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THE INFLUENCE OF THE MINIMALLY INVASIVE PREPARATION AND DIFFERENT IRRIGATION PROTOCOLS ON ROOT CANAL CLEANLINESS (AN IN VITRO STUDY)

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ABSTRACT

Background: The space for irrigant cleansing action that ultimate root canal dimensions is influenced by root canal size and taper. **Aim of the study**: to investigate the effect of minimal invasive endodontic preparation technique with different irrigation protocols on the cleanliness of extracted mandibular permanent molars.

Materials and methods: A total of eighty extracted mandibular permanent molars were selected in this study. All teeth were divided into 4 groups depending on the taper and size of the file that was used for each group: group I: up to size 25 taper 0.04, group II: up to size 25 taper 0.06, group III: up to size 30 taper 0.04 and group IV: up to size 30 taper 0.06. Each group was randomly divided into two subgroups: In Subgroup A: traditional irrigation technique without activation of the irrigant while in Subgroup B: traditional irrigation technique with ultrasonic activation of the irrigant.

Results: By using Chi square and Paired-t tests, when comparing the subgroup A to subgroup B of each group, it revealed significant difference between them regarding group I, group II and group III, but no significant difference between them regarding group IV in case of debris removal. But, it revealed no significant difference between them regarding smear layer removal except in group I.

Conclusion: A root canal preparation to a size 25 taper 0.04 with irrigant activation resulted in significantly less residual debris in the root. In addition to, there is no significant difference in smear layer removal between all the groups.

KEYWORDS: Root canal taper, canal cleanliness, smear layer, debris, ultrasonic activation

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INTRODUCTION

In endodontic treatment, one of the most important prior measures in ensuring a successful positive prognosis for an endodontically treated tooth is to prepare suitable access cavities to the pulp chamber and root canal system. An adequate access cavity allows for straight-forward canal localization, quick assessment of the working length, appropriate chemo-mechanical preparation, and root canal filling. Deficient cavity and root canal preparation restricts debridement, disinfection, and obturation of the root canal system.[1,2]

Chemo-mechanical preparation is an important step in root canal treatment because it cleans the root canal system of microorganisms and contaminated dentin and prepares the root canal dimensions for retaining the obturating material. Previously, shaping of the root canals was done using standard 2% taper hand instruments. As dentistry progressed, a wide range of Ni-Ti rotary and reciprocating instruments entered the market. Because of their physical design, taper, and metallurgical qualities, which enable excellent root canal preparation, they significantly enhanced root canal preparation and lowered the time factor. Due to the increased taper of these files, it resulted in aggressive removal of the radicular dentin and decreased teeth fracture strength.

When utilizing hand instrumentation files, it was formerly considered that the apical region of the root canal should be as wide as possible to allow irrigants to reach the apical 3mm and minimize or eradicate the bacterial load. Using nickel-titanium rotary systems is thought to allow for less apical preparation while increasing the taper of the root canal, which in turn leads to a larger space for irrigation fluids to be deposited. At the same time, more dentin would be removed from the canal walls, resulting in a cleaner root canal.

Although debris was more successfully removed when the apical preparation was increased due to the more the size of the canal, the more irrigant can be delivered into the canal and the more flushing action of the irigant [3], apical enlargement with continuous tapering will remove more dentin from the coronal and middle thirds, making the tooth more prone to vertical root fracture.[4,5] As a result, in accordance with the concept of minimally invasive treatment, they employed files with less taper to do more preparations in the apical thirds while maintaining dentin in the coronal and middle third.

Utilizing irrigation activation methods can facilitate the cleansing of the root canal walls. Ultrasonic technology is the most often employed way for activating irrigants. This involves employing cordless devices that utilize ultrasonic waves to activate the irrigants. Acoustic streaming is the characteristic that enables substantial agitation of the irrigant in this approach. The previously described method led to heightened antibacterial efficacy and increased tissue breakdown.[6,7]

MATERIALS AND METHODS

Selection of samples

Eighty extracted mandibular molars were selected for this study. Only the mesio-buccal (MB) and mesio-lingual (ML) canals of the mandibular molars were used. The teeth were immersed in a 5.25% sodium hypochlorite solution for a duration of 5 minutes in order to eliminate the periodontal ligament. Any leftover organic residues were removed from the external root surface with a scaler.

Classification of samples

The eighty samples were divided into four equal groups according to final root canal preparation size and taper done using EdgeEndo NiTi rotary files (Perfect Dent, EdgeEndo, Albuquerque, Mexico) as follows in **figure (1)**:

1) Group I canals were prepared up to size 25 taper 0.04.

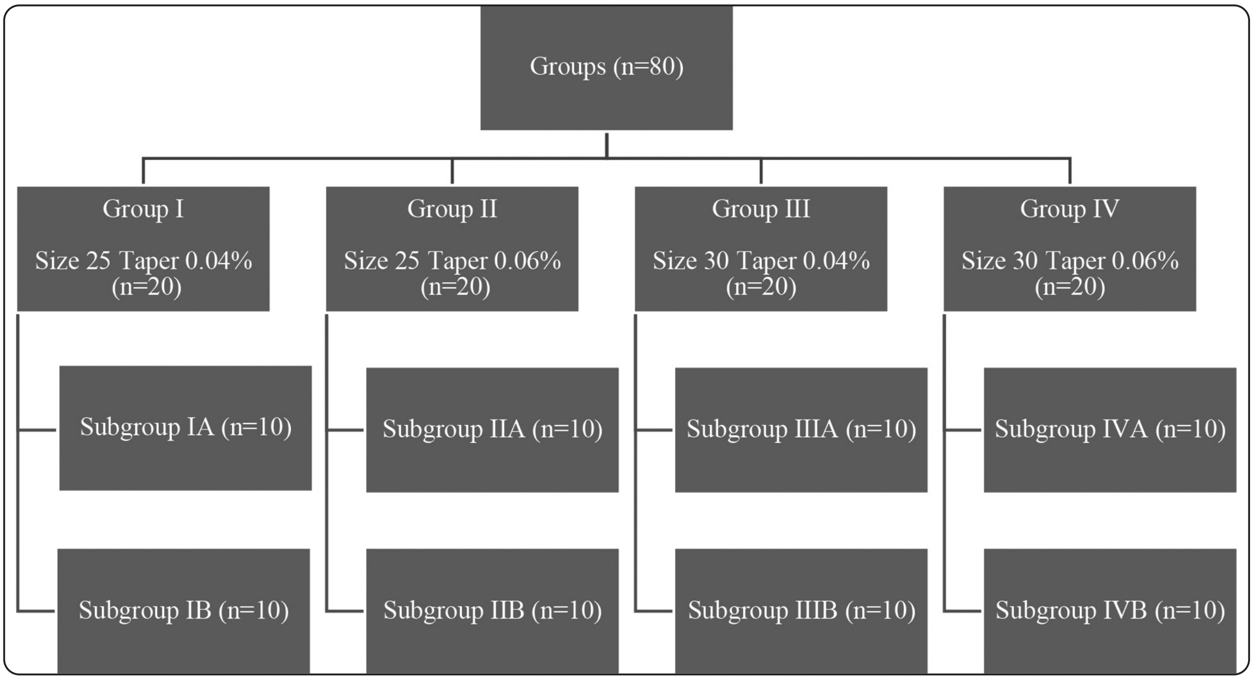

Fig. (1) Showing groups and subgroups

2) Group II canals were prepared up to size 25 taper 0.06.
3) Group III canals were prepared up to size 30 taper 0.04.
4) Group IV canals were prepared up to size 30 taper 0.06.

Each Group were further subdivided into two subgroups according to the irrigation protocol as follows:

a) Subgroup A without activation of the irrigant.
b) Subgroup B with ultrasonic activation of the irrigant.

Two periapical radiographs were taken in a bucco-lingual direction with two different angulations for studying root canal anatomy and curvature, identify the radiographic apex and to confirm the size of pulp chamber for doing conservative access cavity. Also, to confirm that each tooth had two separate mesial canals. The Schneider approach involves drawing a straight line from the canal orifices to the point of curvature, and another line from the apex for the apical curvature. The angle is then determined at the point where these two lines connect.[1,8]

Preparation of samples

Access cavity preparation

A conservative approach was employed, utilizing magnification to focus on the area between the roots and existing root canals. The access was extended only as needed to reach the canal openings, while ensuring the preservation of the pericevical dentin and a portion of the chamber roof. This was achieved by using a round diamond bur (Mani, Utsunomiya, Japan) attached to a high-speed handpiece, with adequate water-cooling to prevent overheating. Once the root canal openings were located, the accessibility of the (MB) and (ML) canals was assessed using a size 10 K-file (Mani, Utsunomiya, Japan). This was followed by manual cleaning and shaping of the canals using size 15 and 20 K-files (Mani, Utsunomiya, Japan) to ensure a smooth pathway for the rotary files.[9]

Cleaning and shaping of samples

The files were operated at a speed of 300 rpm and a torque of 2.5 Ncm using an NSK torque control endodontic motor (NSK, Kanuma, Japan), following the manufacturer's guidelines. Each instrument was gradually adjusted to the working length with gentle pressure at the apex using a simultaneous method. The patency of the mesio-buccal (MB) and mesio-lingual (ML) canals of the mandibular molars was assessed by employing a size 10 K-file, followed by manual instrumentation using files of size 15 and 20 K-file to establish a smooth pathway for the rotary files. Once the clinician experienced a sense of resistance, the instruments were carefully pulled back by 1-2 mm. This allowed for a brushing motion to be used, selecting eliminating any obstructions and progressing towards the apex. After each file had achieved the desired length, the apical patency was assessed by inserting the tip of a size 10 K-file 0.5 mm into the foramen. Each file was utilized to prepare a maximum of four root canals, and any instruments displaying any signs of deformation following root canal preparation were destroyed and replaced.[5]

Root canal irrigation protocol

All groups and subgroups had the same irrigation technique, which involved utilizing a 31-gauge endodontic side-vented needle. The needle was inserted 1 mm before reaching its binding point and a maximum of 1 mm short of the working length, both before and after the instrumentation process. The irrigation protocol was standardized as follows: each root canal was flushed with 5 mL of freshly made 2.5% sodium hypochlorite (NaOCl). The irrigation process was completed by using 5 mL of a 17% EDTA (Prevest Direct, Jammu. India) solution for a duration of 2 minutes. Subsequently, a final rinse was conducted in each root canal using 2.5 mL of saline solution to thoroughly cleanse any remaining irrigant. In subgroup B, root canals were irrigated with 2.5 mL of 2.5% NaOCl, stopping 1 mm before reaching the working length, after the last instrument was used for root canal preparation. Next, the irrigant will be activated using an ultrasonic method. This will be done by utilizing an E-98 silver activator tip (Woodpecker, Guilin, China), which has a size of 25/0.02 and a length of 21mm. The tip will be linked to a Woodpecker ultrasonic activator device. The activation process will consist of 3 cycles of ultrasonic activation, each lasting 20 seconds. The tip was maintained at a distance of 1 millimeter from the working length in the center of the canal, and pumping motions spanning 2-3 millimeters in the apical-coronal direction were done. Consequently, every canal was subjected to 1 minute of ultrasonic activation.[5,10]

Methods of evaluation

Scanning electron microscopy (SEM)

After the canal procedures, the mesial roots were separated from the distal root using a high-speed bur coated with diamond. The roots were subsequently divided lengthwise. Each root should have two shallow longitudinal grooves cut in a bucco-lingual orientation. It is important to ensure that the grooves align with the curvature and do not go into the canal. The roots were subsequently divided into mesial and distal portions using a disk, as seen in **figure (2)**. Both halves were processed for scanning electron microscope (SEM) analysis, and all root canals were examined by taking one image for each magnification to assess the cleanliness of the canal walls using different magnifications (100x, 1000x). The images were evaluated and examined blindly by three trained observers. The grading method proposed by Gutmaann et al. was employed to assess the quantity of surface debris and the existence of smear layers.[11]

The following criteria that were used for debris evaluation[11]:

- Score 1, none to slight presence of superficial debris covering up to the 25% of the dentinal surface.

Fig. (2) Image of the inner wall of the root canal

- Score 2, little to moderate presence of debris covering between 25% and 50% of the surface.
- Score 3, moderate to heavy presence of residual debris covering between 50% and 75% of the surface.
- Score 4, heavy amount of aggregated or scattered debris covering over 75% of the surface.
- The following criteria that were used for smear layer evaluation11 as in figure (3):
- Score 1, little or no smear layer, covering <25% of the specimen with tubules visible and patent.
- Score 2, little to moderate or patchy amounts of smear layer, covering between 25% and 50% of the specimen with many tubules visible and patent.

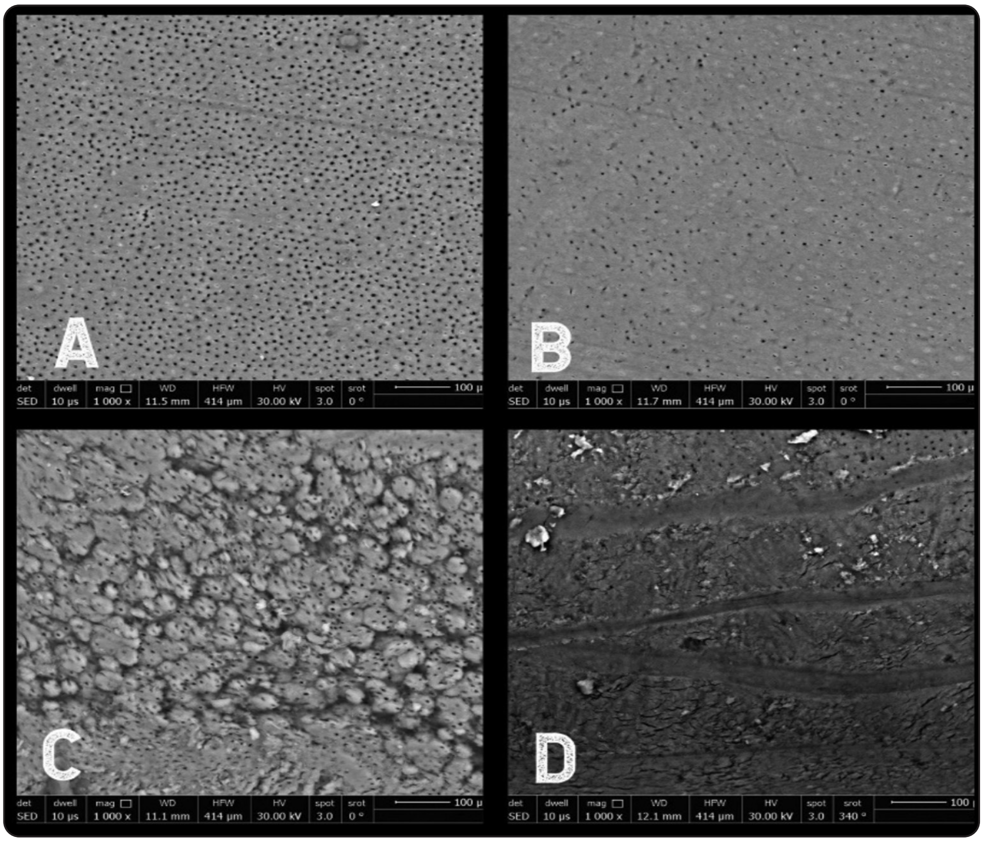

Fig. (3) Representative scanning electron microscopy images under mag X1000 of smear layer scores. A) Smear layer score 1; B) Smear layer score 2; C) Smear layer score 3; D) Smear layer score 4

- Score 3, moderate amounts of scattered or aggregated smear layer, covering between 50% and 75% of the specimen with minimal to no tubules visible or patent.
- Score 4, heavy smear layer covering over 75% of the specimen with no tubule orifices visible or patent.

RESULTS

All results were presented as:

1) Comparison between subgroup A and B within each group regarding the debris Scores as showed in **table (1)** and **figure (4)**:

Comparison between different subgroups was performed by using chi square test (frequency) and Paired t test (Mean) which revealed significant difference between them group I (p=0.005), group II (p=0.04) and group III (p=0.02) but no significant difference between them regarding group IV (p=0.08) as :

- Group I: In subgroup A, score 2 (60%) was the highest, score 3 (40%) was the lowest, while there were no cases revealed score 1 and 4 (0%). But in subgroup B, score 2 (60%) was the highest, score 1 (40%) was the lowest, while there were no cases revealed score 3 and 4 (0%).
- Group II: In subgroup A, score 3 (70%) was higher than score 1 (20%) and score 2 (10%), while no cases revealed 4 (0%). But in subgroup B, score 3 (40%) was higher than score 1 and 2 (30%), while no cases revealed 4 (0%).
- Group III: In subgroup A, score 4 (50%) was the highest, score 2 (20%) was the lowest, while there were no cases revealed score 1 (0%). But in subgroup B score 3 (80%) was the highest, score 2 (20%) was the lowest, while there were no cases revealed score 1 and 2 (0%).
- Group IV: In subgroup A, score 3 (50%) was higher than score 2 and 4 (20%), then score 1 (10%) was the lowest. But in subgroup B, score 3 (60%) was higher than score 2 (30%) and score 1 (10%), while no cases revealed score 4 (0%).

2) Comparison between subgroup A and B within each group regarding the smear layer scores as showed in **table (2)** and **figure (5)**:

Comparison between different subgroups was performed by using chi square test (frequency) and Paired t test (Mean) which revealed insignificant difference between them regarding all groups as group II (p=0.08), group III (p=0.31), group IV (p= 0.65), except in group I (p=0.01) as:

- Group I: In subgroup A, score 4 (40%) was higher than score 2 and 3 (30%), while no samples revealed score 1 (0%). But in subgroup B, score 2 (60%) was higher than score 3 (30%) and score 4 (10%), while no samples revealed score 1 (0%).
- Group II: In subgroup A, score 2 and 3 (40%) were higher than score 4 (20%), while no samples revealed score 1(0%). But in subgroup B, score 2 and 3 (50%) were the same, while no samples revealed 1 and 4 (0%).
- Group III: In subgroup A, score 1 and 3 (30%) were the highest scores, while score 2 and 4 (20%) were the lowest scores. But in subgroup B, score 2 and 3 (40%) were higher than score 1 (20%), while no samples revealed score 4(0%).
- Group IV: In subgroup A, score 1 (60%) was higher than score 1 (40%), while no samples revealed score 3 and 4 (0%). But in subgroup B, score 1 (70%) was higher than score 2 (20%) and score 4 (10%), while no cases revealed score 3 (0%).

TABLE (1) Debris scores in Subgroup A and Subgroup B regarding all groups, comparison between them using chi square test (frequency) and Paired t test (Mean):

		Comparison using Chi square test				Comparison using Paired t test		
Group	Score	Subgroup A		Subgroup B		Subgroup A	Subgroup B	P value
		N	%	N	%	M ± SD	M ± SD	
Group I	Score 1	0	0.00%	4	40.00%	2.4 ± 0.52	1.6 ± 0.52	0.005*
	Score 2	6	60.00%	6	60.00%			
	Score 3	4	40.00%	0	0.00%			
	Score 4	0	0.00%	0	0.00%			
Group II	Score 1	2	20.00%	3	30.00%	2.5 ± 0.85	2.1 ± 0.88	0.04*
	Score 2	1	10.00%	3	30.00%			
	Score 3	7	70.00%	4	40.00%			
	Score 4	0	0.00%	0	0.00%			
Group III	Score 1	0	0.00%	0	0.00%	3.3 ± 1.32	2.8 ± 0.42	0.02*
	Score 2	2	20.00%	2	20.00%			
	Score 3	3	30.00%	8	80.00%			
	Score 4	5	50.00%	0	0.00%			
Group IV	Score 1	1	10.00%	1	10.00%	2.8 ± 0.92	2.5 ± 0.71	0.08
	Score 2	2	20.00%	3	30.00%			
	Score 3	5	50.00%	6	60.00%			
	Score 4	2	20.00%	0	0.00%			

TABLE (2): Smear layer scores in Subgroup A and Subgroup B regarding all groups, comparison between them using chi square test (frequency) and Paired t test (Mean):

		Comparison using Chi square test				Comparison using Paired t test		
Group	Score	Subgroup A		Subgroup B		Subgroup A	Subgroup B	P value
		N	%	N	%	M ± SD	M ± SD	
Group I	Score 1	0	0.00%	0	0.00%	3.1 ± 0.88	2.5 ± 0.71	0.01*
	Score 2	3	30.00%	6	60.00%			
	Score 3	3	30.00%	3	30.00%			
	Score 4	4	40.00%	1	10.00%			
Group II	Score 1	0	0.00%	0	0.00%	2.8 ± 0.79	2.5 ± 0.53	0.08
	Score 2	4	40.00%	5	50.00%			
	Score 3	4	40.00%	5	50.00%			
	Score 4	2	20.00%	0	0.00%			
Group III	Score 1	3	30.00%	2	20.00%	2.4 ± 1.17	2.2 ±0.79	0.31
	Score 2	2	20.00%	4	40.00%			
	Score 3	3	30.00%	4	40.00%			
	Score 4	2	20.00%	0	0.00%			
Group IV	Score 1	6	60.00%	7	70.00%	1.4 ± 0.52	1.5 ± 0.97	0.65
	Score 2	4	40.00%	2	20.00%			
	Score 3	0	0.00%	0	0.00%			
	Score 4	0	0.00%	1	10.00%			

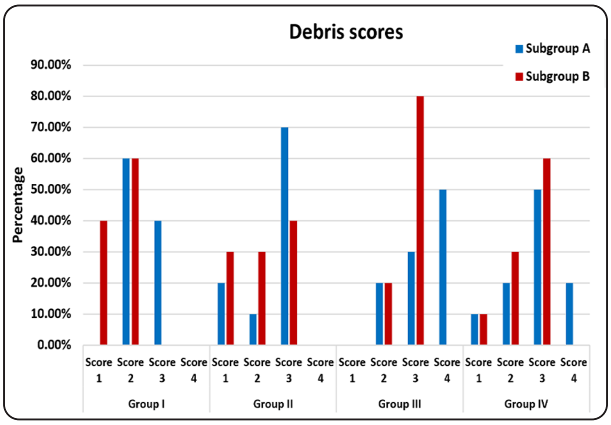

Fig. (4): Bar chart showing all debris scores in Subgroup A and Subgroup B

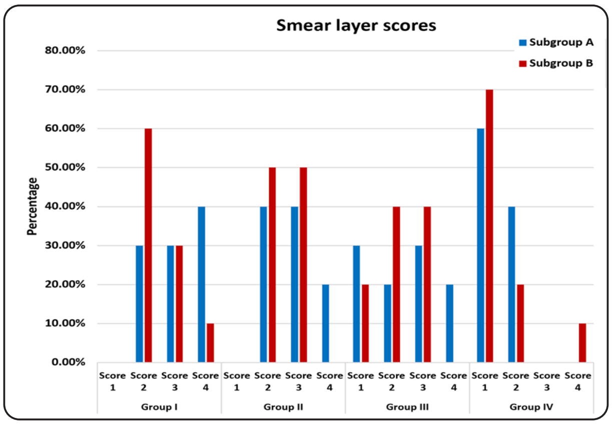

Fig. (5): Bar chart showing all smear layer scores in Subgroup A and Subgroup B.

DISCUSSION

Chemical disinfection is carried out by utilizing chemical irrigants, which are crucial for ensuring disinfection and the effectiveness of the procedure. Merely altering the geometry of the root canal is insufficient for effectively eliminating bacteria from the endodontic system. Irrigation solutions are crucial for enhancing the efficacy of root canal cleaning and the elimination of debris. Sodium hypochlorite (NaOCl) is considered the gold standard irrigant due to its several benefits, including antibacterial activity, capacity to break down pulp tissue, lubricating action, and ability to remove debris from canals. While NaOCl has remarkable antibacterial characteristics, its impact in eliminating the smear layer from dentin walls is minimal. Instead, ethylene-diamine-tetra-acetic acid (EDTA) is highly regarded for its capacity to remove calcium deposits and bind to inorganic tissue.[11]

The utilization of ultrasonic cordless devices to activate irrigants has been the standard way for activating irrigants in many applications. Through the phenomenon of acoustic streaming, this method enables vigorous agitation of the irrigant. The previously described technique leads to enhanced antibacterial efficacy and more prominent tissue degradation..[10–13]

Even in narrow root canals, such as the mesial root canals of mandibular molars used in this study, the small sizes of preparation tested (tip size 25, .04 or .06 taper) may not be sufficient to completely remove debris and smear layer from the canal walls in the apical third. Although the high-power ultrasonic device is used to activate the irrigating solution, it seems that this activation does not replace the need for effective enlargement of the apical area to enhance the flow of solutions into the deepest part of the root canal. However, it is worth noting that this system has been proven to successfully reduce the presence of microbes within the canal.[5,14]

Multiple studies have found that mandibular first and second molars are the most frequently treated teeth in dental treatment.[15,16] Mesial roots of mandibular first molars are often tight and are recognized for their complicated internal architecture due to the high incidence of curvatures and internal connections, making them particularly difficult for clinicians to treat.[17]

The preferred alloy was CM-wire because to its exceptional cycle fatigue resistance, which may be attributed to its characteristic nano-crystalline martensitic microstructure. EdgeEndo files possess a consistent taper, a triangle cross-section, and a helix angle that varies. The flexible design of the EdgeEndo file accurately adapts to the shape of the canal, without losing its curvature, hence reducing the possibility of complications such as ledging, transportation, and perforation. The adoption of a flexible shaft prevents the requirement for excessive straight-line access, so conserving a greater amount of dental structure.[18,19]

The cleaning effectiveness of several irrigation techniques was evaluated in this study using debris and smear layer as indicators. Debris refers to the presence of dentine chips and residual vital or necrotic pulp tissue that attach to the contaminated root canal wall. Debris present in dentinal tubules or canal isthmuses might potentially interfere with the effectiveness of antimicrobial treatments like as irrigant. Consequently, biofilm and infected tubules might continue to exist in areas of the canal wall that are covered with debris.[6]

The cleaning effectiveness was investigated in this work using a scanning electron microscope (SEM) assessment of internal wall of the root canals using a numerical evaluation system for debris and smear layer. However, it should be noted that SEM studies have significant limitations in that they can only analyze a restricted portion of the canal wall. The bi-dimensional analysis of debris and smear layer is another restriction of SEM assessments. As a result, the thickness of both residues could not be measured using this approach.[6]

In this study, the results showed that group I subgroup B (preparation to a size of 25 taper 0.04 with irrigant activation) has the best results in debris removal in comparison to the other subgroups. The explanation of this finding that the more size and taper would lead to more debris accumulating on the inner walls of the canals. Also, activation of the irrigants causing rapid fluid waves of the irrigants around the ultrasonic tip and cavitation leading to formation or expansion of gases (bubbles) existing in a chemical solution, created by tensile stresses and driven by high-speed fluxes. These bubbles expand and then collapse with the canal's dentinal walls, increasing the elimination of residual pulp tissue, bacteria, and smear layer.[5, 20]

While in case of smear layer removal assessment, there is no significant difference between all groups. This can be explained by the fact that less smear layer was formed since the rotary files were smaller than the apical region of the canals, only partially contacting the canal walls and therefore forming less smear layer on the dentinal surface. However, group IV subgroup A and B (tip size 30 taper 0.06 with and without irrigant activation) had the cleanest root canal wall and less smear layer. As a result of increased taper allows for more dentin removal from the canal walls and offers a larger base diameter to the cone-like preparation to the root canal, allowing for better penetration of the irrigant and expression of cleaning efficacy of the irrigants, resulting in a cleaner root canal.[3,4,21]

These results were supported by Plotino et al.[5] who conducted a study to see if a minimally invasive basic root canal preparation approach affects the cleanliness of root canals in extracted mandibular molars. Their findings indicated that employing a basic root canal preparation with a tip size of 25 led to a significant reduction in remaining debris and smear layer in the apical third. The results of this study indicate that the increase in taper from 4% to 6% did not have any impact on the presence of residual debris and smear layer in the apical third. It was shown that increasing the taper associated with a 30 apical size did not impact the presence of smear layer in the apical third. According to the study, the root canal cleanliness was not affected by the taper of the root canal preparation. The apical region exhibited significantly higher levels of debris and smear layer compared to the middle and coronal thirds in all groups.

Also, Brunson et al.[4] further mentioned that using bigger preparation tapers may not be needed and might potentially result in the weakening of the tooth or root structure, particularly in the cervical location. It was found that increasing the initial taper would lead to a rise in the amount of irrigant used. The volume percentage gains increased by almost 74% from 40.02 to 40.04, 5.4% from 40.04 to 40.06, and 2.4% from 40.06 to 40.08 by increasing the initial taper from 0.02 to 0.08. Each group showed statistically significant differences compared to the others. The volume increase from 40.02 to 40.04 taper was 74%, which was 14 times more than the following increases to 40.06 and 40.08 (5.4% and 2.4% respectively).

Akhlaghi et al.[22] conducted a study to examine how varying the size and taper of the master apical file affects the cleanliness of root canals and the decrease of bacterial count in curved mesiobuccal canals of mandibular first molars. It was found that there was no notable difference among the experimental groups that had the same sizes but various tapers, nor between the groups that had same tapers but different sizes. However, there was significant variation between each experimental group and the control group.

Tabrizizadeh and Shareghi[23] assessed the impact of canal preparation size on the cleanliness of the root canal. They reached the conclusion that enlarging the canal preparation did not lead to enhanced cleanliness or elimination of the smear layer.

Arvaniti et al.[21] assessed the impact of taper on the cleanliness of root canals. The researchers discovered that root canals were produced using GT files with a size of 30, and there were no statistically significant differences seen across groups with different tapers. Nevertheless, it was shown that the taper of the root canal only impacts the removal of debris if the ultimate size of the instrument is smaller than 30. Furthermore, a statistically significant difference in the existence of smear layer was observed between the apical and middle thirds of the canals.

These findings were opposed by Jain et al.[3] by assessing the combined impact of taper and various irrigating chemicals on the cleanliness of the root canal. Their conclusion was that the rotary files with a larger taper of 6% results in a cleaner canal compared to files with lower tapers of 2% or 4%. The study found that a 6% taper consistently produced the cleanest canals, independent of the irrigation method or geographical location.

In addition to, Akhlaghi et al.[24] revealed significant differences between groups 25.04 and 25.06 and the other groups. There were no statistically significant differences between the 30.06, 35.04, and 35.06 groups. These groups demonstrated adequate debridement. According to their findings, increasing the size and taper of master apical file at working length enhanced debris and smear layer removal.

De gregorio et al.[25] stated that the optimal size and taper for the apical preparation was 40.04, leading to a 44% increase in the amount of irrigant compared to 35.06. However, when the taper was increased to 40.06, a significantly greater volume of irrigant was seen in root canals with moderate and severe curvatures. Nevertheless, enlarging the apical size to ISO 45 did not lead to a significant augmentation in the amount of irrigant used in any of the groups. Indeed, across all three curvature groups, the volume obtained with 45.04 was consistently lower than the volume achieved with 40.06.

Boutsioukis et al.[26] according to their findings, increasing the taper of the root canal directly affected the flow of the irrigant, leading to more efficient removal of debris in the lower part of the root canal. Additionally, it made it easier for the needle to reach closer to the working length.

CONCLUSION

Based on the findings of this investigation, it could be concluded that the least residual debris in the root canal was found in a root canal prepared up to size 25 taper 0.04 with irrigant activation while the least residual smear layer was found in a root canal prepared up to size 30 taper 0.06 with or without irrigant activation. Also, the ultrasonic activation method was superior compared to manual irrigation regarding debris and smear layer removal.

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