Root canal cleaning with different reciprocating and rotary instrumentation systems

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Abstract

Aim: The purpose of the present study was to compare the cleaning effectiveness of two reciprocating single-file systems with ProTaper Next and ProTaper Universal rotary instruments during the preparation of single-rooted extracted teeth.

Methodology: Sixty freshly extracted single-rooted human teeth were randomly divided into 4 groups (n=15). In group 1, root canals were prepared with ProTaper Universal, in group 2, they were prepared with ProTaper Next, in group 3, they were prepared with WaveOne and in group 4, root canals prepared with Reciproc systems. Canals were prepared to the following apical sizes: ProTaper Universal F3, ProTaper Next X3, WaveOne Primary and Reciproc 25. The irrigant in all groups was 2ml 2.5% sodium hypochlorite (NaOCl) solution, the final irrigation after preparation all groups was 2ml NaOCl, 2ml EDTA and 2ml saline solution. The roots were split longitudinally into halves and the canals examined using a scanning electron microscope. The presence of a debris and smear layer was recorded at the coronal, middle and the apical thirds of root canals using a five-step scoring scale. Data were statistically analyzed using Kruskal-Wallis and Mann-Whitney U tests.

Results: All groups showed more efficient smear layer and debris removal coronally than in the middle and apical regions, whereas the mean total debris score and the mean smear layer score in all groups were less in the WaveOne and the Reciproc groups.

Conclusions: Under the conditions of this study, for root canal cleanliness Reciproc and WaveOne may be preferred rather than ProTaperUniversal and ProTaperNext.

Keywords: Debris, ProTaper Next, Reciproc, WaveOne, SEM

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Introduction

Mechanical and biological aims of root canal therapies are properly cleaning and shaping root canals, removing all bacteria and their products, pulp tissue as well as giving an appropriate morphology for subsequent sealing (1, 2). This can be achieved by proper chemo-mechanical preparation (3). But, no instrument can predictably clean the entire root canal system (3-5).

Many instruments and techniques have been described for root canal preparations (6, 7). Nickel-titanium (Ni-Ti) instruments have been widely used in endodontic practice because of their relatively greater reliability and efficiency compared to hand-held instruments (8). Ni-Ti rotary files have significantly better flexibility and cutting abilities and provide higher quality in the preparation of root canals with higher fracture resistance and cyclic and torsional fatigue (9). The capability of these Ni-Ti instruments to remove debris and smear layer has also been studied by several researchers, using various evaluation methods with different root canal systems (10, 11).

Among the Ni-Ti systems ProTaper Universal (PTU) (Dentsply Maillefer, Ballaigues, Switzerland) is a rotary system of conventional Ni-Ti wire that has been widely used and studied (6, 8, 12). It has a variable taper along the length of the instrument, a convex triangular cross-section, and sharp tip (13, 14). Another system, the ProTaper Next (PTN) (Dentsply Maillefer, Ballaigues, Switzerland) files are made of a special Ni-Ti alloy called M-Wire that created by an innovative thermal-treatment duration. The advantage of this M-Wire NiTi alloys is increased flexibility of the instruments and improved resistance to cyclic fatigue (15). ProTaper Next files have off-centered rectangular cross-section design. They are available in five sizes: X1 (tip size 17 with a taper of .04), X2 (tip size 25 with a taper of .06), X3 (tip size 30 with a taper of .07), X4 (tip size 40 with a taper of .06) and X5 (tip size 50 with a taper of .06) (16). Both PTU and PTN systems are used with a continuous rotary motion inside the root canal, usually with a crown-down technique. reciprocating rotary motion systems such as Reciproc (VDW, Munich, Germany) and WaveOne (Maillefer, Ballaigues, Switzerland) as one-file systems have been introduced, with the aim of reducing the number of steps and files to reach a correct endodontic treatment. They are both made with M-wire alloy (Ni-Ti), which provides more flexibility, greater resistance to cyclic fatigue and better handling (17, 18).

Reciproc files are available in different sizes 25 (taper .08), 40 (taper .06), 50 (taper .05) and WaveOne are available in the sizes 21 (taper .06), 25 (taper .08) and 40 (taper .08). These files are used with reciprocal motion that requires special automated devices. The reciprocating working motion include a counterclockwise (cutting direction) and a clockwise motion (relieve of the instrument), while the angle of the counterclockwise cutting direction is greater than the angle of the reverse direction (19).

The aim of this study was to compare the cleaning efficacy (residual debris and smear layer) after preparation of single rooted extracted human teeth using the two new single-file systems Reciproc and WaveOne compared with the ProTaper Next and ProTaper Universal systems.

Materials and Methods

This study was approved by the Institutional ethical committee for non-invasive clinical researches and human subjects or specimens (Ethical: 2014-02).

Sixty freshly extracted single-rooted human teeth with thin straight single root canals were used. The teeth had been extracted due to periodontal reasons and none of the teeth had previous restorative or endodontic therapy. Following extraction, the teeth were stored in isotonic saline solution to avoid any effect that a fixative might have on the dissolution of organic tissue. Teeth were intact and free of visible cracks. The crown was sectioned at the cementoenamel junction by using a high-speed bur under water cooling. Conventional endodontic access cavities were prepared (Endo Access Bur, Dentsply Maillefer, Ballaigues, Switzerland) in a high-speed handpiece. To determine the working length, a size 15 K-file was inserted until it reached the apical foramen and one milimeter was subtracted from this length. Teeth having more than one canal were excluded from the study. The samples were divided randomly into four groups (n=15) according to the file system used for preparation of root canals with ProTaper Universal, ProTaper Next, WaveOne and Reciproc files. Rotary instruments are used with a continuous rotary motion inside the root canal, usually with a crown-down technique.

Group 1 (ProTaper Universal group): Coronal third was prepared using ProTaper Universal Sx, in brushing manner and glide path was established using K-file (015/02). S1-F3 ProTaper files were used endodontic motor (X-Smart-Plus, Dentsply Maillefer, New York, USA) according to the manufacturer’s recommendations to the WL with final apical preparation being completed using F3 corresponding 030 size (Torque 2 Ncm, speed-250 rpm).

Group 2 (ProTaper Next group): Coronal third was prepared using P1, P2 in brushing manner and glide path was established using K-file (015/02). X1-X3 ProTaper next files were used endodontic motor (X-Smart-Plus) according to the manufacturer’s recommendations to the WL with final apical preparation being completed using X3 corresponding 030 size. (Torque 2 Ncm, speed-300 rpm).

Group 3 (WaneOne group): The WaveOne group was instrumented with WaveOne Primary file. WaveOne Primary files used with an endodontic motor (X-Smart Plus) according to the manufacturer’s recommendations to the WL with crown-down technique, using reciprocating motion.

Group 4 (Reciproc group): The Reciproc group was instrumented with R 25 file. R 25 file used endodontic motor (X-Smart Plus) according to the manufacturer's recommendations to the WL with crown-down technique, using reciprocating motion.

All root canal preparations were performed by one operator to maintain the uniformity. In all groups, during instrumentation, the canals were irrigated with 2 ml % 2.5 NaOCl solution using a plastic syringe with a 27-G closed-end needle. After instrumentation, all groups were irrigated with 2 ml % 2.5 NaOCl, 2 ml %17 EDTA and 2 ml distilled water and dried with paper points.

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, and the half containing the most visible part of the apex was conserved and coded. The specimens were dehydrated in oven (Nuve Incubator EN 120, Ankara, Turkey) at 50 C for 24 hours. After that, the specimens were mounted on coded stubs (all samples of 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 examined under scanning electron microscopy (SEM) (SEM, JEOL, JSM-5200, Tokyo, Japan). Photomicrographs from the approximate center of the coronal, middle and the apical thirds of each specimen were taken at x 200 for debris and x 1000 for smear layer evaluation. The photographs were blindly evaluated using modified Drukteinis and Balciunine criteria (20) by two endodontists. The cleanliness of each canal was evaluated by means of a numeric evaluation scale as follows:

Debris score (dentinal chips, pulp remnants, and particles loosely attached to the canal wall):

Score 1: Little or no superficial debris covering up %25 of the canal wall

Score 2: Little to moderate debris covering between % 25 and %50 of the canal wall

Score 3: Moderate to heavy debris covering between %50 and %75 of the canal wall

Score 4: Heavy amounts of aggregated or scattered debris over %75 of the canal wall

Score 5: Complete covering of the canal wall by debris.

Smear layer score (dentin particles, remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigant):

Score 1: Little or no smear layer; covering less than %25 of the canal wall; tubules visible and patent

Score 2: Little to moderate or patchy amounts of smear layer; covering %25 and %50 of the canal wall; many tubules visible and patent

Score 3: Moderate amounts of scattered or aggregated smear layer; covering between %50 and %75 of the canal wall; minimal tubul visibility or patency

Score 4: Heavy smear layer covering over %75 of the canal wall; minimal to no tubule visibility or patency

Score 5: A thick homogenous smear layer covering the entire canal wall.

Statistical Analysis

Data were entered into Excel sheet (Microsoft Excel 2007) and were analyzed using Statistical Package of Social Science version 20 ((IBM-SPSS Inc, Chicago, IL). Descriptive analyses were performed, and mean debris, smear layer scores were evaluated statistically using the Kruskal-Wallis test. For pairwise comparisons, Mann- Whitney U test was used. The significance level was set at 0.05.

Results

Instrumented canal walls exhibited varying amounts of remaining debris and smear layer along the entire length. The mean and standard deviation values for debris and smear layer scores are presented in Table 1.

Debris scores

For the coronal, middle and apical regions and the total debris score (Table 1), there was a significant difference between groups ($p<0.05$).

At the coronal region, the ProTaper Universal group showed the highest debris score (Fig 1-C). There was no significant difference between the ProTaper Universal and Reciproc groups ($p>0.05$) Debris scores of 1 or 2, representing a clean root canal surface in %95 of the cases at coronal thirds of the root canal for Wave One Group (Fig 3-C). None of the samples in all groups were characterized as having a debris score of 4 or 5 at coronal thirds of the root canal. ProTaper Next, WaveOne and Reciproc groups were not statistically different, all showed lower mean scores ($p>0.05$).

At the middle and apical regions, the ProTaper Universal and ProTaper Next groups showed the highest mean (Fig 1-2, A-B).

Debris scores of 4, representing the incomplete debris removal in %95 of the cases at apical thirds of the root canal for ProTaper Universal and ProTaper Next groups (Fig 1-2, A). Debris scores of 1 or 2 in %90 of the cases at apical thirds of the root canals for

WaveOne Group (Fig 3-A). There was no significant difference between WaveOne and Reciproc groups, all showed lower mean scores (p>0.05).

A comparison between root regions in the ProTaper Universal and ProTaper Next groups showed the coronal region had the lowest mean score, and the apical region showed the highest mean score. Although there was a noticeable different in Wave One group, there was no significant difference between coronal, middle and apical region for the WaveOne and Reciproc groups (p>0.05) (Fig 3-4).

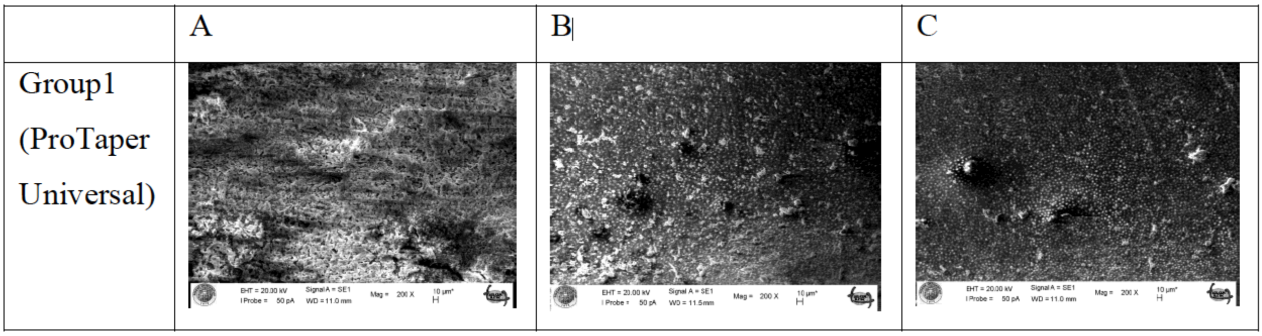

Figure 1. Scanning electron microscopic photomicrographs representative of debris in Group 1 (ProTaper Universal) **A)** Apical, **B)** Middle, **C)** Coronal at 200x magnification.

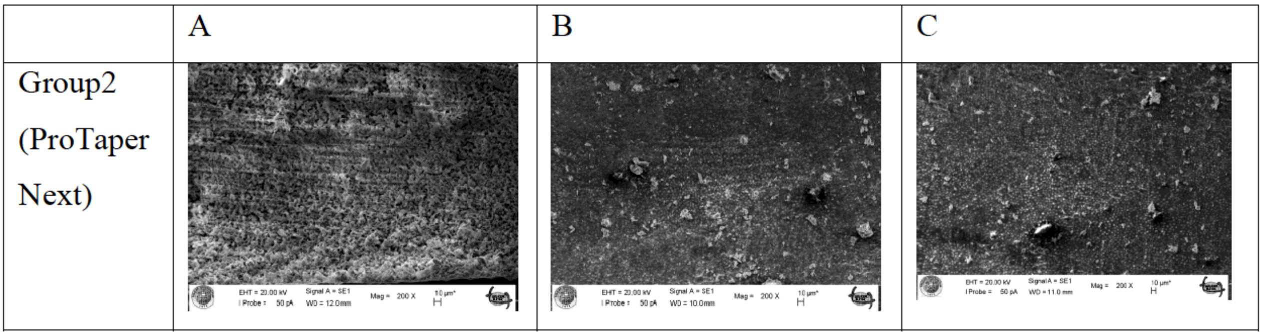

Figure 2. Scanning electron microscopic photomicrographs representative of debris in Group 2 (ProTaper Next) **A)** Apical, **B)** Middle, **C)** Coronal at 200x magnification.

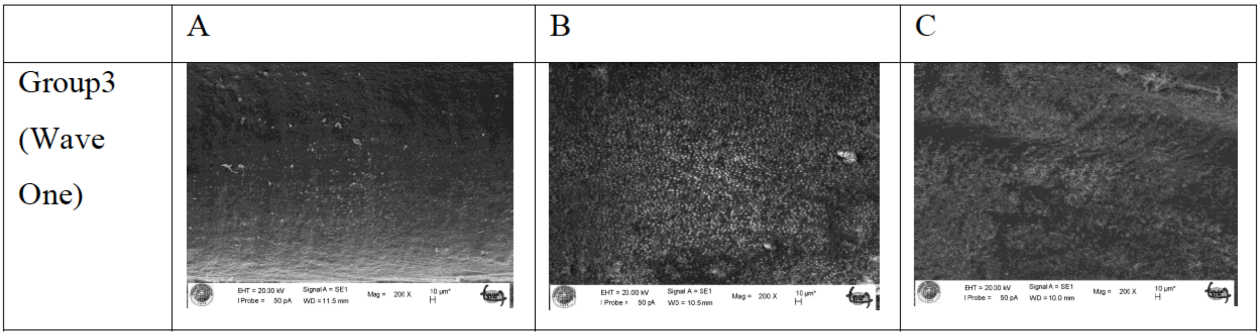

Figure 3. Scanning electron microscopic photomicrographs representative of debris in Group 3 (WaveOne) **A)** Apical, **B)** Middle, **C)** Coronal at 200x magnification.

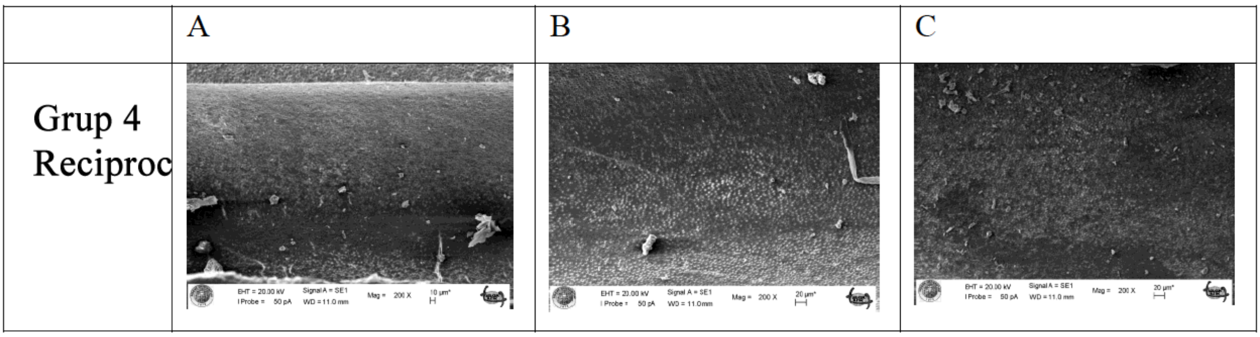

Figure 4. Scanning electron microscopic photomicrographs representative of debris in Group 4 (Reciproc) **A)** Apical, **B)** Middle, **C)** Coronal at 200x magnification.

Table 1: Mean debris scores (± SD)

Groups	Coronal	Middle	Apical	Mean
ProTaper Universal	2.26 ± 0.22	3.60 ± 0.32	4.16 ± 0.15	3.34 ± 0.23
ProTaper Next	1.53 ± 0.19	3.00 ± 0.37	4.46 ± 0.23	2.99 ± 0.26
WaveOne	1.26 ± 0.15	1.40 ± 0.16	1.33 ± 0.12	1.33 ± 0.14
Reciproc	1.80 ± 0.29	1.86 ± 0.27	1.80 ± 0.24	1.82 ± 0.26

Smear Layer Scores

For the coronal, middle and apical regions and the total smear layer score (Table 2), there was a significant difference between groups (p<0.05).

At the coronal region, the ProTaper Universal group showed the highest smear layer score. In ProTaper Universal Group scores of 1 or 2, representing clean canal walls in %45 of the cases at coronal thirds whereas smear layer score of 3 was reported for only %25 of the samples (Fig 5-C). In the WaveOne group showed the lowest smear layer scores, scores of 1 or 2 in all samples at coronal third for Wave One group (Fig 7-C). ProTaper Next and Reciproc groups were not statistically different.

At the middle region, the ProTaper Universal group showed the highest smear layer score. Scores of 4 representing the incomplete smear layer removal in %55 of the samples at middle thirds whereas smear layer score of 1 was reported for only %25 of the samples (Fig 5-B). Scores of 1 or 2 representing clean canal walls in %90 of the samples at middle thirds of the root canals for WaveOne group (Fig 7-B). There was no significant difference between the ProTaper Next, WaveOne and Reciproc groups, all showed lower mean score (p>0.05).

At the apical region, there was no significant difference between ProTaper Universal and ProTaper Next groups, all showed higher mean score (p>0.05) (Fig 5-6, A). Smear layer scores of 4 representing the incomplete smear layer removal in %95 of the samples at apical thirds of the root canals for both ProTaper Universal and Protaper Next groups. There was no significant difference between WaveOne and Reciproc groups, all showed lower mean score (p>0.05). Smear layer scores of 4 in %45 of the samples at apical thirds of the root canals for both WaveOne and Reciproc groups (Fig 7-8, A).

A comparison between root regions in the ProTaper Universal group showed the coronal region had the lowest mean score, and the apical region showed the highest mean score (p<0.05). In the ProTaper Next and Wave One groups showed the apical region had the highest mean score, and there was no significant difference between middle and coronal region, all showed lower mean score (p>0.05). In the Reciproc group, there was no significant difference between coronal, middle and apical region (p>0.05) (Fig 8).

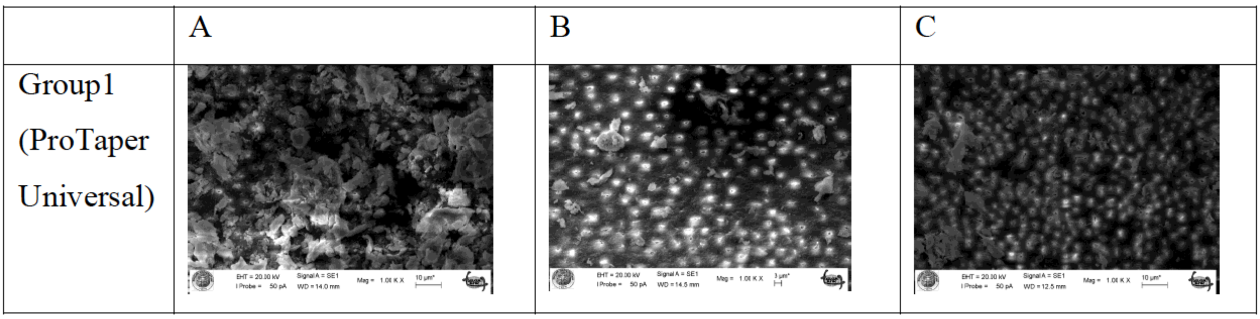

Figure 5. Scanning electron microscopic photomicrographs representative of smear layer in Group 1 (ProTaper Universal) A) Apical, B) Middle, C) Coronal at 1000x magnification.

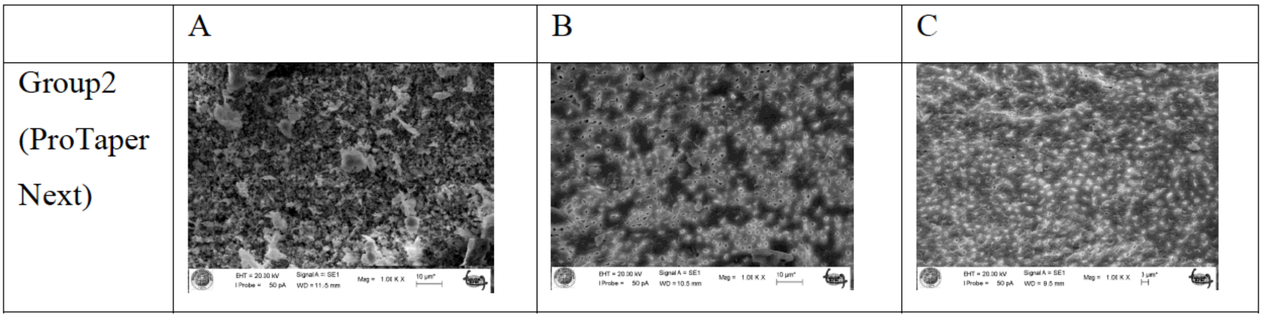

Figure 6. Scanning electron microscopic photomicrographs representative of smear layer in Group 2 (ProTaper Next) **A)** Apical, **B)** Middle, **C)** Coronal at 1000x magnification.

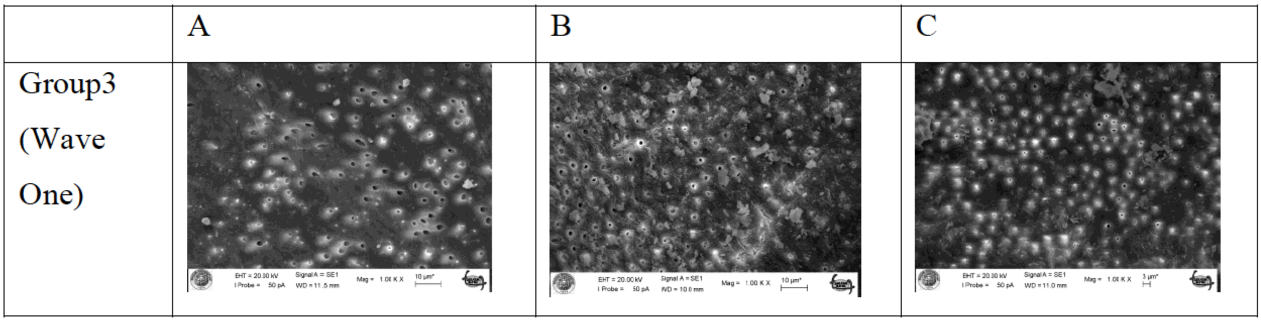

Figure 7. Scanning electron microscopic photomicrographs representative of smear layer in Group 3 (WaveOne) **A)** Apical, **B)** Middle, **C)** Coronal at 1000x magnification.

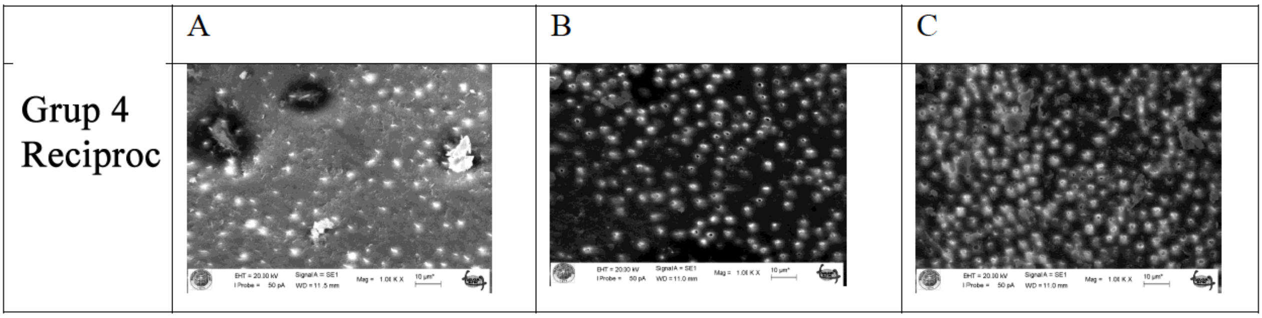

Figure 8. Scanning electron microscopic photomicrographs representative of smear layer in Group 4 (Reciproc) **A)** Apical, **B)** Middle, **C)** Coronal at 1000x magnification.

Table 2: Mean debris scores (± SD)

Groups	Coronal	Middle	Apical	Mean
ProTaper Universal	2.06 ±0.30	3.20 ± 0.41	4.80 ± 0.10	3.35 ± 0.27
ProTaper Next	1.46 ± 0.23	2.46 ± 0.41	4.66 ± 0.23	2.86 ± 0.29
WaveOne	1.20 ± 0.10	1.40 ± 0.16	2.80 ± 0.36	1.80 ± 0.20
Reciproc	2.06 ±0.30	2.13 ± 0.37	2.93 ± 0.44	2.37 ± 0.37

Discussion

The present study was conducted to evaluate the canal cleaning ability of various rotary and reciprocal endodontic files with instrumented canals under scanning electron microscopy (SEM). Human extracted teeth were used in the present study to provide conditions the same as clinical situations (21). Therefore, the teeth in all groups were studied in this study to balance with respect to the angle, apical diameter and length.

Debris and smear layer have been used as criteria in this study to evaluate the cleaning ability of the different instruments because debris includes dentine chips, residual vital or necrotic pulp tissue attached to the root canal wall that is thought to be infected in many cases (22). Debris and smear 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 disinfectant and obturated material its loosely adherent nature is a potential avenue for leakage (23). Debris and smear layer removal depends not only the irrigation method but also on the design of endodontic instrument (size, taper, cross-section, etc), the way instrument is used (rotational or reciprocal) and the method of preparation (step back or crown-down) (10, 24). Here, two reciprocal files were compared with traditionally used rotary systems (that is ProTaper file) for their canal cleaning ability and reciprocal instruments better than rotational systems for debris and smear removal. In the present study our ProTaper universal and Protaper next results similar the Jadhav's research (23).

Lateral canals and apical ramifications are most commonly present in apical third of the root. It can make these areas inaccessible to instruments (25). Complete sterility of these areas is difficult to achieve and any residual debris leftover following chemomechanical preparation leads to treatment failure (26). 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 (27). So, in the present study, more debris and smear layer were found in the apical third of the roots in all groups.

Considering the major objective of the present study, a simple irrigation protocol with only NaOCl was used, as final irrigation EDTA and saline solutions were used. %2.5 NaOCl was used as an irrigant because it has the unique capacity to dissolve necrotic tissue and organic components of the smear layer but can not dissolve its inorganic components (28). Thus, it should be emphasized that the cleaning efficiency of the instruments evaluated in the present investigation might be enhanced using a combination of NaOCl and EDTA as a chelating agent (19)

NiTi instruments have improved a lot in the last 20 years; new designs and better alloys increase the shaping ability and resistance to fracture (29, 30). New generation files have reciprocal motions, single-file, and single-use features. Protaper instruments with its convex triangular cross section and reduced radial lands are more aggressive and create more debris and smear layer (31). Protaper next file system showed better debris and smear layer removal versus to protaper, because of its offset mass of rotation which allowed two pointed contacts of a file to the canal at a time that reduced the chances of compressing the debris into the root canal wall with high canal cleaning ability (32). However, difference between Protaper and Protaper next was not statistically significant. Jadhav et al showed the same result in their study (23). In the present study, WaveOne and Reciproc groups showed better result than ProTaper groups.

SEM is a valuable method to assess the cleaning effects because of allowing evaluations of the entire section of both halves of the canal on the basis of a separate numeric evaluation scheme for debris and smear layer (23). In the present study, the cleaning efficiency was analyzed by means of an SEM-evaluation of the coronal, the middle and the apical parts of the canals (22). With all four file systems, partially un-instrumented areas with remaining debris were found in all canal sections. This finding has also been described by others (5, 19, 22, 23). In the present study, completely cleaned root canals were not found in any group. The present results confirm previous investigations that cleanliness decreased from the coronal to the apical part of the root canal (5, 19, 33).

Conclusions

Under the conditions of this study, Reciproc and Wave One instruments were more efficient in cleaning the root canal than ProTaper Universal and ProTaper Next.

Ethical Approval: This study was approved by the Institutional ethical committee for non-invasive clinical researches and human subjects or specimens (No:2014/02).

Peer-review: Externally peer-reviewed.

Author Contributions: Conception - S.İ.Y.; Design - S.İ.Y.; Supervision - H.A.A.; Materials - S.İ.Y.; Data Collection and/or Processing - S.İ.Y.., H.A.A.; Analysis and/or Interpretation - H.A.A.; Literature Review - S.İ.Y.; Writer - S.İ.Y.; Critical Review - H.A.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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