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An in-Vitro Comparative Evaluation in The Removal of Smear Layer and Debris During Root Canal Instrumentation Using Two Rotary (Protaper Gold, Trunatomy) and Two Reciprocating (Wave One Gold, Reciproc Blue) File Systems With Scanning Electron Microscope (SEM) Analysis

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Abstract

Aim: In-vitro comparative evaluation in the removal of Smear layer and Debris during root canal instrumentation using Two Rotary and Two Reciprocating file systems with Scanning Electron Microscope analysis.

Materials & Method: Eighty extracted human permanent mandibular single rooted premolar teeth were

collected and randomly divided into four groups, 20 teeth per group based on type of files used for root canal instrumentation. Group 1: ProTaper Gold (PTG) and Group 2: TruNatomy (TN) Rotary file systems. Group 3: Wave One Gold (WOG) and Group 4: Reciproc Blue (RB) Reciprocating file systems. All root canals were irrigated with Sodium hypochlorite and Ethylene-diamine-tetra acetic acid during canal instrumentation. The Coronal, Middle and Apical-third's of root canals in all specimens were then examined using Scanning Electron Microscope (SEM) for the presence (or) absence of Smear layer and Debris.

Results: One-Way Anova and Tuckey Post-hoc tests were used for statistical analysis. Statistically significant difference was seen in the removal of debris and smear layer among the four groups, P≤ 0.05. Group 3 (Wave One Gold) followed by Group 2 (TruNatomy) showed the presence of least or minimal smear layer and debris at all 3-levels of root canals. Whereas, Group 1 (ProTaper Gold) showed the presence of maximum smear layer and debris at all 3-levels of root canals.

Conclusion: Wave One Gold Reciprocating file showed maximum efficiency and ProTaper Gold showed least efficiency in the removal of both Smear layer and Debris at all 3-levels of root canals compared to other file systems used.

Keywords: Smear Layer, Debris, Rotary File, Reciprocating File, Scanning Electron Microscope

Introduction

Successful endodontic treatment relics on thorough cleaning, shaping and an adequate obturation of the root canal system to eliminate bacteria and prevent reinfection. Mechanical instrumentation, when combined with irrigants, facilitates removal of pulp tissue, microorganisms and debris.[1] According to **Herbert** Schelder[2] the primary objective of canal preparation is to remove of organic substrate from the canal system through chemomechanical preparation and to achieve three-dimensional shaping of the root canal system into a continuously tapering preparation while maintaining the original outline and form of the canal. However, during root canal preparation, a smear layer composed of dentin particles, pulp remnants and bacteria is formed, which may compromise disinfection and sealing if not adequately removed. The American Association of Endodontists defined Smear layer as a surface film of debris retained on dentin or other surfaces, after instrumentation with either rotary instruments or endodontic files consists of dentin particles, remnants of vital or necrotic pulp tissue, bacterial components and retained canal irrigants.[3] Debris was defined as dentin chips and vital or necrotic pulp remnants loosely attached to the canal walls.[4] Smear layer is a "Muddy" layer, Whereas the surface debris has a "Dusty" pattern under SEM(Scanning Electron Microscope) examination[1]. McComb and Smith[5] were the first researchers to characterize the smear layer present on the surface of instrumented root canals. This smear layer impedes the penetration of irrigants into the dentinal tubules and influences the adaptation of root canal filling materials.

The introduction of Nickel–Titanium (NiTi) endodontic files has revolutionized root canal preparation offering superior flexibility, shape memory and resistance to procedural errors compared to traditional stainless-steel files.[6] With continued innovation, two major kinematics have emerged: rotary systems that use continuous rotation and reciprocating systems that employ alternating clockwise and counter-clockwise movements. Rotary systems allow efficient and predictable canal shaping with constant taper, while reciprocating instruments reduce file stress and risk of separation,

making them widely accepted in modern endodontics. NiTi files promoted the emergence of instruments with a continuous rotary motion inside the root canal, usually with a crown-down technique.[7] Despite these advantages, Rotary file systems are associated with smear layer and debris formation on root canal walls.[7] The cleaning and shaping efficacy of these Ni-Ti file systems should greatly improve the success of root canal treatment.[8] In our study, we used four endodontic file systems, two Rotary or two Reciprocating files.

ProTaper Gold (PTG: Dentsply Maillefer, Ballaigues, Switzerland) is a new rotary NiTi file system introduced as a modified version of the Protaper Universal and developed with proprietary advanced metallurgy through the heat treatment. ProTaper Gold has all the features as the ProTaper Universal files including a convex triangular cross section, progressive taper and non-cutting tip with a neutral rake angle.[9] A positive rake angle permits the instrument to cut more aggressively whereas a negative or neutral rake angle will only grind the root canal wall. It consists of 8 files, 3 files for coronal shaping; Sx (19/0.04 taper), S1 (size 18/0.04 taper), S2 (size 20/ 0.04 taper) and 5 finishing files for apical shaping; F1 (size 20/0.07 taper), F2 (size 25/0.08 taper), F3 (size 30/0.09 taper), F4 (size 40/0.06 taper), F5 (size 50/0.05 taper).[9]

Reciproc Blue (RB) (VDW, Munich, Germany) is a reciprocating single file systems manufactured with M (Memory)-Wire alloy (NiTi), which provides more flexibility, greater resistance to cyclic fatigue and improved navigation of curved, narrow and deep canals. Typically utilizing one of the three files (R25, R40, R50) (tip diameter and taper): R25 (25/0.08), R40 (40/0.06), R50 (50/0.05) for comprehensive root canal instrumentation. It features S-shaped cross-sectional design with a non-cutting tip and two cutting edges. Reciproc Blue showed enhanced all-around performance regarding microhardness, resistance to fatigue and flexibility.[10]

Wave One Gold (WOG: Dentsply Maillefer, Ballaigues) represents a novel reciprocating single NiTi file system, serving as an enhanced iteration of WaveOne. This system is developed through heat treatment of metallic wire called ‘Gold-wire’. WaveOne Gold files are characterized by their gold color and a modified offset parallelogram cross-sectional design, featuring a rounded tip. This design facilitates alternating single-one point contact between the file and the root canal walls. WOG files are offered in 4 sizes; 20: small, 25: primary, 35: medium, 45: large.[11] The WOG files operate with a preprogrammed motor in a reverse “balanced force” action, with a counter clockwise movement greater than the clockwise movement that allows the file to progress apically while the latter disengages the file and eliminates file binding, completing one reverse rotation in three reciprocating cycles.[12]

TruNatomy (TRN) (Dentsply Sirona), represents the next generation of rotary files. They are manufactured using a thermal process that produce a file with super-elastic NiTi metal properties, exhibiting less memory compared to conventional NiTi or M-Wire. These files feature a variable regressive taper, two cutting edges and an off-center square parallelogram cross-section. The TRN is designed with a post diameter of 0.8 mm, contrasting with the standard 1.2 mm design commonly employed by other rotary systems The TruNatomy file system are available in three sizes: Small (20/0.04 taper), Prime (26/0.04 taper), Medium (36/0.03 taper) for different clinical applications.[13]

The Smear layer and Debris, particularly in the apical-third of root canals remains challenging to eliminate despite the combined use of sodium hypochlorite and

EDTA. Since instrument motion, design, and metallurgy significantly influence cleaning ability, it is essential to compare rotary and reciprocating systems for their smear layer removal efficacy.[14]

So, the aim of our In-vitro study was comparative evaluation in the removal of Smear layer and Debris during root canal instrumentation using Two Rotary (ProTaper Gold, TruNatomy) and Two Reciprocating (Reciproc Blue, WaveOne Gold) file systems with Scanning Electron Microscope (SEM) analysis**.**

Materials and Method

The present in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics after obtaining the Institutional Ethical Committee clearance; TIDSHRC/ IEC/2024/D0021. Eighty freshly extracted human mandibular single rooted premolar teeth were collected, only the teeth extracted either for orthodontic reasons or periodontally compromised were used in the study. Teeth without any previous; Carious lesions, endodontically treated, fractured, cracks on the root surface, resorptive defects, calcifications, open root apices, single rooted and single canal as verified clinically and radiographically were only included in our study. Digital periapical radiographs of teeth were taken using Radiovisiography (RVG) (Kodak, Carestream Health India Pvt Ltd, Maharashtra, India) in bucco-lingual and mesio-distal directions to confirm the presence of a single straight canal and absence of any accessory canals, calcifications, resorptive defects and other anatomical anomalies and only the teeth with the degree of Root canal curvature between 10° to 20° according to Schneider SW[15] criteria were only included in our study.

All teeth were examined under Stereomicroscope (Olympus SZ61, Olympus Optical Co., Tokyo, Japan) at 10X magnification to ensure that they were intact and without any caries or non-caries lesions, devoid of restorations, clinically detectable fractures, cracks or enamel hypoplasia following strict inclusion criteria. Preliminary preparation involved diligent cleaning of all collected extracted teeth using ultrasonic instruments to remove superficial debris, calculus and residual tissue tags. Occupational Safety and Health Administration (OSHA) and Center for Disease Control and Prevention guidelines were followed throughout specimen collection, sterilization and handling process. All specimens were stored in 0.5% Thymol at room temperature until use.

All teeth were then decoronated upto the level of 2mm coronal to Cementum-Enamel Junction using a diamond disc (DFS, Germany) attached to straight micromotor handpiece (NSK, Japan) at low-speed, to standardize length of all teeth. Endodontic access was done using round bur no. 2 (Mani, Japan) attached to high-speed contra-angled air-rotor handpiece (NSK, Japan) and canal orifices were located and pulp tissue was extirpated using barbed broaches (Mani, Japan). A no.10 K(Kerr)-file (Mani INC, Japan) was placed into the root canal to establish the patency and the working length was determined by subtracting 0.5mm from the length achieved with the tip of the trial file just visible at the apical foramen in each specimen. All specimens (n=80) were then randomly divided into four groups with 20 specimens each, based on the type of file system used for root canal instrumentation.

Group 1 (n=20): ProTaper Gold Rotary(PTG) files at 300 rpm (Revolutions Per Minute) were used for root canal instrumentation upto pre-determined working length following the sequence: S1 (18/.02), S2 (20/.04), F1 (20/.07), F2 (25/.08), F3 (30/.09) of Size and Taper.

Group 2(n=20): TruNatomy (TN) Rotary files at 500 rpm were used for root canal instrumentation upto their pre-

determined working length in the file sequence: Glider (17/.02), Small (20/.04), Prime (26/.04), Medium (36/.03) of Size and Taper.

Group 3 (n=20); WaveOne Gold (WOG) Reciprocating file was used. Medium file 35/6% size and taper at 350 rpm was used for root canal instrumentation upto pre-determined working length.

Group 4 (n=20); Reciproc Blue (RB) Reciprocating file was used. R25/8% size and taper at 300rpm was used for root canal instrumentation upto pre-determined working length.

All files were used attached to CanalPro CLi2 endomotor handpiece (Coltene Whaledent Pvt. Ltd., Altstatten, Switzerland) and each rotary and reciprocating file was used according to their manufacturer's instructions. During root canal instrumentation, 2ml of 17% EDTA solution (Ethyline Diamine Tetra Acetic acid) (Prime Dental Products Pvt Ltd, Thane, India), 2ml of 3% Sodium hypchlorite solution (Neelkanth Health Care Pvt Ltd, Jodhpur, India) and 2ml of 0.9% normal saline (Nivy Remedies Pvt. Ltd., West Bengal, India) were used as root canal irrigants per specimen. Each root canal was then finally flushed with 1 ml of 17% EDTA, 1 ml of 3% NaOCl solutions followed by 2 ml of 0.9% normal saline. All specimens were then dried with sterile paper points. Each rotary or reciprocating file was used for instrumentation of only five root canals and were then discarded, followed by the use of new file. Root canals in all specimens were instrumented by one clinician (Myself).

A diamond disc (DZ, Munchen, Germany) attached to micromotor straight handpiece (NSK, Japan) was then used to make two initial longitudinal grooves, on buccal and lingual surfaces of each specimen at low-speed of 20,000 RPM to assist for precise vertical splitting of tooth. To prevent any splattering of cutting debris of tooth into the root canal space, a gutta-percha point (Dentsply, Maillefer, Switzerland) corresponding to the size and taper of the last file used for canal instrumentation was placed into the root canals of each specimen. The gutta-percha point was placed into each root canal for validating the depth during longitudinal groove preparation using diamond disc, thus preventing the cutting debris from entering into root canal space.[1]

Each specimen was then carefully and precisely splitted bucco-lingually using a hand chisel (GDC, India) into 2 equal halves; mesial and distal, we chosed only the most representative half of each specimen, with the other halve discarded, thus eighty samples were selected. Each root halve was then marked at 3mm (apical-third), 6mm (middle-third) and 9mm (coronal-third) from the predetermined working length. Using Scanning Electron Microscope (ZEISS EVO 18, Germany) (Figure no. 1) at 2000X magnification, each sample was examined at all 3-levels of root canals. The SEM photomicrographs of each sample were then analysed following the criteria of Hulsmann M et al[16] for the extent of presence (or) absence of Smear layer and Debris.

Residual Smear layer scoring criteria:

Score 1: No smear layer, dentinal tubules open.

Score 2: Small amount of smear layer, some dentinal tubules open.

Score 3: Homogenous smear layer covering the major part of the root canal surface, few dentinal tubules open.

Score 4: Homogenous smear layer covering the root canal surface, no open dentinal tubules.

Score 5: Heavy, non-homogenous smear layer covering the root canal surface.

Residual Debris scoring criteria **:**

Score 1: Clean root canal wall with only few small debris particles.

Score 2: Few small agglomerations of debris.

Score 3: Moderate amount of debris with less than 50% of the root canal surface covered.

Score 4: Substantial debris with more than 50% of the root canal surface covered.

Score 5: Thick layer of debris covering the whole or almost the entire root canal surface.

The obtained data was then tabulated, recorded and subjected to statistical analysis.

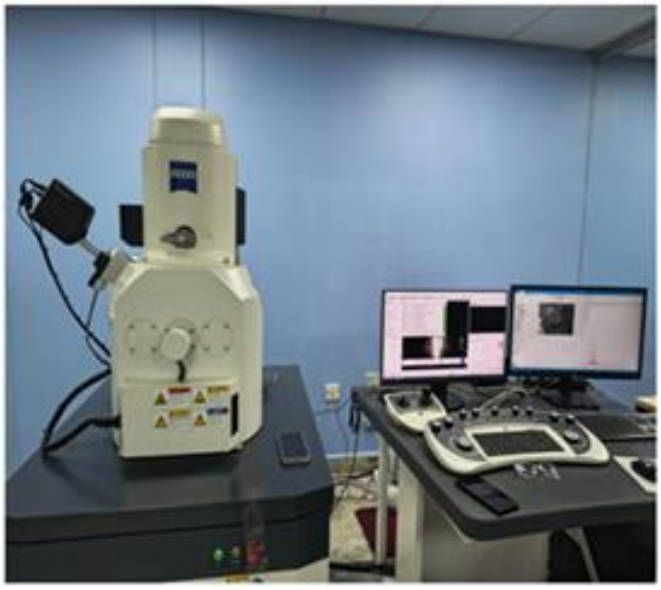


Figure 1: Scanning Electron Microscope (ZEISS EVO 18, Germany)

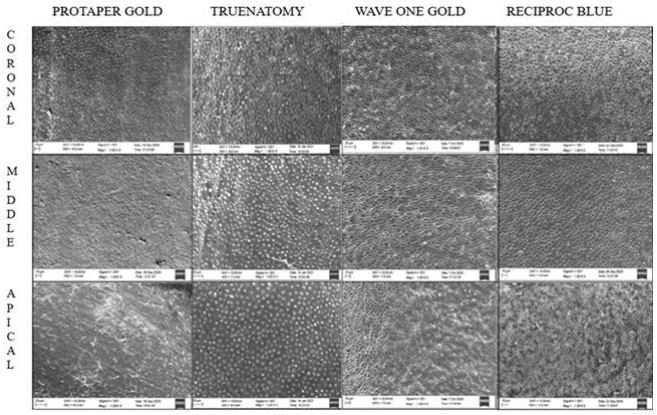


Figure 2: Scanning Electron Microscope - Photomicrographs at coronal, middle and apical-third's of root canal surfaces for the presence or absence of Smear layer and Debris among the four groups.

Results

The tabulated Scores of residual Smear layer and Debris in all samples, at coronal, middle and apical- thirds were statistically analyzed with computer software; Statistical Package for Social Sciences (SPSS) version 24, using OneWay ANOVA and Tuckey Post-hoc tests.

Presence of smear layer: The mean comparison between two rotary file systems (Protaper Gold & TruNatomy) showed highly significant difference in the presence of smear layer. TruNatomy file system (Group 2) showed least or minimal presence of smear layer compared to PTN file system (Group 1) at all 3-levels of root canals, $P<0.05$.

The mean comparison between two reciprocating files (Wave One Gold & Reciproc Blue) showed highly significant difference in the presence of smear layer. WOG file (Group 3) showed presence of least or minimal smear layer compared to Reciproc Blue file (Group 4) at all 3-levels of root canals, $P<0.05$ (Table 1).

Table 1: One Way ANOVA test for Comparison in the presence of Smear layer among the four groups.

Groups	Mean ± SD			P-value
	Coronal-third	Middle-third	Apical-third	
Group 1: PTG Rotary file	3.65 ± 0.72	3.85 ± 0.67	4.20 ± 0.57	P=0.01 (Significant)
Group 2: TN Rotary file	2.55 ± 0.69	3.10 ± 0.64	3.40 ± 0.75	P= 0.04 (Not significant)

Group 3: WOG Reciprocating file	1.60 ± 0.60	1.75 ± 0.60	2.55 ± 0.59	P<0.01 (Significant)
Group 4: RB Reciprocating file	2.95 ± 0.76	3.10 ± 0.82	3.45 ± 0.59	P=0.03 (Not significant)

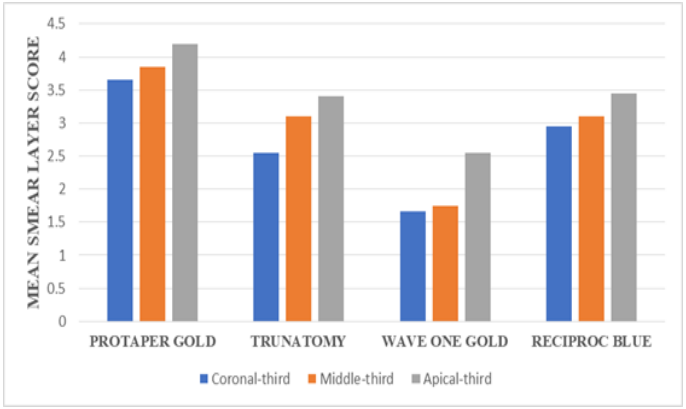
P: Probability, S.D: Standard Deviation

Table 2: Tuckey Post-hoc test for Inter-group comparison among the four groups for the presence of Smear layer

At 3-levels of root canals	Inter-group comparison	P-value
Coronal-third	Group 1 *Vs* Group 3	P<0.001 (Highly significant)
	Group 1 *Vs* Group 2	P=0.011(Significant)
	Group 1 *Vs* Group 4	P=0.24 (Not-significant0
	Group 3 *Vs* Group 2	P=0.01(Significant)
	Group 3 *Vs* Group 4	P=0.01(Significant)
	Group 2 *Vs* Group 4	P=0.14 (Not-significant)
Middle-third	Group 1 *Vs* Group 3	P<0.001(Highly significant)
	Group 1 *Vs* Group 2	P=0.003(Not-significant)
	Group 1 *Vs* Group 4	P=0.03(Significant)
	Group 3 *Vs* Group 2	P=0.002(Significant)
	Group 3 *Vs* Group 4	P=0.01(Significant)
	Group 2 *Vs* Group 4	P=0.31 (Not-significant)
Apical-third	Group 1 *Vs* Group 3	P=0.0017(Highly significant)
	Group 1 *Vs* Group 2	P=0.31(Not-significant)
	Group 1 *Vs* Group 4	P=0.02(Not-significant)
	Group 3 *Vs* Group 2	P=0.01(Significant)
	Group 3 *Vs* Group 4	P=0.012(Significant)
	Group 2 *Vs* Group 4	P=0.38(Not-significant)

Tuckey Post-hoc test was done for inter-group comparison. Statistically significant difference was seen in the presence of smear layer among the four file systems. WaveOne Gold reciprocating file (Group 3) showed the lowest smear layer score and ProTaper Gold rotary file system showed the highest smear layer score at all three levels of root canals **(**WaveOne Gold file showed maximum removal and ProTaper Gold file system showed poor removal of smear layer) (Table 2).

Graph 1: Presence of Smear layer at three levels of root canals among the four groups



Presence of Debris: The mean comparison between two rotary file systems (Protaper Gold & TruNatomy)

showed highly significant difference in the presence of debris. TruNatomy file system (Group 2) showed least or minimal presence of debris compared to PTN file system (Group 1) at all 3-levels of root canals, P<0.05. The mean comparison between two reciprocating files (Wave One Gold & Reciproc Blue) showed highly significant difference in the presence of debris. WOG file (Group 3) showed presence of least or minimal smear layer compared to Reciproc Blue file (Group 4) at all 3-levels of root canals, P<0.05 (Table 3).

Table 3: One Way ANOVA test for Comparison in the presence of Debris among the four groups

Groups	Mean ± SD			P-value
	Coronal-third	Middle-third	Apical-third	
Group 1: PTG Rotary file	3.60 ± 0.70	3.45 ± 0.65	4.14 ± 0.75	P= 0.01 (Significant)
Group 2: TN Rotary file	2.15 ± 0.55	2.90 ± 0.24	2.40 ± 0.75	P= 0.03 (Not significant)
Group 3: WOG Reciprocating file	1.55 ± 0.45	1.55 ± 0.60	2.25 ± 0.57	P<0.01 (Significant)
Group 4: RB Reciprocating file	3.04 ± 0.76	3.10 ± 0.82	3.25 ± 0.55	P= 0.04 (Not significant)

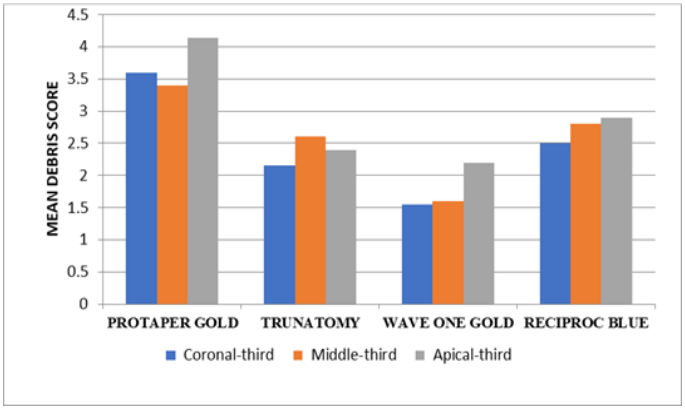
Table 4: Tuckey Post-hoc test for Inter-group comparison among the four groups for the presence of Debris

At 3-levels of root canal	Inter-group comparison	P-value
Coronal-third	Group 1 *Vs* Group 3	P=0.001(Highly Significant)
	Group 1 *Vs* Group 2	P=0.011(Significant)
	Group 1 *Vs* Group 4	P=0.23 (Not Significant)
	Group 3 *Vs* Group 2	P=0.03(Significant)
	Group 3 *Vs* Group 4	P=0.017(Significant)
	Group 2 *Vs* Group 4	P=0.04(Significant)
Middle-third	Group 1 *Vs* Group 3	P<0.001(Highly Significant)
	Group 1 *Vs* Group 2	P=0.001(Significant)
	Group 1 *Vs* Group 4	P=0.04(Significant)
	Group 3 *Vs* Group 2	P=0.03(Significant)
	Group 3 *Vs* Group 4	P=0.034(Significant)
	Group 2 *Vs* Group 4	P=0.13(Not Significant)
Apical-third	Group 1 *Vs* Group 3	P=0.001(Significant)
	Group 1 *Vs* Group 2	P=0.002(Significant)
	Group 1 *Vs* Group 4	P=0.2(Not Significant)
	Group 3 *Vs* Group 2	P=0.001(Highly Significant)
	Group 3 *Vs* Group 4	P=0.012(Significant)
	Group 2 *Vs* Group 4	P=0.4 (Not Significant)

Tuckey Post-hoc test was done for inter-group comparison. Statistically significant difference was seen in the presence of Debris among the four file systems tested. WaveOne Gold reciprocating file (Group 3)

showed the lowest Debris score and ProTaper Gold rotary file system showed the highest Debris score at all three levels of root canals **(**WaveOne Gold file showed maximum removal **and** ProTaper Gold file system showed poor removal of debris) (Table 4).

Graph 2: Presence of Debris at three levels of root canals among the four groups



Discussion

Effective debridement of the root canal system is essential for successful endodontic therapy, as it enhances complete disinfection of root canals along with the removal of smear layer and debris, thus improves sealer penetration and 3-dimensional obturation of root canals. Reciprocating single-file system exhibit less stress on the canal surface and offer a faster time for completion of canal instrumentation compared to rotary multi-file system.[7] The cleaning effectiveness of reciprocating files seems to be comparable to rotary files. However, the metallurgical properties of the file, its design and their kinematics are more decisive than the number of files used on their cutting efficiency, removal of smear layer and debris, cleaning ability of files.[7]

Reciproc Blue (VDW, Munich, Germany) and Wave One Gold (Dentsply Maillefer, Ballaigues, Switzerland) are two of the main examples of reciprocating systems. Both instruments are manufactured with Control Memory (CM) wire technology. CM-wires are thermo-mechanically treated Ni-Ti alloys, have lower nickel (Ni) content than conventional Ni-Ti files. The high thermal treatment of these two files followed by their slow cooling, increases their flexibility and cyclic fatigue resistance.[17] These design features minimizes the contact between the file and the root canal dentin, producing lesser smear layer and debris on the surface of root canals.[18]

The findings of our study are in concurrence with Maya Feghali et al[11] concluded that WaveOne Gold file showed better smear layer and debris removal compared to Reciproc Blue file, especially at the apical-thirds of root canals. Irresepective of the type of file used for instrumentation of root canals, smear layer is formed over the root canal surface. Smear layer constitutes organic and inorganic contents that include remnants of pulp tissue, dentin chips, microorganisms and necrotic tissue, occluding the dentinal tubules and prevents complete disinfection of root canal space. The presence of smear layer also prevents 3-dimensional obturation of root canal system.

Many studies[1,6,19]showed that formation of smear layer is highest in the apical-thirds followed by middle and coranal-thirds of root canals. In our study, canal instrumentation using WOG files showed better removal of both smear layer and debris at all 3-levels of root canals. The findings of our study are in accordance with Suparna SG et al[20] also reported that WOG files resulted in cleaner canals devoid of smear layer and debris at all 3-levels of root canals compared to other file systems used. This may be due to a decrease in the taper of the WOG file system, 0.7% taper in coronal-third, 0.6% taper in middle and 0.3% at apical-thirds of files. Additionally, these files has offset of mass of rotation and parallelogram cross-section.

The findings of our study were also in accordance with De Carvalho FM et al[21] concluded that canal

instrumentation using reciprocating files resulted in better removal of smear layer and debris compared to rotary files. Haapasalo M et al[14] emphasized that instrumentation alone cannot ensure complete canal disinfection, but effective use of root canal irrigants is also equally important for smear layer and debris removal, especially in the apical-thirds of canals due to vapor lock effect and limited irrigant exchange.

Conclusion

Under the parameters of our in-vitro study, WaveOne Gold reciprocating file exhibited maximum removal of both smear layer and debris at all 3-levels of root canals followed by Trunatomy rotary file system. ProTaper Gold rotary file system showed the least removal of both smear layer and debris from the root canal surface. Further studies are needed to extrapolate the findings of our study to clinical situations.

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