among three different sites (Coronal, Middle, Apical) for each group

Group	Site	Min.	Max.	Median	MR	Kruskal-Wallis test	
						Chi-square	P-value
CB	Coronal	1.00	3.00	2.00	22.43	2.307	0.316 NS
	Middle	1.00	3.00	2.00	20.23		
	Apical	1.00	3.00	2.00	26.33		
	Total	1.00	3.00	2.00			
EA	Coronal	1.00	3.00	2.00	18.33	9.198	**0.010 Sig**
	Middle	1.00	3.00	2.00	20.83		
	Apical	2.00	3.00	2.00	29.83		
	Total	1.00	3.00	2.00			
XP	Coronal	1.00	2.00	2.00	18.20	7.059	**0.029 Sig.**
	Middle	1.00	3.00	2.00	21.70		
	Apical	1.00	3.00	2.00	29.10		
	Total	1.00	3.00	2.00			
XP-R	Coronal	.00	2.00	1.00	17.50	7.578	**0.023 Sig.**
	Middle	.00	2.00	1.00	21.90		
	Apical	.00	2.00	1.00	29.60		
	Total	.00	2.00	1.00			

P ≤ 0.05 significant(S), P>0.05 non-significant (NS).

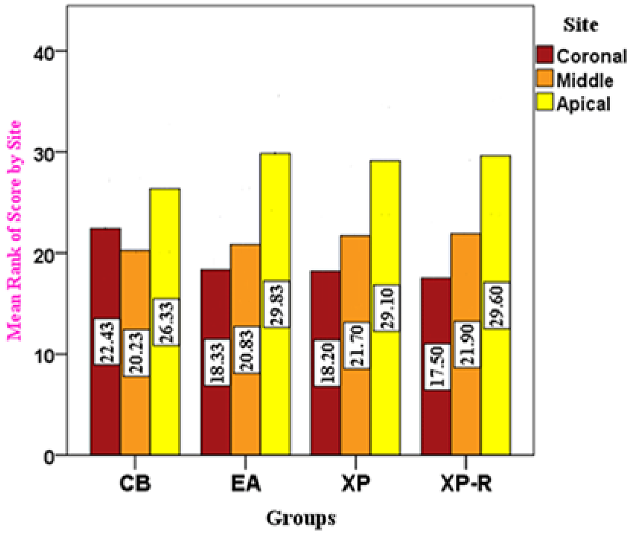

Figure (3-2): Bar chart showing mean rank for scores of $Ca(OH)_2$ remnants among three different sites for each group

By performing Kruskal-Wallis test **Table (3-3):**
For all groups (I, П, III, and IV) the highest of mean rank was found in apical site. While the lowest mean rank was found in coronal site for all group except for CanalBrush where the lowest mean rank was found in the middle site. In CanalBrush group a non-significance differences was found while for other groups a significance differences were found**.**

Table (3-4): Wilcoxon Sum rank test for $Ca(OH)_2$ scores between three different sites (Coronal, Middle, Apical) for each group

Group	Site	Site	Wilcoxon Sum rank test		
			Z	P-value	
EA	Coronal	Middle	0.627	1.00	NS
	Middle	Apical	2.256	0.072	NS
	Apical	Coronal	2.883	**0.012**	**Sig.**
XP	Coronal	Middle	0.835	1.00	NS
	Middle	Apical	1.766	0.232	NS
	Apical	Coronal	2.602	**0.028**	**Sig.**
XP-R	Coronal	Middle	0.989	0.968	NS
	Middle	Apical	1.730	0.251	NS
	Apical	Coronal	2.719	**0.020**	**Sig.**

P ≤ 0.05 significant(S), P>0.05 non-significant (NS)

Wilcoxon Sum rank test for the score of $Ca(OH)_2$ remaining at three different sites for each group showed that in all groups except Canal Brush, a significant differences (p≤ 0.05) were found between coronal and apical grooves while no significant difference (p> 0.05) were found between coronal and middle grooves, and between apical and middle grooves **(Table 3-4)** .

4. Discussion

The primary aim of root canal treatment is to reduce or eliminate bacteria and their by-products from an infected root canal system **[34].** To this end, intracanal medication has been advocated to disinfect the root canal system and as a consequence increase therapeutic success **[35]**. For this purpose, $Ca(OH)_2$ paste as intracanal medicament during endodontic therapy due to its antimicrobial efficacy and biological properties is used, but reportedly, failing to completely remove $Ca(OH)_2$ from the root canal walls following therapy influences dentin bond strength **[36]** and sealer penetration into the dentinal tubules,as well as markedly compromises the quality of the seal provided by the root filling. As a result of the previously mentioned reasons, removal of the $Ca(OH)_2$ medicament prior to root filling is mandatory. After removal of $Ca(OH)_2$ paste from the main canal, remnants can persist in canal extensions or in irregularities and this was the case in this study.

4.1 Discussion of methodology

Root canal anatomy possess numerous geometrical probabilities in cross section; for instance: round, oval, long oval, flattened or irregular **[37].** These anatomic complexities have been represented physical restrictions that pose a serious challenge for adequate root canal instrumentation and disinfection **[38].** Palatal root of freshly extracted human maxillary molars teeth was used in this study, since its canal has a more round cross section when compared to other teeth. In view of the fact that most of the enlarging instruments was resulted in circular carving motion **[39].** Therefore, using a root canal with round cross section would result in similarity between root canal geometry and the enlarging instrument, which consequently increased the similarity and standardization among the samples.

The length of the root was standardized to a uniform length (12mm) to obtain fixed and reliable reference point and for enhancement of instrumentation, and elimination of any variables in the access during the instrumentation and to facilitate the creation of groove standardized in size and location.

A preparation size (40) was estimated for representation of an adequate balance between the apical enlargement, the preservation of tooth structure, and the inhibition of technical mishaps. In addition, the preparation eased insertion of the irrigation and agitation devices to 1–2 mm short of WL, because the penetration depth of the irrigation needle has an influence on the mechanical efficiency of irrigation **[40]** and subsequently on the elimination of medicament.

The usage of NaOCl alone as a sole irrigation solution in this study, was done to concentrate on the effects of different instruments rather than investigate the influences of the irrigation solution. In this study, the agent, volume and the procedure for irrigation have been standardized for all experimental groups **[41].**

The benefit of the groove model was standardized the size, location of the grooves and the volumes of medicament used **[31; 26; 29; 30; 17].**Grooves also may be considered as typical irregularities of a root canal which are most difficult to clean from the medication. In spite of this, the complexity of root canal anatomy cannot be completely simulated by this model **[42].**

Scoring of cleanliness of the grooves probably would be easier and more reproducible than scoring of such a large area as the whole root canal wall **[42].** Additionally, this experimental design did not address medicament that diffused into the dentinal tubules. The model of this study was based on studies illustrated by **[31; 26;29; 24].**

Various techniques have been applied for evaluating $Ca(OH)_2$ removal from the root canal system **[43; 44; 11].** In this study, the samples were longitudinally split, and the percentage of residual $Ca(OH]_2$ was calculated from images have been taken under magnification of the whole area desired at Stereomicroscopy. Three different parts of the tooth were evaluated: the apical, middle, and coronal grooves. This method has been described as an effective method in determining the amount of $Ca(OH)_2$ residue using Stereomicroscopic analysis that evaluated the remnants in a more wide view considering the debris, differently from SEM that enables the researchers to view both debris and the smear layer **[45]**. In addition to the above-mentioned difference SEM have been required sectioning of tooth which may cause loss of material which effect the result. In addition to that only small area of the root canal could be observed since it operated at very high magnifications, resulting in certain observer bias.

Nainanet al. in 2013 **[46]** have been used volumetric analysis with spiral CT to evaluate the removal of three calcium hydroxide preparations used as intracanal medicaments. Although this technique permitted, three-dimensional measurement of $Ca(OH)_2$ existed in canal system and could be done without sectioning the teeth and thus preventing any loss of $Ca(OH)_2$ paste. In spite of that, it was not possible to assess the removal of filling material segmented into thirds, as long as the CT image analysis software did not provide a tool for dividing the structure examined into an equal parts. For that reason, the volume of initial and residual filling material were analyzed as a whole.

Moreover, μ-CT has anthor limitation that should be taken into consideration in evaluating the removal efficacy of $Ca(OH)_2$ paste in separate from other root canal filling materials such as gutta-percha or sealer. Generally, the radioopacity of $Ca(OH)_2$ paste, with the exclusion of iodoform-based material, is lower than that of gutta-percha or sealer. For that reason, the removal efficiency of less radiopaque material could be exaggerated as the residual material might not be recognized in scanned images **[47].**

Certain studies calculated the $Ca(OH)_2$ remnants in the root canal system by means of measuring the surface area of the $Ca(OH)_2$ residue existing in the canal in terms of mm_2**[43; 8].**On the other hand, the disadvantage of this technique might be the loss of material throughout sectioning.

In this study, a pixel count of $Ca(OH)_2$ remaining on the artificially created grooves was calculated and measured in terms of percentile values of the overall groove surface and these were then scored from 0 to 3 **[32; 33]**.The elimination of the subjectivity of some previous studies where evaluators gave the grooves a score of no, light, moderate or heavy for the amount of $Ca(OH)_2$ residual was the benefit of this method.

In this study, the effectiveness of different activation instruments Canal Brush, EndoActivator, XP-endo Finisher and XP-endo Finisher R were compared for their efficiency in removing $Ca(OH)_2$ paste.

All the canals were instrumented by one operator (the researcher) to minimize the variables during the study, The researcher was trained to practice the removal techniquesof $Ca(OH)_2$ paste before starting the actual experimental research work, which was achieved according to the manufacturer's instructions.

4.2 Discussion of results

4.2.1 Comparison of $Ca(OH)_2$ removal between the four different instruments groups

According to the results of this study, none of the instruments could completely remove all remnants of $Ca(OH)_2$ in all three root regions,this finding has also been described by other studies **[25; 24].** XP-endoFinisher R showed the lowest score than other groups in the removal of $Ca(OH)_2$ in all 3 sites of the root canal and significantly difference from XP-endoFinisher, EndoActivator and Canal Brush.

This result may be related to the features of XP-endo Finisher Rwhich is a new variation of the XP-endo Finisher file. The XP-endo Finisher R have differents in its core diameter larger (ISO 30) and in the angulation of its tip in comparison with the XP-endoFinisher (ISO 25), making it stiffer and also more efficient in removing root fillings materials adhering to the root canal walls **[28].** According to the manufacturer, it has been developed for removal of medicament and for retreatment cases, depending on the shape-memory principles of the alloy MaxWire and due to its flexibility, the XP-endoFinisher R has the ability to expand and contract with an improved reach of 6 mm in diameter or 100-fold when compared with a standard instrument of the same size. Its ability to expand and its sickle shape permits it to access and clean areas previously impossible to reach **[16]**.

No studies in literature, were found in term of $Ca(OH)_2$ removal by XP-endoFinisher R in compared with XP-endoFinisher, EndoActivator and Canal Brush.

Hashemi and Mackevičiūtė stated that the use of XP-endo Finisher R showed a significant difference in cleaning ability in every part (coronal, middle and apical) and increased cleaning efficiency when comparing with other instrument and found that there was a significant difference between the two groups in term of the total root canal filling material removal.

The XP-endo Finisher R have been made from entirely different technology that permits it to adapt and "scout" in searching for the remnants of root canal filling material and in following the morphology more precisely owing to its mixed phase technology.

Even there was a non-significant difference between XP-endo Finisher file, EndoActivator and Canal Brush; XP-endo Finisher file showed less amount of $Ca(OH)_2$ remnants than both of them in all three grooves. This finding have been related to the ability of debris and smear layer removal by XP-endo Finisher file which evaluated through SEM to its metallurgy which mean that when the file is subjected to the body temperature (the canal) it would convert it to austenitic phase in the rotation mode because of its shape-memory, this feature would permit the file to contact and clean areas that are otherwise difficult to reach with regular instruments **[48].**

It have been noticed that Canal Brush and EndoActivator groups did not have the same ability to follow the canal morphology and making a straight path towards the apex and not "scout" for $Ca(OH)_2$ remnants as XP-endo Finisher and XP-endo Finisher R.

CanalBrush that is used with a circumferential motion with a 2–3 mm up and down motion as a file creating space by scraping the $Ca(OH)_2$ bulk and the packed, scattered $Ca(OH)_2$ in the irregularities of the root canal, for that reason it was less effective in removing $Ca(OH)_2$ paste from the irregularities of the root canal system [**7; 19].**

While EndoActivator polymer tip have been produced vigorous intracanal fluid agitation throughout its swirling movement and cavitation by its pumping action in short 2-3mm vertical strokes at 10,000 cycles/min, 2mm shorter than the WL. Once EndoActivator tip is placed in the apical level of the root canal, there is a potential dampening effect that occur when there is contact with the apical root canal walls that might have restrained the displacement amplitude of the agitation devices and thus decreased agitation energy.

This result is coincided with the result of Göktürket al., 2018 **[49]** this study was evaluated the removal efficacy of $Ca(OH)_2$ by using CanalBrush, XP-endo Finisher, laser-activated irrigation (LAI), conventional syringe irrigation (CSI), passive ultrasonic irrigation (PUI) and Vibringe in the root canal walls and found that none of the protocols resulted in complete removal of $Ca(OH)_2$ from the canal walls and there were no significant differences among the investigated protocols. Also this result in parallel with the result of Göktürk et al., 2016 **[25**]**;** Göktürk et al., 2017 **[24]** who found a non-significance difference between XP-endo Finisher file and Canal Brush in the middle and apical region.

The result of this study in agreement with the result of Elnaghy et al., 2017 **[48]** who found that there was no significant difference between XP-endo Finisher and EndoActivator groups.

But this result in disagreement with Keskin et al., 2017 **[19]** who found that XP-endo Finisher removed significantly more $Ca(OH)_2$ than EndoActivator and CanalBrush. The reasons for this difference between the results may reflect different variable that the former study removed $Ca(OH)_2$ from standardized internal resorption simulated cavities with 0.8-mm depth and 1.6-mm diameter which prepared with burs at the level 5 mm above the anatomic apex in each halves of samples. These cavities have regular borders in comparison with the natural resorption, which are irregular lesions. Moreover, XP -endo Finisher had the ability to adapt and "scout" in search for root canal filling remnants and follow the round morphology of the internal resorption more precisely than Canal Brush and EndoActivator groups which did not have the same ability to follow the canal morphology, and making a straight path towards the apex. Thus, it might be easier to remove $Ca(OH)_2$ from simulated cavities **[19].** While in this study, $Ca(OH)_2$ was removed from artificial standardized grooves (coronal, middle, apical third] with 3mm in length,0.3 in width and 0.5 in depth.

Also this result disagreed with the result of Fahad and Luis who found in their study that EndoActivator was significantly removed more $Ca(OH)_2$ from root canal walls than XP-endo Finisher file. The reasons for this disagreement might be due to difference in methodological design including samples, evaluation technique and the concentration of irrigant solution; the authors used single-rooted teeth and after the combined usage of the removal instruments and 18% EDTA and 1% NaOCl as irrigant solution, the teeth were sectioned and $Ca(OH)_2$ remnants were evaluated by using SEM.

On the other hand Wigler et al., 2016**[17]** was assessed the efficacy of XP-endo Finisher file to remove $Ca(OH)_2$ from artificial grooves and stated that the claims of reaching the irregularities of the root canal anatomy were not fulfilled and also reported that XP-endo Finisher file have a possible shortcoming is that the operator has little influence on the amount of time that the file would actually contact a certain irregular area since the working time is the only factor that have been influenced by the operator.

There was no significance difference between EndoActivator and Canal Brush in the result of this study. This result was supported by other studies Topcuoglu et al., 2015 **[7];** Keskin et al., 2017 **[19];** Pabel and Hülsmann, 2017 **[42]**.This finding was coincided with Al-Garni et al studywhich have been reported that the use of EndoActivator system did not improve the efficiency of $Ca(OH)_2$ removal in comparison with other group at the middle and apical thirds.

And in agreement withSingh et alwho stated that the efficiency of Canal Brush is more than EndoActivator but the difference was not statistically significant ($P > 0.05$).

4.2.2 Comparison of $Ca(OH)_2$ removal at the three different sites (apical, middle, coronal).

The apical third was exhibited higher amounts of $Ca(OH)_2$ residual than the middle and coronal thirds in all experimental groups, apically is statistically significant difference from coronally except for Canal Brush . This finding is in line with the results of Gorduysus et al., 2012 **[50]**; Elnaghy et al., 2017 **[48]**; Gokturk et al., 2017 **t**

Although the middle section showed no significance difference from the apical and coronal sections, it exhibited lower amount of $Ca(OH)_2$ residual than apical section. The aforementioned observations might be correlated with the accumulation and transmission of $Ca(OH)_2$ residual to the apical region, that has smaller canal area and smaller volume of irrigation solution, in company with the anatomic complexity of apical third; therefore, the action and circulation of irrigants might be hindered.

In addition to previously mentioned factors, the depth of the irrigation needles penetration was restricted to 2 mm from the WL.
Therefore, apical section of canals would not get sufficient irrigation and subsequently obtain high scores. However, as compared to apical and middle section of the canals, coronal section of the canals which have a relatively larger volume would get a sufficient mechanical flushing. Simultaneously, the vapor lock which occurs as a consequence of air bubbles stuck in the apical third throughout irrigation decreases the effects of the irrigation solutions in the apical region **[51].**

This result disagree with Pabel and Hülsmann, 2017**[42]** who found that the coronal grooves showed more $Ca(OH)_2$ remnants than the apical groove. The conflicts in the published results might be related to many different factors like the diameter of apical preparation, volume of irrigant, length of time devoted to irrigation and the irrigation protocol that was used.

XP endoFinisher removed less $Ca(OH)_2$ in the apical groove than middle and coronal regions. This result is in parallel with the findings reported by Göktürk et al., 2018 **[49]** and could be related to change in instrument shape to a spoon upon rotation in the canal and expansion of the middle part of the instrument by more than its tip.

Although Canal Brush exhibited higher amounts of residual $Ca(OH)_2$ in the apical third in compared to the coronal and middle thirds, the difference was not statistically significant. This result in line with other studies Göktürk et al., 2016 **[25];** Göktürk et al., 2017 **[24].** Also it was reported that the minimum mean of $Ca(OH)_2$ remnants scores in Canal Brush group were observed at the middle grooves and this finding in parallel with Uzunoglu et al., in 2015 **[52].**Since Canal brush was more effective regarding debris removal in the narrower parts of the root canal where it was in better contact with the root canal surface **[53].** On the other hand, Canal brush was reported to be packed the remnant of $Ca(OH)_2$ mainly in the apical third of the root .The Canal brush might be act as a file creating space by means of scraping the $Ca(OH)_2$ bulk, the packed and scattered $Ca(OH)_2$ in the irregularities [**50; 7; 19].**

EndoActivator removed more $Ca(OH)_2$ in the coronal and middle third in compared with the apical third of the root canal. The reason for the above-mentioned results that once EndoActivator tip is placed in the apical level, there is a potential amount of dampening effect that happens when there is contact with the canal walls since the amplitude at the antinode might be as large as 2 mm**[19]** which is larger than the diameter of a root canal which denotes extensive wall contact between the tip and the root canal wall. This prevents free oscillation of the sonic tip, reducing the efficient streaming of the irrigant and as consequence the activation of the irrigant.

In parallel with the findings of the present study,Özyürek et al., 2017 **[54]** was reported thatCanal Brush showed less residual in the middle groove but higher residual in the coronal one when compared with Endoactivator.

5. Conclusions and Suggestions

5.1 Conclusions

According to the proposed methodology and based on the results of this an in vitro study, the following conclusions could be drawn:-

1) None of the investigated instruments were able to completely remove all $Ca(OH)_2$ from three regions.
2) XP-endo Finisher R removed significantly more $Ca(OH)_2$ paste than other instruments at all canal levels.
3) 3. No difference in the ability of XP-endo Finisher, Canal Brush and EndoActivator in the removal of $Ca(OH)_2$.
4) Apical level of all canals showed greater amountof$Ca(OH)_2$ remnants in compared to middle and coronal levels, regardless of instruments were used.

5.2 Suggestions

Suggestions for further studies:

1) Evaluation of the efficacy of investigated instruments in removal of other
2) types of intracanal medicaments.
3) Evaluation of the efficacy of investigated instruments for the removal of $Ca(OH)_2$ with different irrigation protocols.
4) Evaluation of the efficacy of anthor instruments for the removal of Intracanal medicaments.
5) Evaluation of the efficacy of the instruments in the removing of intracanal medicament using other assessment method.
6) Evaluation of the efficacy of the instruments in the removal of intracanal medicament in curved root canals.

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