

Original Article

Comparative evaluation of canal cleaning ability of various rotary endodontic files in apical third: A scanning electron microscopic study

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ABSTRACT

Background: The purpose of this study was to evaluate the canal cleaning ability of three novel endodontic rotary instruments and compare with ProTaper files as a control in apical third of root canals under scanning electron microscopy (SEM).

Materials and Methods: Eighty freshly extracted mandibular premolars were selected according to inclusion criteria. Buccal cusp tips were ground to ensure having a flat coronal reference point with a total tooth length of 16 mm for all samples. Teeth were divided equally into four groups: Group I (ProTaper group), Group II (ProTaper next group), Group III (variable taper group), and Group IV (self-adjusting file [SAF] group). Using SEM, the dentinal surfaces were observed and rated at apical thirds with a magnification of $\times 1000$ for the presence/absence of smear layer and debris. Descriptive analysis was performed, and analysis of variance with Bonferroni *post hoc* test was carried out for comparison between the groups, at a significance level of 0.05.

Results: There was statistically significant difference between Group II and Group IV for debris ($P = 0.047$) and smear layer ($P = 0.037$).

Conclusion: In apical third of root canal, SAF showed statistically significant canal cleaning ability due to combined effect of continuous streaming irrigation with effectively replacing the irrigant from the apical portion of the root canal, irrigants activation through the creation of turbulence, and its self-adapting design to root canal anatomy with a scrubbing motion on the canal walls.

Key Words: Adjusted, Filing, rotary, scanning electron microscopy, self, variable

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INTRODUCTION

One of the criteria for the successful outcome of root canal treatment is elimination of microorganisms from the root canal system.^[1] Mechanical instrumentation alone cannot reduce the microbial population in the root canal system as it forms debris and smear layer that comprises inorganic and organic substances such

as fragments of odontoblastic processes (Tomes fibers), necrotic tissues, microorganisms, and their metabolic byproducts.^[2] such tissue remnants and debris prevent the penetration of irrigants and medicaments into the dentinal tubules and avoid the close adaptation of root

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canal filling onto canal walls.^[3] Degradation of the smear layer after treatment may contribute to leakage and reinfection of the root canal space.^[4] Hence, evaluation of removal of debris and smear layer, which correlates with the canal cleaning efficacy of endodontic files, is of prime importance. The apical area in the root canal system is the critical zone for instrumentation.^[5] Ramifications can be observed anywhere along the the root canal but occur more frequently in the apical portion of root canal and in the posterior teeth.^[6] The treatment outcome will be guarded if these anatomical anomalies are not identified, prepared, and obturated. The apical third of the root canal faces to the problem of achieving cleanliness compared to the coronal and middle thirds.^[7]

In scanning electron microscope (SEM), images are visualized at higher magnification. The basic principle of working in SEM is that an electron beam scans the surface of the sample to produce a variety of signals and is collected by a detector.^[8] It proved to be a valuable method in the comparison of the volume of debris and smear layer remnants on root canal wall after preparation with different instruments. Recently, wide ranges of rotary endodontic files such as ProTaper next, variable taper rotary files (V taper files), and self-adjusting file (SAF) were introduced with variations in their design and mechanism of action. Variations in the designs of rotary nickel-titanium (NiTi) instruments result in variation in their debris removal and smear layer production. Extrapolating from the above, this *in vitro* study was planned to comparatively evaluate the canal cleaning ability of three novel endodontic rotary instruments with ProTaper files as a control in apical third of root canals under SEM.

MATERIALS AND METHODS

Sample collection

One-hundred freshly extracted human mandibular premolars with straight single root canals were selected for the study. All calculus and soft-tissue remnants were removed from the root surfaces using ultrasonic scalers and stored in sterile saline solution at room temperature.

Inclusion criteria ($n = 80$)

Inclusion criteria included teeth with straight and single patent root canal without any anatomical variation on buccal and proximal radiographs with completely formed apices.

Exclusion criteria ($n = 20$)

Exclusion criteria included teeth with visible root caries, signs of external or internal resorption, cracks or fracture lines viewed under microscope with $\times 16$ magnifications.

Teeth preparation for the study

Buccal cusp tips were ground using a diamond disk (DZ, Darmstadt, Germany) to ensure having a flat coronal reference point with a total tooth length of 16 mm for all samples. Coronal access cavity was prepared with high-speed bur, and all the canals were checked for apical patency with K-file (015/02) (Mani, Japan). Working length (WL) was obtained by measuring the length of the initial instrument (015/02 K-file) at apical foramen minus 1 mm.

Sampling

The samples were divided randomly into four groups according to the file system used for the preparation of root canals as follows:

- Group I ($n = 20$) (ProTaper group) (Dentsply Maillefer, New York, USA): Coronal third was prepared using ProTaper Universal S_x in brushing manner and glide path was established using K-file (015/02). S1-F2 ProTaper files were used with endodontic motor (X-Smart, Dentsply Maillefer, New York, USA) according to the manufacturer's recommendations to the WL with final apical preparation being completed using F2 corresponding 025 size (Torque - 2 Ncm, speed - 300 rpm)
- Group II ($n = 20$) (ProTaper next group) (Dentsply Maillefer, New York, USA): Coronal third was prepared using ProTaper Universal S_x in brushing manner and glide path was established using K-file (015/02). Apical preparation was done with X₁ (017/04) sequentially followed by X₂ (025/06) till WL (Torque - 2Ncm, speed - 300 rpm)
- Group III ($n = 20$) (V taper group) (SS White, Philadelphia, USA): Coronal shaping was done using 025/08. Glide path was established using K hand file (015/02). Apical shaping was done using 020/06 with endodontic motor (X-Smart, Dentsply Maillefer, Ballaigues, Switzerland) according to the manufacturer's recommendations to the WL. Final preparation was done till 025/08 (Torque - 4.5 Ncm, speed - 250 rpm)
- Group IV ($n = 20$) (SAF group) (Re Dent Nova, Ra'anana, Israel): Glide path was established using K-file (015/02), followed by K-file (020/02) to the

WL as instructed by the manufacturers. Then, the SAF (2.0 mm diameter, 21 mm length) was used in canal using RDT3-NX handpiece that produced 5000 vibrations/min with 0.4 mm of amplitude. SAF was used for 4 min with distilled water irrigation at flow rate of 5 ml/min.

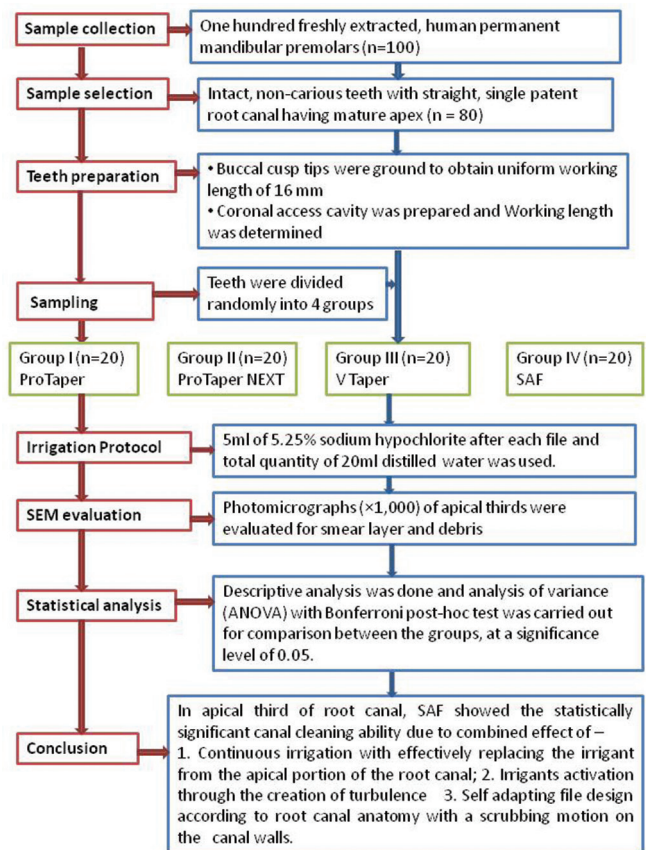
All root canal preparations were performed by one operator to maintain the uniformity. In all groups, 5 ml of 5.25% sodium hypochlorite was used after each file, and total quantity of 20 ml distilled water was used between each file [Flowchart 1].

Scanning electron microscopy procedure

Two longitudinal grooves were prepared in the buccal and lingual surfaces using a diamond disc with a marking on disc at 2 mm, without exposing the root canals. Thereafter, each root was split into two equal pieces with a hammer and chisel. The specimens were dehydrated sequentially by increasing concentrations of ethyl alcohol: 30% for 10 min, 50% for 20 min, 70% for 20 min, 90% for 30 min, 100% for 30 min, and 100% for 30 min. After that, the specimens were mounted on coded stubs (all samples of an appropriate size were mounted rigidly on a specimen holder called a specimen stub), air dried, placed in a vacuum chamber, and sputter-coated with a gold layer. For imaging in the SEM, specimen's surface must be electrically conductive. Therefore, specimen's surface is coated with an ultrathin coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. In the present study, conductive coating material used was gold. The specimens were then analyzed using SEM (CamscanMV 2300, Oxford Instrument, UK). The dentinal surfaces were observed at apical thirds with a magnification of $\times 1000$ for the presence/absence of debris, smear layer, and visualization of the entrance to dentinal tubules. Photomicrographs ($\times 1000$) of these areas on apical thirds were taken [Figure 1a-d].

Scanning electron microscopy evaluation

Two endodontists (who were not involved in the study) were trained to interpret the photomicrographs by rigorous; multiple training sessions until consensus was reached between them. The photomicrographs were interpreted by both trained endodontists independently and jointly to arrive at a consensus. The findings were entered into an Excel sheet (Microsoft, Seattle, WA). To cross-check for further intrinsic interobserver variability, each of the photomicrographs was analyzed



Flowchart 1: Flowchart of the protocol.

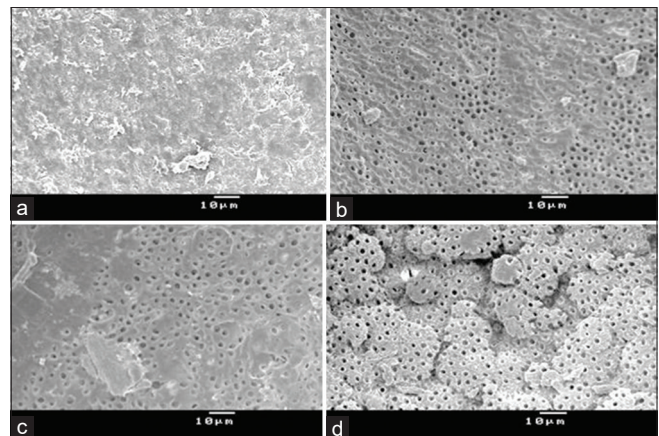


Figure 1: Photomicrographs ($\times 1000$) of the dentinal surfaces at apical thirds of roots for evaluation of smear layer and debris in Group I (a), Group II (b), Group III (c), and Group IV (d).

for thesecond time 1 week after the initial examination by the same endodontist. The cleanliness of each root was evaluated at apical third by means of a numerical evaluation scale scoring system as follows:

Scores for the superficial debris

- Score 1: Absent
- Score 2: Minimal presence of pulpal-fibrous debris

- Score 3: Partial presence of pulpal-fibrous debris
- Score 4: Presence of an organized collagenous matrix.

Scores for the smear layer

- Score 1: Absent, more than 75% of tubules exposed and free from smear layer; tubules completely opened
- Score 2: Present in limited areas, <75% of tubules uncovered; tubules partially opened
- Score 3: Present, tubules visible in limited areas and partially closed; <50% of dentinal tubules visible
- Score 4: Homogeneous smear layer present above all dentin; dentinal tubules not visible.

Statistical analysis

Data were entered into excel sheet (Microsoft Excel 2010) and were analyzed using Statistical Package of Social Science version 21 (IBM, New York). Descriptive analysis was performed, and analysis of variance with Bonferroni *post hoc* test was carried out for comparison between the groups, at a significance level of 0.05.

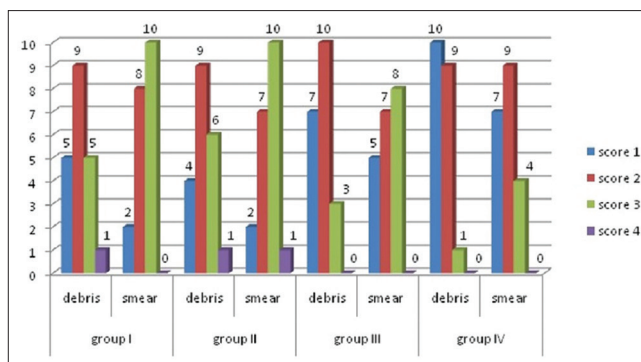
RESULTS

Debris score

Debris evaluation of the dentinal surfaces of root canals at apical third resulted in debris scores of 1 or 2, representing a clean root canal surface in 95% of the cases at apical thirds of the root canals for Group IV(SAF group) [Graph 1]. None of the samples in Group III (V taper group) [Figure 1c] and Group IV (SAF group) [Figure 1d] were characterized as having a debris score of 4. In Group I (ProTaper group) [Figure 1a] and Group II (ProTaper group) [Figure 1b], 30% and 35% of cases showed debris scores of 3 or 4, respectively, indicating incomplete debris removal [Table 1]. The mean difference between the groups was found to be statistically significant ($F = 3.075, P = 0.033$). On applying the Bonferroni *post hoc* test, the mean difference was found significant only between the Group II and Group IV ($P = 0.047$).

Smear layer score

In Group IV [Figure 1d], scores of 1 or 2, representing clean canal walls, were reported for 16 of 20 (80%) of the samples, whereas smear layer score of 3 was reported for only 4 (20%) of 20 samples [Graph 1]. The difference between the means of the groups was found to be statistically



Graph 1: Smear layer and debris scores of the root canal dentinal surfaces at apical third in all four groups. X axis showing four groups with each group is divided into halves; first half showing debris score, second half showing smear layer score and Y axis showing number of samples.

Table 1: Debris score of the dentinal surfaces at apical thirds of roots in Group I, Group II, Group III, and Group IV

n=20	Group I	Group II	Group III	Group IV
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	2	1	1
6	2	2	1	1
7	2	2	1	1
8	2	2	2	1
9	2	2	2	1
10	2	2	2	1
11	2	2	2	2
12	2	2	2	2
13	2	2	2	2
14	2	3	2	2
15	3	3	2	2
16	3	3	2	2
17	3	3	2	2
18	3	3	3	2
19	3	3	3	2
20	4	4	3	3

significant ($F = 2.982, P = 0.037$). On applying the Bonferroni *post hoc* test, the difference of means was found significant only between the Group II and Group IV ($P = 0.037$). The combined action of the SAF with the continuous irrigation regimen resulted in a root canal surface free from smear layer [Figure 1d and Table 2].

DISCUSSION

The present study was conducted to evaluate the canal cleaning ability of various rotary endodontic

Table 2: Smear layer score of the dentinal surfaces at apical thirds of roots in Group I, Group II, Group III, and Group IV

n=20	Group I	Group II	Group III	Group IV
1	1	1	1	1
2	1	1	1	1
3	2	2	1	1
4	2	2	1	1
5	2	2	1	1
6	2	2	2	1
7	2	2	2	1
8	2	2	2	2
9	3	2	2	2
10	3	3	2	2
11	3	3	2	2
12	3	3	2	2
13	3	3	3	2
14	3	3	3	2
15	3	3	3	2
16	3	3	3	2
17	3	3	3	3
18	3	3	3	3
19	2	3	3	3
20	2	4	3	3

files at apical third of instrumented canals under scanning electron microscopy (SEM). The present study employed human teeth although these can show large variations in root canal morphology and dentine hardness as this is the only way to evaluate the cleaning ability of various instruments.^[9] The teeth in both groups were balanced with respect to the angle, length, and dimensions to ensure comparability of the experimental groups.

Canal cleaning ability of endodontic files can be evaluated from its ability to remove debris and smear layer which is an essential prerequisite for the successful outcome of endodontic treatment.^[7,10] Smear and debris layer lead to following difficulties during endodontic treatment: an unpredictable thickness and volume due to greater water portion limits its removal and optimum penetration of disinfectants,^[11] contains bacteria, their by-products^[12] and necrotic tissue which is a reservoir of microbial irritants^[13] allowing their deeper penetration in the dentinal tubules,^[14] compromises the seal of obturated material,^[15] its loosely adherent nature is a potential avenue for leakage. Debris and smear layer removal depends not only on the irrigation method but also on the design of endodontic instrument (size, taper, cross-section, etc.), the way instrument is used (rotational or vibrational), and the method of preparation (step back or crown down).^[16-18] Here,

three recently introduced files were compared with traditionally used rotary system (that is ProTaper file) for their canal cleaning ability.

Lateral canals and apical ramifications are most commonly present in apical third of the root. It can make these areas inaccessible to instruments.^[19,20] Complete sterility of such areas is difficult to achieve, and any residual debris leftover following chemomechanical preparation leads to treatment failure.^[21] Significant numbers of residual bacteria found in ramifications in the apical third of root canal have easy access to periradicular tissue, which then leads to the development of disease.^[21-23] It has been suggested that more emphasis on chemomechanical preparation of apical third of root canal is needed to decrease the bacterial load to the point where root canal failure can be avoided.^[24] Seventy percent of cases of refractory apical periodontitis had significant apical ramifications in the apical third of the root apex of teeth.^[25] This suggested a close relationship between the anatomic complexity of the root canal system in apical third and the persistence of periradicular pathosis. Hence, in the present study, apical third of the root was taken into consideration to evaluate the removal of smear layer.

ProTaper instruments with its convex triangular cross section and reduced radial lands allow more aggressive and unconstrained cutting, produced more debris and smear layer.^[26] ProTaper next file system showed better debris and smear layer removal compared to ProTaper due to its offset mass of rotation which allowed two pointed contact of a file to the canal at a time that reduced the chances of lateral compaction of debris with improved canal cleaning ability.^[27,28] The Variable Taper rotary file (SS White, Philadelphia, USA) has a parabolic cross section, variable helical angle, and variable flute pitch with decreasing rate of taper from tip to shaft that enhanced the debris removal. Hence, it showed better canal cleaning ability than ProTaper and ProTaper next. However, difference between them was not statistically significant.

SAF (ReDent Nova, Ra'anana, Israel) is a novel instrument consisting of a hollow NiTi file composed of an abrasive metal lattice that allows for dentin removal with a back and forth grinding motion.^[29] In addition to effectively replacing the irrigant from the apical portion of the root canal and the activation of the irrigant through the formation of turbulence, the SAF file also induces a scrubbing motion on the canal

walls that must have obviously contributed to the clean surface. The continuous rotary motion results in an increased enlargement on the external side of the canal in the apical third, leaving the inner curvature relatively untouched. The reciprocating motion leads to a more centered preparation when compared with continuous rotating motion. This leads to superior cleaning efficacy.^[30] Hence, SAF groups showed the best canal cleaning ability than all other file systems.

It is concluded that in apical third of root canal, SAF showed the statistically significant canal cleaning ability due to combined effect of continuous irrigation with effectively streaming the irrigant from the apical portion of the root canal, irrigants activation through the creation of turbulence, and its self-adapting design according to root canal anatomy with a scrubbing motion on the canal walls.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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