



Debridement Ability of TruNatomy, S-One Plus, and Other Single File Systems

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Abstract

Edited by: Katerina Spiroska
Citation: Waleed D, Selivany BJ. Debridement Ability of TruNatomy, S-One Plus, and Other Single File Systems. Open Access Maced J Med Sci. 2022 Jan 27; 10(D):91-97. <https://doi.org/10.3889/oamjms.2022.8398>
Keywords: Smear layer; SEM; TruNatomy; Wave one gold; S-one plus
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Received: 26-Dec-2021
Revised: 14-Jan-2022
Accepted: 17-Jan-2022
Copyright: © 2022 Duaa Waleed, Bahar Jaafar Selivany
Funding: This research did not receive any financial support
Competing Interests: The authors have declared that no competing interests exist
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BACKGROUND: Rotary nickel titanium instrument are an essential part of endodontic treatment, it is important to compare the root canal cleaning ability of these instruments.

AIM: This study aimed to compare the amount of smear and debris layer remained following the use of four rotary instruments with an irrigant solution: TruNatomy (TRN), Protaper Next (PTN), S-One Plus and Wave One Gold (WOG).

METHODS: A total of 80 extracted mandibular premolars were used and decoronated to the cemento-enamel junction. The roots were randomly divided into four groups of 20 specimens each. The roots were instrumented according to the manufacturer's instructions of each file, the root canals were irrigated with sodium hypochlorite (NaOCl), Ethylene-diaminete-traacetic acid (EDTA) and Normal saline with each file use, two grooves were prepared on the buccal and lingual surfaces by disc to facilitate vertical splitting with a chisel. The presence of the smear layer and the debris layer were evaluated under Scanning Electron Microscope.

RESULTS: Trunatomy remove the smear layer substantially better than PTN and S-one Plus. Wave one gold significantly removes smear layer better PTN. The amount of debris remained in TruNatomy group was significantly lower than other groups, all experimental files significantly removes the smear layer and debris layer better in the middle and coronal thirds compared to apical third.

CONCLUSION: TruNatomy showed better cleaning capacity than all other experimental groups and all experimental groups demonstrated better cleanliness at the coronal and middle third of the roots.

Introduction

A biomechanical debridement of the root canal system is required during the root canal instrumentation, which combines mechanical instrumentation with chemical disinfection to eradicate the majority of infective micro-organisms, as well as inorganic contaminant debris and dentin, from the root canal system. Cleaning and shaping the root canal system not only removes micro-organisms but permits better adaptation of the filling material, also enhances the action of irrigants and intracanal medicaments [1], [2], [3].

The invention and diversification of multiple rotary nickel-titanium file systems, characterized by super-elasticity and employed under well-defined torque and speed values, as well as diverse types of rotary movement (constant, reciprocal) were used to achieve this goal, to produce a tapered root canal with minimal chance of the original canal being transported and improves its cleaning and shaping ability [4], [5].

When rotary or hand files are used in root canals, a significant amount of debris and a smear layer are commonly produced. Any material left between the canal wall and the root canal filling may prevent intimate

adaptation between them and may provide space for bacterial leakage and proliferation [6]. Dentin particles, remnants of living or necrotic pulp tissues, bacterial components, and retained irrigants make up the smear layer, which is a 1 to 2 μm thick surface coating [7]. The smear layer is a "muddy" layer, whereas the surface debris has a "dusty" pattern [8]. Debris and smear layer were regarded as criteria to evaluate the cleaning ability.

TruNatomy heat-treated NiTi instruments (TRN; Dentsply Sirona) were recently created and are available in three sizes: small; size 20, 0.04 taper, prime; size 26, 0.04 taper, and medium; size 36, 0.03 taper. The TRN instrument has a slip shaping feature that allows for more debridement space, as well as being more flexible and fatigue resistant due to a specific heat treatment and design [9].

ProTaper Next (Dentsply Sirona, Ballaigues, Switzerland) is made of M-wire premanufacturing heat treatment technology with a rectangular asymmetric cross section, variable taper PTN X2, (0.25 mm tip and 6% taper) and is run by a clockwise (CW) continuous rotation [10].

The S-one Plus Single NiTi Reciprocation File (Foshan Soco Precision Instrument Co.,Ltd) is a single file which is more flexible than the traditional single file

and have a good variable pitch design for quick and automatic removal of debris to the crown side, variable pitch design and S-section enhance transverse cutting force, to complete the preparation with unusual sharp section and enhance the capacity to evacuate the chip.

Wave one gold (WOG) Primary (25,0.07) variable taper with a parallelogram cross section with two cutting edges in contact with the canal wall, alternating with an off-centered cross section. It rotates in a reciprocal motion, with preset values set by the manufacturer in clockwise/counter-clockwise angles, counterclockwise which is greater than clockwise allows the file to progress apically while the latter disengages the file and eliminates file binding [11].

The cleaning and shaping efficacy of the newly introduced NiTi rotary system should be thoroughly investigated to provide endodontists with a reliable recommendation for improving root canal treatment outcomes [12].

This study aimed to assess the cleaning efficacy of single-file systems, such as Trunatomy 26/0.04%, Protaper Next 25/0.06% in full rotation motion and in reciprocating motion S-one plus 25/0.06%, and Wave one gold 25/0.07%, using a serial scanning electron microscope at various magnifications.

Materials and Methods

A total of 80 single-rooted lower premolars teeth were selected for this study and put in thymol 0.1 percent immediately after extraction for orthodontic reasons. The inclusion criteria were morphological resemblance, single-canal roots, straight roots, absence of root caries, absence of previous endodontic treatment, and periapical lesion.

Root canal instrumentation

A carborundum diamond disc (D+Z, Diamond, Germany) was used to remove the crown of each tooth at the level of the cementum-enamel junction (CEJ) (Fig. 1) to create root segments of approximately 15 mm in length [13], before root canal preparation, the patency of the root canal was determined by inserting a hand K-file #10 into the apical foramen. Two mm of root apices were sealed with melted beading wax (Associated Dental Products Ltd; Wiltshire, UK) and polyvinyl siloxane PVS (Zhermack SpA, Badia Polesine, Italy) impression material using a plastic ice mold, each mold consisted of 15 parts of (2×2) in diameter to access the instrumentation, then divided into four experimental groups, each with 20 roots [14].

Group 1; TruNatomy and Group 2; Protaper Next: The files were used in full rotation with a 6:1

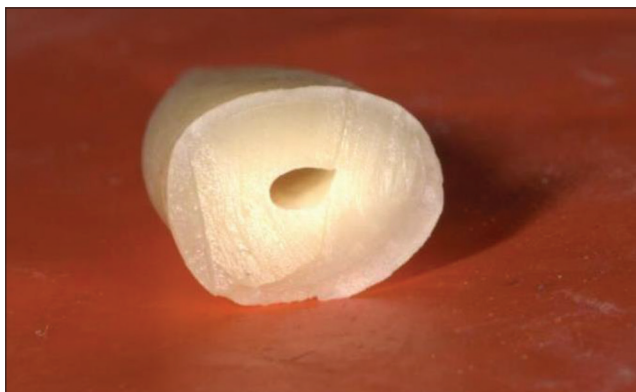


Figure 1: Tooth crown was removed at the level of the cementum-enamel junction by a carborundum diamond disc (D+Z, Diamond, Germany)

contra-angle handpiece (Sirona, Bensheim, Germany) powered by a torque-limited electric motor (VDW gold Reciproc motor; VDW GmbH, München, Germany) according to the manufacturer's instructions. The roots were instrumented in group one (500 rpm, torque 1.5) and in group two (300 rpm, maximum torque 2.5 N/cm) in crown down technique [15], in-and-out pecking motions and a side-to-side/up-and-down motion [16]. Intermittently, three to four times, the file was used in a slight lifting motion while stroking, to facilitate outward removal of debris, with each stroke the file was reinserted exerting a buccal to lingual cutting pressure on the out-stroke [13].

In Group 3; S-one Plus and Group 4; Wave one gold: They were used in a reciprocating motion, slow in-and-out pecking motions and a side-to-side/up-and-down motion with the dedicated reciprocating motor (Gold Reciproc, VDW) according to the manufacturer configuration setup. The flutes of the instrument were cleaned after 3 in and out movements [13].

In all groups, individual instruments were discarded after use in each root canal and irrigation was performed after each pecking motion during instrumentation using disposable syringes and 30-gauge needles, with a side vent that had been placed down the canal until slight resistance was felt [17].

In all experimental groups, 5.25% sodium hypochlorite and 15% EDTA, were used as per the manufacturer's instructions during a sequential crown down instrumentation technique [4]. Irrigation protocol was 1.0 ml normal saline followed by 2.0 ml of 5.25 % NaOCl solution after every pecking motion and kept flooded with irrigant during the instrumentation phase, then 1.0 ml of 15% EDTA solution left for 1 min and a final rinse with 1.0 ml saline to neutralize the action of the irrigating agents [18].

A gutta-percha cone (ProTaper F2) was inserted into the canal as an indication for determining the longitudinal groove depth without perforating the canal for scanning electron microscopy analysis [19]. This precaution was adopted to prevent the cutting disc from splattering cutting debris into the canals, potentially contaminating the specimens [14]. A diamond disc (D+Z,

Diamond, Germany) was used to create two longitudinal grooves on the lingual and buccal sides of each root to assist vertical splitting with a chisel (Fig.2: A and B) [4].

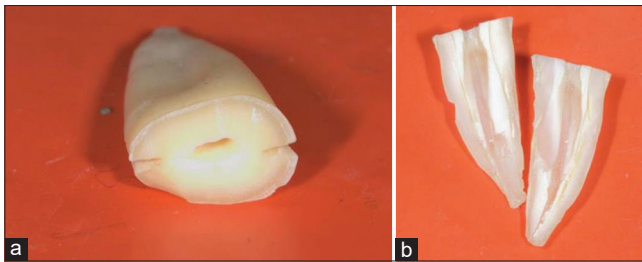


Figure 2: (a) Two longitudinal grooves were prepared on the lingual and buccal surfaces of each root with a diamond disc (D+Z, Diamond, Germany). (b) Splitting of the prepared root with a chisel

Preparation of SEM

The preparation of the samples took less than one hour. First, a very thin gold layer was deposited on the teeth by DC sputtering method. The thickness of the gold film was around 20 nm, and the deposition rate was 2 nm/min. Then, the specimens were examined under Scanning Electron Microscope, the SEM imaging (MV2300, VEGA, TESCAN) was carried out at 30 KV for assessment of the microscopic pattern of magnification and a standardized series of three photomicrographs each was taken for comparison in the apical, middle and coronal thirds of the canal at X200 for debris and X1000 for the smear layer. Using the scanned images, two trained observers conducted separate blind evaluations for the remaining debris and smear layer.

The smear layer and the surface debris were each given a standardized semi-quantitative evaluation in four classes, according to the classification [20]. The following were the scoring criteria:

A score of superficial debris : score 1: little or no superficial debris covering up to 25% of the specimen; score 2: little to moderate debris covering between 25 and 50% of the specimen; score 3: moderate to heavy debris covering between 50 and 75% of the specimen; and score 4: heavy amount of aggregated or scattered debris over 75% of the specimen.

A score of the smear layer was as follow, score 1: little or no smear layer; covering less than 25% of the specimen; tubules visible and patent; score 2: little to moderate or patchy amounts of smear layer; covering between 25 and 50% of the specimen; many tubules visible and patent; score 3: moderate amounts of scattered or aggregated smear layer; covering between 50% and 75% of the specimen; minimal to no tubule visibility or patency, and score 4: heavy smear layering covering over 75% of the specimen; no tubule orifices visible or patent [21]. The Kruskal–Wallis test and the Mann–Whitney test were used to statistically examine the data from the scanning electron microscopic images, and the level of statistical significance was at $p < 0.05$.

Results

Smear layer

Table 1 and Fig. 3 show that there were no significant differences in smear layer removal between Trunatomy and Wave One Gold, Trunatomy removes the smear layer substantially better than PTN and S-one Plus. Wave one gold significantly removes smear layer better PTN. Furthermore, there was no significant difference between PTN and S-one Plus, S-one Plus and Wave One Gold.

Table 1: Summary of scores of smear layers of the prepared canals

Experimental groups	Mean ± ED	Mean ± ED	p-value
Trunatomy PTN	2.12 ± 0.99	2.8 ± 1.07	0.000*
Trunatomy S-One Plus	2.12 ± 0.99	2.67 ± 0.91	0.003*
Trunatomy Wave One Gold	2.12 ± 0.99	2.4 ± 0.99	0.12
PTN S-One Plus	2.8 ± 1.07	2.67 ± 0.91	0.464
PTN Wave One Gold	2.8 ± 1.07	2.4 ± 0.99	0.029*
S-One Plus Wave One Gold	2.67 ± 0.91	2.4 ± 0.99	0.143

*The mean difference is significant at the 0.05 level, PTN: ProTaper next.

Fig. 3 shows scanning electron microscope scans of canal wall after preparation with rotary NiTi instruments in middle third. Trunatomy group: Slight smear layer with mostly open dentinal tubules (score 1 magnification 1000X). PTN group: Smear layer with some open dentinal tubules (score 2 magnification 1000X). S-one Plus group: Slight smear layer with mostly open dentinal tubules (score 1 magnification 1000X). WOG group: Slight smear layer with mostly open dentinal tubules (score 1 magnification 1000X).

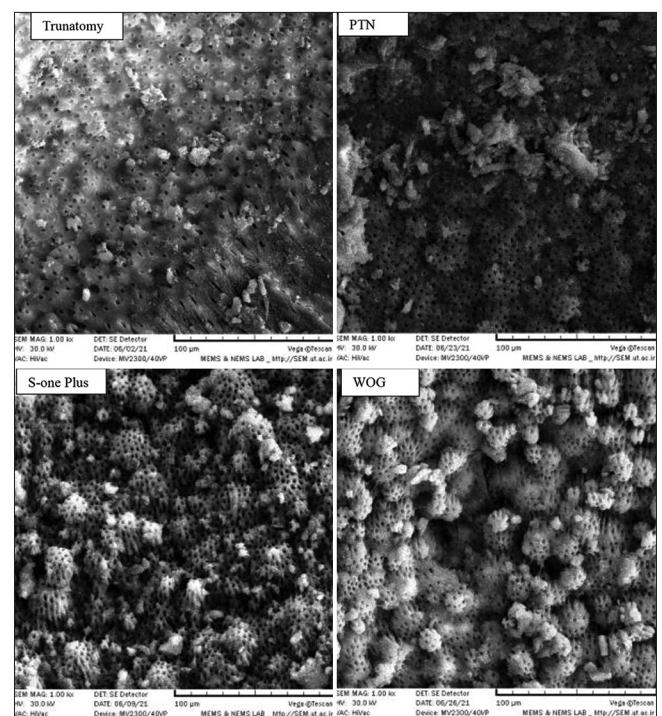


Figure 3: Root dentinal tubules after instrumentation with Trunatomy, ProTaper next, S-One Plus and Wave One Gold file 1000× for Smear layer

Table 2 and Fig. 4 show that Trunatomy significantly removes in the smear layer better than

Table 2: Intergroup comparison of mean debris removal scores at coronal, middle, and apical third

Inter group comparison		Smear layer			
		Apical	Middle	Coronal	Total
Trunatomy	PTN	0.242	0.021*	0.014*	0.000*
Trunatomy	S-One Plus	0.301	0.060*	0.003*	0.003*
Trunatomy	Wave One Gold	0.820	0.231	0.052	0.120
PTN	S-One Plus	0.758	0.369	0.820	0.464
PTN	Wave One Gold	0.134	0.157	0.495	0.290
S-One Plus	Wave One Gold	0.192	0.495	0.547	0.143

*The mean difference is significant at the 0.05 level, PTN: ProTaper next.

PTN and S-One Plus in the middle and coronal thirds, while there was no significant difference between other groups in smear layer removal in apical, middle and coronal thirds.

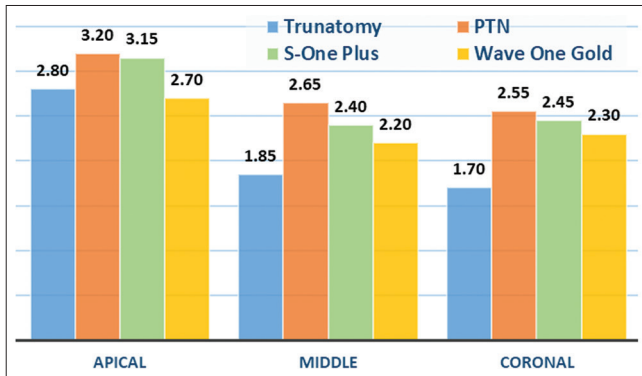


Figure 4: Bar graph shows summary of the scores of smear layer in three regions of the prepared canals

Debris layer

Table 3 and Fig. 5 show that the Trunatomy file significantly removed the debris layer better than all other groups. There were significant differences between all groups except PTN and S-one Plus, as well as between S-One Plus and Wave One Gold.

Table 3: Summary of scores of debris of the prepared canals

Experimental groups	Mean ± ED	Mean ± ED	p-Value
Trunatomy PTN	1.95 ± 0.96	2.65 ± 0.89	0.000*
Trunatomy S-One Plus	1.95 ± 0.96	2.48 ± 0.91	0.002*
Trunatomy Wave One Gold	1.95 ± 0.96	2.30 ± 0.91	0.038*
PTN S-One Plus	2.65 ± 0.89	2.48 ± 0.91	0.322
PTN Wave One Gold	2.65 ± 0.89	2.30 ± 0.91	0.038*
S-One Plus Wave One Gold	2.48 ± 0.91	2.30 ± 0.91	0.277

*The mean difference is significant at the 0.05 level, PTN: ProTaper next.

Fig. 5 show scanning electron microscope scans of canal wall after preparation with rotary NiTi instruments in middle third. Trunatomy group: Slight debris layer with mostly open dentinal tubules (score 1 magnification 200X). PTN group: debris layer with some open dentinal tubules (score 2 magnification 200X).

Table 4: Intergroup comparison of mean debris removal score at coronal, middle, and apical thirds

Inter group comparison		Debris removal (p value)			
		Apical	Middle	Coronal	Total
Trunatomy	PTN	0.028*	0.006*	0.009*	0.008*
Trunatomy	S-One Plus	0.081	0.012*	0.052	0.020*
Trunatomy	Wave One Gold	0.602	0.081	0.018*	0.038*
PTN	S-One Plus	0.620	0.495	0.512	0.322
PTN	Wave One Gold	0.011*	0.289	0.947	0.038*
S-One Plus	Wave One Gold	0.038*	0.583	0.495	0.027*

*The mean difference is significant at the 0.05 level, PTN: ProTaper next.

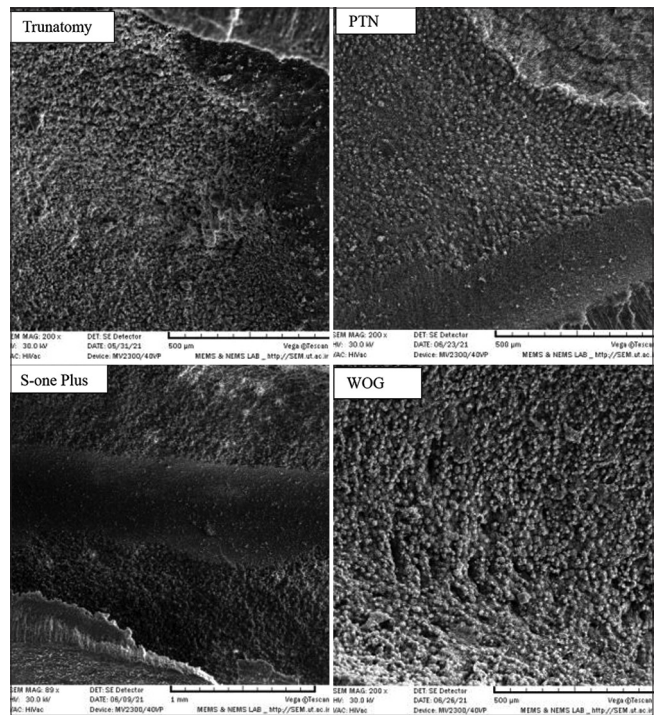


Figure 5: Root dentinal tubules after instrumentation with Trunatomy, ProTaper next, S-One Plus, and Wave One Gold file 200x for debris layer.

S-one Plus group: Slight debris layer with mostly open dentinal tubules (score 1 magnification 200X). WOG group: Slight debris layer with mostly open dentinal tubules (score 1 magnification 200X).

Table 4 and Fig. 6 show that Trunatomy significantly removes the debris layer better than PTN file in all root thirds, also Trunatomy significantly removes the debris layer better than S-one plus in the middle third and better than Wave One Gold in the coronal third only, while WOG removes the debris layer significantly better than PTN and S-One Plus in the apical third. However, there was no significant difference between PTN and S-one Plus in debris removal in all root thirds.

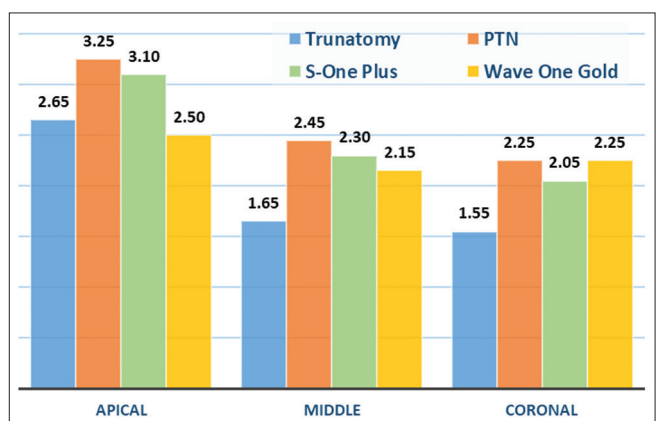


Figure 6: Bar graph shows summary of the scores of the debris layer in three regions of the prepared canal

Discussion

The removal of vital and necrotic pulp tissue, dentin debris, and infected dentin is one of the most important goals of root canal instrumentation to eliminate the majority of bacteria from the root canal system [8] in order to allow the root filling to adapt closely to the canal walls, mechanical instrumentation on the other hand, was developed to allow for successful cleaning and shaping while avoiding excessive loss of sound dentin, perhaps leading to minimally invasive endodontic therapy [16].

The influence of endodontic instruments on the morphology of dentin surfaces appears to be well investigated using SEM examination [22]. SEM provides high-resolution pictures that enable the study of debris and smear layer-covered areas, as well as the detection of patent dentinal tubules [23]. However, there is no agreement on how to standardize debris and smear layer measurements. In this research, micrographs at higher magnifications 1000X were used to evaluate the smear layer on the root surface and dentinal tubules, whereas 200X magnification was utilized to evaluate the debris layer on the root canal surfaces [4] [24].

Previous research has shown that neither instruments nor techniques can entirely clean canal walls; our findings support the previous research finding, demonstrating that none of the instruments or operating principles used could completely clean (smear and debris-free root) canal surfaces [16].

On the basis of the findings, the removal of debris and smear layers is not only depend on the irrigation method and type, but also on the design of the endodontic file (size, taper, cross-section, and so on), as well as how the instrument is used (rotational or reciprocal) [25].

Tables 1 and 3 show that Trunatomy system resulted in the formation of less amount smear layer and debris compared to other systems, it seems that this ability is due to the unique design of Trunatomy files, slim NiTi wire design with 0.8mm maximum flute diameter, with generic progressive tapered file had variable taper ensuring that the shank ends up again with a maximum flute diameter of 0.8 mm, these files have a off-centred parallelogram cross-sections, active cutting flutes, this design helps reduce the risk of obstruction of the pathway and minimizes the accumulation of smear and dentinal chips [26].

Wave One Gold came in second place after TruNatomy in terms of producing better results than S-one Plus and ProTaper Next, which are in agreement with Feghali et al., 2019, who concluded that Wave One Gold showed better results in term of cleanliness [27]. While contradicts with the findings of Al-Khafaji and Al-Huwaizi in 2019, Ismail et al., 2019 [28] [29] which they concluded that ProTaper Next showed

less average means of smear layer and debris layer compared to WaveOne Gold.

Wave One Gold's cross-section is a parallelogram with two 85-degree cutting edges in contact with the canal wall, alternating with an off-centred cross-section with only one cutting edge in contact with the canal wall, reducing the contact area between the file and the canal wall and, combined with a constant helical angle of 24 degrees along the active length of the instrument, ensuring little or no screwing in [30].

Although, S-one Plus and ProTaper have more smear layer and debris development compared to TruNatomy, which could be due to S-one Plus had a variable pitch design, S shaped cross-section, deep flutes, and the distance between the cutting blades increased from the file tip to the shank with transverse cutting force.

However, ProTaper Next system were designed so that the center of mass and the center of rotation are off-set. This feature generates a mechanical wave of motion that travels along the active length of the file and provides a better reduction of the engagement between the file and dentin [31]. These files' lower cutting capacity and higher smear layer and debris accumulation are thought to be due to their off-centered rectangular cross-section, which causes the file to "swagger" as it goes through the root canal [32].

On the other hand, the efficacy of the working motion of the files selected reciprocating motion and full clockwise rotation motion- in terms of root canal wall cleanliness was compared. Trunatomy with full rotation and Wave One Gold with reciprocating showed the best performance in cleanliness in comparison to other instruments, as a result this could be explained that the kinematics of the instruments did not affect the cleaning capacity, preparation with reciprocating or complete rotation resulted in equivalent efficacy in terms of smear and debris layer removal, this finding are in agreement with Ismail, et al., 2019 finding [29].

While disagreeing with a previous finding by Robinson et al., 2013; Poggio et al., 2014, they found more smear and debris layer in the apical areas of root canals prepared by reciprocating instruments compared to instruments operated in continuous rotation [33][13]. The results of this study also disagree with Al-Khafaji and Al-Huwaizi, 2019 who found that continuous rotation produced a higher smear layers in the apical third, but there were no significant differences in smear and debris layers in the other thirds [28].

All experimental files in tables 2 and 4 showed significant levels of cleanliness and smear layer reduction at the coronal and middle thirds compared to the apical, which come agreement with previous research findings Vincenzi et al., 2011 [34], However it disagrees with Ibrahim et al., 2019 who concluded experimented files failed to remove the smear layer in

the coronal, middle, and apical thirds with no significant difference between the three levels [7].

Although the tested files have different tapers, an increase in the taper from 4% to 7% did not significantly reduce the residual debris and smear layer in the apical third, all files were effective in cleaning the root canal surfaces at the coronal and middle thirds as shown in Tables 2 and 4, this findings are in agreement with Schäfer and Zapke, 2000; Arvaniti and Khabbaz, 2011; Zarei et al., 2016; Feghali et al., 2019; Andreani et al., 2021[23][35][27][36] [37], who reported that an increase in taper associated with an apical size 30 did not affect the amount of smear layer in the apical third. On the other hand disagreeing with Plotino et al., 2019 who concluded in their study that 0.04 taper removed less smear and debris layer in the apical third compared to the middle and coronal thirds [38].

Conclusion

Completely clean root canals were not found after instrumentation with any of the examined rotary files. TruNatomy showed better cleaning capacity than the other groups. All files demonstrated better cleanliness at the coronal and middle third compared to the apical third.

Acknowledgment

The authors would like to gratefully acknowledge the support from the MEMS Lab at the University of Tehran for SEM and Behin Negareh Company, Tehran, Iran, for image processing.

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