EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 785:796, January, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

EDJ
EGYPTIAN DENTAL JOURNAL

Conservative Dentistry and Endodontics

Submit Date : 08-09-2024 • Accept Date : 22-09-2024 • Available online: 10-01-2025 • DOI : 10.21608/edj.2024.316930.3192

EVALUATION OF SMEAR LAYER REMOVAL DURING CANAL PREPARATION USING AURUM BLUE, PROTAPER NEXT, AND HYFLEX FILE SYSTEMS: IN VITRO COMPARATIVE STUDY

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ABSTRACT

Ensuring an effective endodontic therapy, requires free dentinal walls from any smear layer. Smear layers formed during canal debridement, any remanent of this layer may reduce the overall efficacy of therapy.

Aims: This study aims to evaluate the clearance of smear layer by using three different systems with different tapers, namely, Protaper Next (PTN) :(X1=17/04& X2=25/06) (Dentsply Maillefer, Ballaigues, Switzerland), Hyflex CM (HCM)(20/04&25/06) (Coltene-Whaledent AG, Allstetten, Switzerland) , Aurum Blue™ (Meta Biomed, Korea) (20/04&25/06%).

Materials and Methods: Ninety extracted mandibular premolars with a single canal were chosen for each taper. The teeth were randomly grouped evenly to three groups of 15 specimens. Analysing samples was runs out by using a Scanning Electron Microscope (SEM) at a magnification of 2000x at the centre of the three thirds: coronal, middle, and apical areas. Statistical analysis: of the data was conducted using the Kruskal-Wallis and Mann-Whitney tests.

Results: The study revealed a lower mean of the smear layer across all groups in the coronal region. No significant differences were found among the coronal thirds of the various groups. Despite some minor differences, all instruments removed smear layer produced during instrumentation. The significant difference was found between the coronal third and the middle as well as the apical thirds among the tested groups.

Conclusion: Root canal preparation with Aurum blue and ProTaper Next instruments resulted in better canal cleanliness in the apical and middle thirds compared with HyFlex CM instruments.

KEYWORDS: Cleanliness, Root canal preparation, NiTi Instrument, Instrument taper, SEM

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INTRODUCTION

The combination of mechanical and chemical preparation is the gold standard for long-term effective root canal therapy. Throughout the preparation phase, file action leads to haphazard formation of smear layers. This layer consists of tissue remnants, debris, and bacteria [(1)]. Thus, eradication of such layer is essential. The canal's final dimension should allow enough room for the irrigant to flow and saturate the entire surface, optimising its efficiency against the smear layer.

In the year of 1965, Wandelt [(2)] proved that a small quantity of the irrigants volume could be applied in narrow dimensional roots canals, which diminishes its effectiveness. Lately, that's statement was confirmed again by another study [(3)], which approved the fact that increasing the canal space dimension by mechanical preparation will subsequently drive more irrigant volume to the root canal. Altering canal dimensions can be managed by the clinician, who is able to use the larger taper and/or sized instruments. At the beginning stage of the endodontic file's use, it was believed that the preparation apically should be maintained wide to allow the irrigant to penetrate, disturb, and destruct the microbial populace along the overcritical region of root canal, the apical region. That was in the (ISO) regulations era [(4)]. With the breakthrough that occurred in nickel titanium rotary system production, increasing the instrument taper to grantee canal cleanliness became the main concept. This allows the preparation apically to be as minimal as possible to fulfil periodontium health. Also, it enhances the volume of the irrigation and simultaneously allows a larger dentinal tissue to be cut from the root canal walls , producing a cleansed wall [(5)].

The most widely used rotary system is ProTaper Next (PTN) (Dentsply Maillefer, Ballaigues, Switzerland). Its rectangular cross-section is designed to have 3 crucial inventions: progressive taper, M wire innovation, and the offset style. The kinematic of usage is continuous rotation. [(6)]

A different system that's newly brought out in the practice is HyFlex -controlled memory rotary instruments (HCM) (Coltene-Whaledent AG, Allstetten, Switzerland). The advanced approach in the alloy production of this file is to control the instrument memory. Which results in a unique design that gives the instrument remarkable flexibility, and in contrast to other standard NiTi systems, its resistance to cyclic fatigue can be increased as high as 300%. In addition, it fulfils the cleansing capability, banding the safety requirements all at once. [(7, 8)].

Aurum Blue ™ (AB) by (Meta-Biomed, Republic of Korea) is another recent born file system.

The "blue treatment" of AB is akin to the unique heat treatment used in the manufacture of these instruments, which gives a characteristic blue hue due to a visible layer of titanium oxide. The producer claims that this type of heat treatment promotes a large percentage of the martensite phase, which gives the instruments exceptional flexibility and fatigue resistance. Furthermore, the instruments undergo an electropolishing procedure to eliminate any surface irregularities and impurities. [(9)].

Controversial opinions had been documented in the literature, as it is not proven yet whether the largest taper and sized instruments produce clean walls more than the smallest ones due to conflicting results of the studies. Thus, the present study conducted an investigation into the way that the taper of the instrument improved the cleanness of the canal's confinement. "The elimination of the smear layer is unaffected by increasing the instrument taper" is the null hypothesis.

MATERIALS AND METHODS

Study design:

The conducted experimental work is carried out with prior approval by Taibah University, Collage of Dentistry Research Ethical Committee (TUCDREC/190524/AALGHAZALY).

Calculation of sample size

It was computed using the version 3.1 of G*Power software. Power analysis indicated a total size of 76 was essential to attain a study power 80% with an 5% alpha error and 0.4 effect size of [10]. The study included six groups, each comprising 90 extracted teeth.

Sample selection and preparation:

Ninety extracted single canalled human mandibular premolars were in use. Teeth were extracted for orthodontic needs and periodontal complications. Two views (mesiodistal and buccolingual) periapical radiographs were recorded using digital X-ray (FONA -XDG, Assago, Italy). Accordingly, only single canalled samples were chosen. Other excluding criteria were teeth with incompletely formed apices, roots with resorption and/or curvature, and obturated canaled. Cleaning the teeth was executed by an ultrasonic scaler to ensure removing all the soft tissues as well as any deposits that existed on the tooth surface. After which, the storage was at room temperature. Storage being in a purified distilled water before starting and through the work.

Canal preparation:

The selected samples were assigned to six groups randomly. Each group had 15 samples in accordance with the used file system and taper. To establish a standard root length amongst the groups: which was 12 mm, the crowns of all the used samples were removed until the cemento-enamel junction level by a diamond wheel and disc mounted on a handpiece, operated at low speed with coolant. Establishing the patency of the root canal was executed by using hand K-file #10 (Dentsply Sirona, Ballaigues, Switzerland). Inserting the file in the canal till passing the apical foramen so the file tip became visible, then determining the working length (WL) by reducing the file length approximately 1mm. Then the next file in sequence is #15 , that was utilized in a watch-winding manner to ensure the canal glide path and to confirm the apical size as well. [11]

Instrumentation of root canal was executed strictly in consonance with the manufacturer's specifications for each individual system. Using Glyde as the lubricant, a 1:16 gear reduction handpiece driven via an X-SmartPlus motor (Dentsply Maillefer, Ballaigues, Switzerland) was used in picking motion. The test groups were classified as shown in (figure 1):

Group 1&2: Aurum Blue™ System (AB):

The two used taper instruments were: 20.04 & 25.06, operated at 500 rpm / 2.0 N/cm torque according to the manufacture's instruction

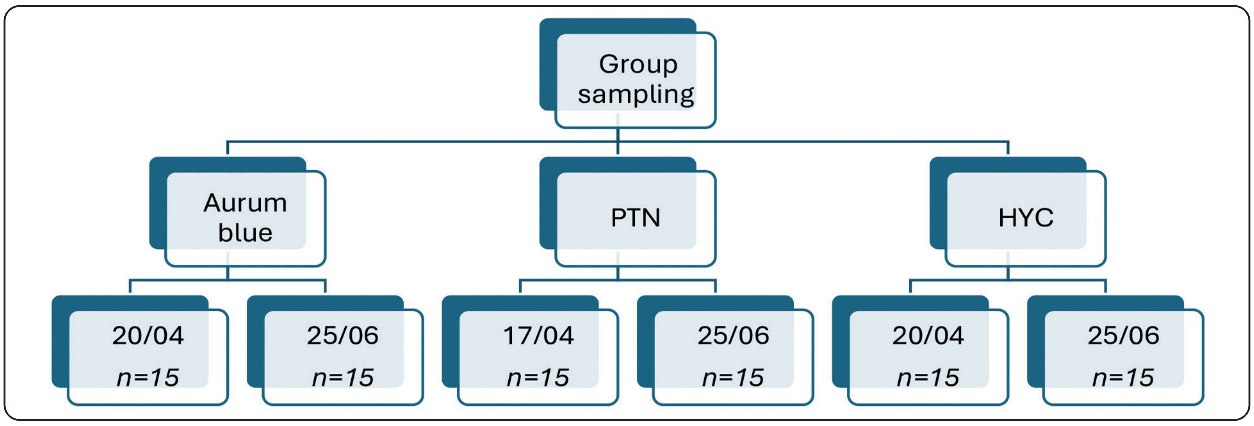

Fig. (1) Represented diagram shows the assigned samples to the different tested groups

Group 3&4:ProTaper Next™ System (PTN):

ProTaper Next X1: (size; 17, taper 0.04) & the second file was X2 (size 25, 0.06 variable taper, were operated at 300 rpm/2 Ncm)

Goup 5&6: Hyflex CM System (HCM)

The two used instrument taper of HCM (size 20/04 & #25/06, operated at speed of :500 rpm, torque of:2.5 Ncm).

The irrigation protocol that was adopted is that three mL of 5.25 percent NaOCl at 50 °C, was injected after every file insertion by an Endo-TOP (CERKAMED, Stalowa Wola, Poland) 30-gauge, side vented needle that was refilled frequently to avoid cooling [12]. Then, 4 milliliters of 17% EDTA were used (ENDOSOLution, CERKAMED, Stalowa Wola, Poland). A matching gutta percha point to the apical size according to each group was used with 2 to 3mm vertical strokes for 60 seconds. Washing of EDTA with 1 milliliter of 5.25% NaOCl for 60 seconds. Ultimately, ethanol was used to wash each canal for 30 seconds, the corresponding size of the paper points to the apical preparation in each group was used for dryness (META BIOMED, Korea).

Smear layer evaluation (SL):

Two deep grooves were created longitudinally on facial surfaces in a way far from exposing the canal space. After which, splitting the root was done by a microblade & mallet into 2 halves. Drying the samples in a series of graded ethanol. Then, the samples were left to dry for one day in dissector. To appraise SL at different zones of the root, a scale of numerical evaluation based on the following standards was utilised [13]:

- ***Score 1:*** There was no SL remnants on the surface of the root, and every tubule was clear & patent.
- ***Score 2:*** No SL, but the tubules is filled by debris.
- ***Score 3.*** The tubules as well as canal surface were covered with heavy smear layer.

Scanning electron microscope analysis:

Samples were secured on aluminum stubs with uniform diameter by using a sticky tape of double faced carbon. Scanning electron microscope (SEM) (Model FEI Quanta 3D 200i) attached with Energy Dispersive X-ray Analyses / thermofisher pathfinder (EDX Unit), was used to examine the smear layer under 30 KV accelerating voltage working conditions, Gun.1 nm resolution, Each region was then studied at a magnification of x2000. Representative images from various thirds were chosen.

Statistical Methodology:

For statistical analysis and for descriptive statistics, Data were imported into version 25 SPSS, represented in mean (SD), mode, minimum and maximum were calculated and represented in (Table 1).

The nonparametric data comparing between the three studied groups at different root areas were examined using the Test: Kruskal-Wallis. Additionally, a Mann-Whitney test with a < 0.05 significance level will be used for further investigation if the Test of Kruskal-Wallis revealed a significant difference amongst the tested groups. (Tables 2,3)

Non parametric comparisons between the taper 0.04 and taper 0.06 groups at different root areas for group 1,2,3 was represented in tables (4-6), and figures (2-4) respectively:

For coronal parts in both tapers 4 & 6%, no difference was considered amongst the three groups. A significant difference was recognized at the middle region as well as in the apical thirds in the two tested tapers as (P≤ 0.05). In taper 6%. A difference was recognized at the middle & apical regions respectively which was significant. In taper 4% A difference was tracked at the middle & apical regions respectively and was significant too.

TABLE (1) Descriptive statistics for all groups and areas

Groups		Areas	Mean (SD)	Mode	Minimum	Maximum
0.06 Taper	**1**	**Coronal**	1.73(0.457)	2	1	2
		Middle	2.4(0.507)	2	2	3
		Apical	3.2(0.414)	3	3	4
	2	**Coronal**	1.933(0.593)	2	1	3
		Middle	2.8(0.414)	3	2	3
		Apical	3.67(0.488)	4	3	4
	3	**Coronal**	2.2(0.56)	2	1	3
		Middle	3(0.000)	3	3	3
		Apical	3.8(0.414)	4	3	4
0.04 Taper	**1**	**Coronal**	1.933(0.258)	2	1	2
		Middle	2.6(0.487)	3	2	3
		Apical	3.2(0.414)	3	3	4
	2	**Coronal**	1.86(0.516)	2	1	3
		Middle	2.86(0.351)	3	2	3
		Apical	3.6(0.507)	4	3	4
	3	**Coronal**	2.266(0.593)	2	1	3
		Middle	3.06(0.258)	3	3	4
		Apical	3.6(0.487)	4	3	4

TABLE (2) Nonparametric comparisons between the test groups at different root areas for taper 0.06.

Taper 0.06			
Areas	**Groups**	**Mean rank**	**(P- value)**
Coronal	**1**	18.8	**0.077**
	2	22.57	
	3	27.63	
Middle	**1**	15.5 [a]	**0.01***
	2	24.5 [a]	
	3	29 [b]	
Apical	**1**	15.0 [a]	**0.03***
	2	25.5 [b]	
	3	28.5 [b]	

Statistically significant with≤ 0.05
Mann-Whitney test pair wise comparisons represented in superscript letters.

TABLE (3) Non parametric comparisons between the test groups at different root areas for taper 0.04

Taper 0.04			
Areas	**Groups**	**Mean rank**	**Kruskal Wallis (P- value)**
Coronal	**1**	21.2	**0.061**
	2	19.93	
	3	27.84	
Middle	**1**	18.67 [a]	**0.026***
	2	23.07 [a b]	
	3	27.27 [b]	
Apical	**1**	16.5 [a]	**0.024***
	2	25.5 [b]	
	3	27 [b]	

Statistically significant with≤ 0.05
Mann-Whitney test pair wise comparisons represented in superscript letters.

In taper 6% the largest score record of SL was accounted to (HCM) files at middle regions, which was statistically significant to both groups (AB & PTN), and in the apical third with significant difference to only AB files. AB files were the cleanest apically than the other tested files with a significant difference.

In taper 4% for the middle thirds, the cleanest group was the AB files, which was significantly different than HCM files. In the apical region, AB files produced the lowest score among the other tested files with a significant difference. HCM files recorded the lowest effect on smear layer apically, the significant difference was found to AB files only.

TABLE (4) Non parametric comparisons between the taper 0.04 and taper 0.06 groups at different root areas for group 1

Group 1= Aurum Blue			
Areas	**Taper 0.06 Mean rank**	**Taper 0.04 Mean rank**	**(P- value)**
Coronal	**14**	**17**	**0.148**
Middle	**13.5**	**17.5**	**0.150**
Apical	**15.5**	**15.5**	**1.000**

TABLE (5) Non parametric comparisons between the taper 0.04 and taper 0.06 groups at different root areas for group 2

Group 2= PTN			
Areas	**Taper 0.06 Mean rank**	**Taper 0.04 Mean rank**	**(P- value)**
Coronal	**15.9**	**15.1**	**0.757**
Middle	**11.43**	**19.57**	**0.003***
Apical	**16**	**15**	**0.710**

In comparison to each system separately in the two tested tapers, no difference was recorded amongst the different zones using files of groups 1& 3. While. In group 2: PTN, the lowest score was in taper 6 at the middle portion, and the highest was in taper 4 at the middle portion with a significant difference (0.003) (Table 5).

SEM images of the different root zones, that are representative of the SL evaluation at (magnification × 2000) are presented from figure (5-8) as the following:

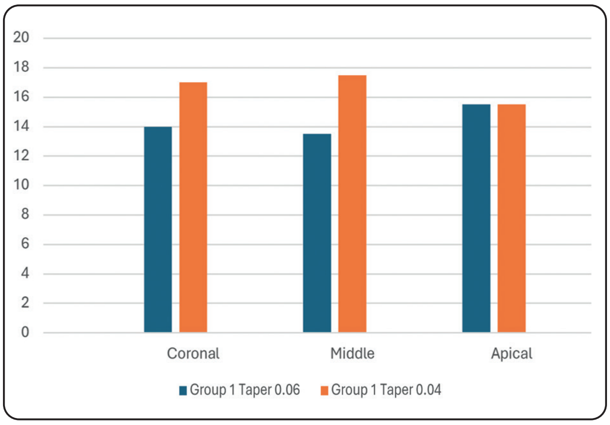

Fig. (2) Bar chart showing mean and standard deviation values (error bars) of smear layer score for GROUP 1:AURUM BLUE fat different root regions

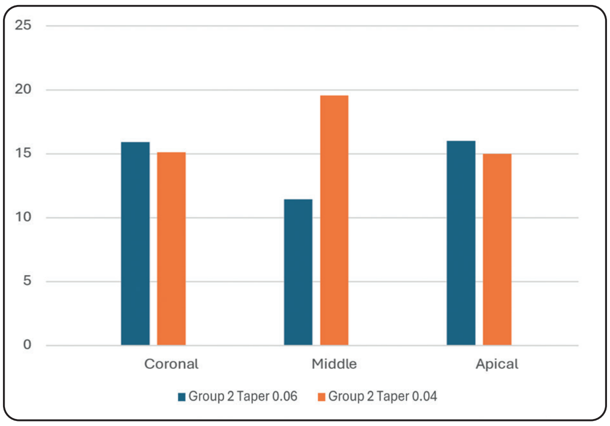

Fig. (3) Bar chart showing mean and standard deviation values (error bars) of smear layer score for GROUP 2:PTN at different root regions

TABLE (6) Non parametric comparisons between the taper 0.04 and taper 0.06 groups at different root areas for group 3

Group 3= Hyflex			
Areas	Taper 0.06 Mean rank	Taper 0.04 Mean rank	(P- value)
Coronal	15.03	15.97	0.732
Middle	15	16	0.317
Apical	16.5	14.5	0.417

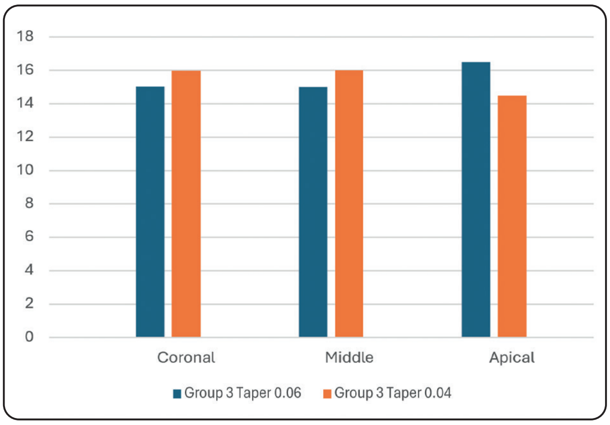

Fig. (4) Bar chart showing mean and standard deviation values of smear layer score for GROUP 3:Hyflex at different root regions

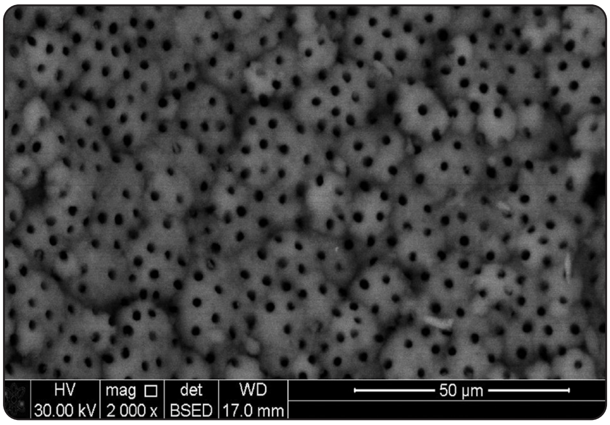

Fig. (5) Aurum blue file tper 6% (at the coronal third, magnification 2000x)

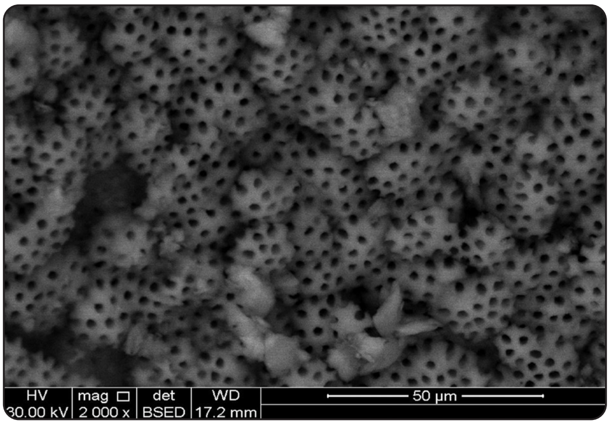

Fig. (6) ProTaper Next 6%(at the middle third, magnification 2000x).

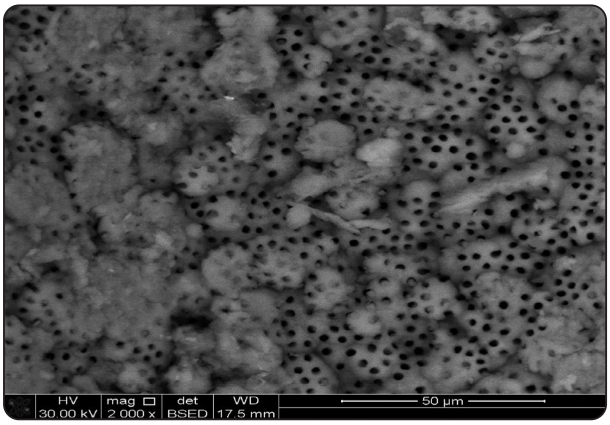

Fig. (7) Hyflex CM taper 4% (middle third, magnification 2000x).

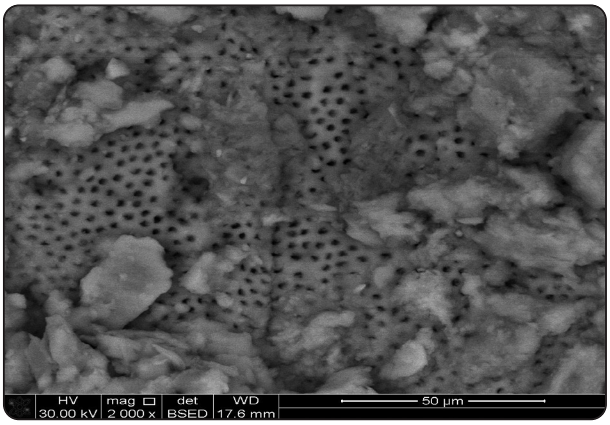

Fig. (8) Canal prepared with HyFlex CM taper 4 %(apical third, magnification 2000x).

DISCUSSION

The cornerstone of an effective endodontic treatment combined chemical as well as mechanical debridement. During such a phase, root dentin is cut and shaped, resulting in smear layer that accumulates and covers the entire surface of the root canal. [14]. A debate had been found through the literature about the benefit of smear layer existence, as it can block the bacterial invasion as well as the fluid leak through the dentinal tubules, but on the other side some studies found that, afterward this layer formation, penetration of obturating material into the dentinal tubules became impossible, moreover intracanal medicament and sealer became isolated from the wall surface due to the existence of this layer, which might affect the root canal seal.[15,16]. Thus, this layer is well approved to have an adverse effect on the treatment prognosis [17,18].

The first description of the smear layer was found within the context of a study in 1975 by pioneer researchers McComb & smith [19]. Another study approved the existence of such a layer on the surface of the instrumented portion of the canal walls and being absent in areas that have not been instrumented [20].

The competence of the tested instruments in SL eradication was assessed using a standard coalition of irrigatnts : NaOCl & EDTA- which contained chelating agents as used in clinics on a regular bases [21]. Irrigation alongside the instruments plays a vital part in the debridement, the intricate root canal system will not be sufficiently cleaned by them. So, additional approaches of activation were used to enhance the irrigation potency. Both thermal and manual agitation were adopted in the current work to enhance the irrigant effectuality.

Syringes with side-vented needles were utilized in this experiment, this type of manual irrigation work by positive pressure [22]. As such needles are designed to be closed ended, with a lumen located 2 mm away from the side. This causes turbulence to surround the needle's tip, which is directed apically at a divergence of around 30° [23]. The irrigant was activated simply and affordably through the experiment consuming the dynamic agitation by manual means. It entails repeatedly inserting a gutta-percha cone that fits well into the working length of a prepared canal. By repeatedly inserting the gutta-percha, apical gas trapping was prevented at 0 to 2 mm of the apical seal, thus enhancing the irrigant flow and allowing it to be replaced as well [24]; thereby it was found to be considerably more effective than the conventional way of irrigation [25].

Another approach of activation was utilized, which is by thermal mean. Based on the result of pervious work that proved that raising the temperature of NaOCl makes it more effective in dissolving tissue [26]. From an electrochemical perspective, a higher temperature makes NaOCl more capable of oxidation-reduction, which makes it a more powerful agent [27].

The smear layer dismissal is highly dependent on the file system performance [16]. And second: by enlarging the canal space dimension during the debridement action, which is the function of instrument taper and size [2, 28].

Preparation with larger tapered instruments oblige more irrigation quantity to reach and affect the entire root surface down to the apex. Bigger instruments started to lose their flexibility and were no longer centred in the canal. Which causes needless removal of dentin from one canal side and doesn't even touch the dentin at the other side, which is particularly problematic in curved canal [29,30]. Thus the maximum taper used in the current study was 6 and 25mm as a maximum size to grantee the minimum required root wall thickness to be left.

The scanning electron microscopywas used for SL measuring at the magnification of (×2000). As higher magnification covers very small surface and gives precise data. In addition, enhancing the visualization of the dentinal tubule openings [31].

In the current work, the outcome showed no significant difference across the six groups regarding the coronal third. Coronal region achieved the highest cleaning efficiency. There was a decline in canal cleanliness from the coronal region down to the apical regions with a significant difference, thus the rejection of the study null hypothesis was confirmed. Coronal third was the cleanest region compared to other regions of the entire root surface; this observation is consistent with previous work. [32, 33,34]. Those studies approved that the wider preparation at the coronal third was the most clean part, as more irrigant volume was induced to the canal space, promoting an effective fluid dynamics and turbulence. In addition, better irrigant exchange within the apical region can be achieved by using an instrument with bigger file sizes.

Best performance in the coronal thirds was recorded for group 1 (taper 6 Aurum Blue) without a significant difference to the other tested files of the same taper in this region. Moreover, the best performance in the apical third was recorded for Aurum blue taper 6 file system with a significant differences to the other tested file systems in the same taper. Higher smear layer was recorded in Aurum blue 20/04 in comparison to Aurum blue 25/06 in both coronal and middle thirds without a significant difference. This could be explained by the different features of both files. As taper 4 AB file is a square shape, its tip diameter is 0.20mm, and less in taper compared to taper 6 AB files, with a convex triangular shape and tip diameter of 0.25mm. So, the largest contact area with small tip sized leaves remanent of smear layer adhered to the canal wall [35]. This is well documented by study that approved that rotary files designed in square cross-section possess the maximum screw-in during debridement, which lessens the chance of debris to flush out. Also, the flexural stiffness increases, those finding being less in the other cross-sectional designs as rectangular and triangular, as well as the slender and rectangular ones [36].

Five files with different lengths, design features, and tapers are included in the PTN files, which is the descendant for the ProTaper Universal files. The variable taper of the tested X1 and X2 files has a great impact on the result of the current study. These files feature an offset mass of rotation starting from D4 up to D16 and a centered rotation extending from D1 to D3. The ProTaper Next's offset design offers several significant benefits. The high cutting efficiency, which is credited the ultimate cleaning capability. And the swaggering impact, which reduces file engagement, providing a greater cross-sectional area for more effective cutting, and debris loading which auguring them out of the canal. Furthermore, it reduces the likelihood of debris compaction on the canal sides, which might impede the radicular space, thus preserving the canal patency.

In the current work, PTN convey significantly cleaner wall at the middle third using taper 6 than in taper 4 instrument. Such finding occurred because of larger room that was kept for irrigation to flush out all the debris as approved in the previous studies [37,38].

The used Protaper next X1 is 4% taper and size #17. Which recorded lower cleaning efficiency in the middle and the apical region than Aurum blue taper 4 with significant difference. The small tip diameter of 0.17mm compared to 0.20 mm is most probably the reason behind this, as the cutting efficiency was decreased [39,40].

Shaping ability of Hyflex file appears to be less efficient as the resultant cleanness was inferior to the remained tested groups. Probably that finding can be explained by the nonuniformity shape, which was left in the radicular space after the preparation process, thus blocking the remnants of smear layer to be flushed out. Which came in accordance with pervious work [41, 42].

None of the file systems that was used in this investigation were able to completely clean all the samples in the designated group. A study by

Ahlquist M et al. and Barbizam JV et al. supports this conclusion [43,44]. Furthermore, the result of the current work is constituent with Arvaniti and Khabbaz et al 2011[45] who stated that only in cases when the ultimate used instrument size was less than 30, may a root canal taper have an impact on debridement quality.

Apical region was confirmed to have more smear layer than the other region through the entire root surface, which can be explained by the finding of the earlier study [46], which stated the smaller apical canal diameters, will prevent irrigants penetration and lead to less interaction to canal walls.

CONCLUSION

Under the study's conditions, it was obvious that the taper of the instrument is the most influential elements that impacting the smear layer elimination. The recent thermal treatment of the rotary files is a footprint in the cleaning capability. Activation of irrigation by the different approaches is irreplaceable and should be adopted during the debridement procedure.

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