SEM Evaluation of Canal Cleanliness Following Use of ProTaper Hand-operated Rotary Instruments and Stainless Steel K-files

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Objective: *To assess debris and smear layer remaining following canal preparation with ProTaper hand-operated rotary instruments and stainless steel K-files.*
Methods: *Sixty freshly extracted single-rooted mandibular premolars due to orthodontic treatment were randomly assigned to three groups of 20 premolars each. The canals were prepared by a rotary or manual ProTaper system using a crown-down technique, or by stainless steel K-files using a step-back technique. After each instrument, the root canals were flushed with 2 ml of a 5.25% NaOCl solution and at the end of instrumentation with 2 ml of a 5.25% NaOCl and 5 ml of distilled water. The amount of debris and smear layer were evaluated at the apical, middle and coronal regions by scanning electron microscopic photomicrographs and the data were analysed separately using Walloon's test.*
Results: *In the coronal and middle thirds, both ProTaper groups achieved better results than the K-file group, and there was no significant difference between the two ProTaper groups. In the apical third, no significant difference for debris and smear layer was found among the three groups.*
Conclusion: *Under the conditions of the present study, ProTaper hand-operated and rotary instruments resulted in relatively good cleaning in the coronal and middle thirds, but there was no difference among the three instruments in the apical third.*
Key words: *canal preparation, cleanliness, nickel-titanium (NiTi), scanning electron microscope (SEM)*

Although success in root canal treatment requires thorough cleaning and shaping of the root canal system, all endodontic instruments create dentine debris and a smear layer as a consequence of their action on root canal walls[1]. It is important to develop an instrument system that produces canal walls with minimal amounts of debris and smear layer. Nickel-titanium (NiTi) instruments have become popular in root canal preparation. The ProTaper® system (Dentsply Maillefer, Switzerland) is one of the NiTi systems that is used widely. ProTaper instruments are characterised by positive rake angles, progressive blade camber and a non-cutting tip[2].

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Research on the cleaning effectiveness of ProTaper instruments has paid attention to the comparison of rotary ProTaper with other rotary systems[3]. The ProTaper system is also available as hand-operated instruments. Data on the cleaning ability of the ProTaper manual system is lacking.

The purpose of the present study was to investigate the efficiency of ProTaper rotary and hand instruments in removing debris and smear layer compared with stainless steel K-files (Dentsply Maillefer).

Materials and Methods

Selection of samples

Sixty single-rooted mandibular premolars with fully developed apices and of similar length, extracted for

orthodontic reasons, were selected. The collected teeth were cleaned and then stored in 2.5% glutaraldehyde in a phosphate buffer solution.

Conventional endodontic access cavities were prepared. Teeth with apical diameters smaller than a size 10 K-file or larger than a size 15 K-file were excluded from the study.

A size 10 K-file was inserted into the root canal and then mesiodistal and buccolingual radiographs were taken by a SIDEXIS X-ray machine. The degree of curvature was measured. Only canals whose degree of curvature ranged between 5 and 15 degrees were included. The teeth were randomly distributed into three groups of 20 teeth each. The teeth were accordingly stratified into three groups in such a manner that the average curvature of root canals in each of the groups was as close to each other as possible. The degrees of curvature were analysed statistically using a variance test. There was no significant statistical difference among the three groups ($P > 0.05$).

Root canal instrumentation

The apical foramen of each root was sealed with wax. Group A was prepared with a stainless steel K-file and a step-back technique; group B with an NiTi rotary ProTaper file and a crown-down technique; group C with an NiTi hand ProTaper file and a crown-down technique. The working length of each root canal was established 1 mm short of the apical foramen with a size 10 K-file.

Group A: stainless steel K-file

Canals were prepared from an initial size 10 K-file up to a size 40 K-file using a step-back preparation technique.

Group B: NiTi rotary ProTaper file

ProTaper instruments were used at a consistent rotation of 250 rpm, according to the manufacturer's instructions. The S1 file was first introduced to two-thirds of the canal depth, followed by the Sx file. The S1 file was then re-introduced to the full working length. The other files were inserted to the full working length in the following sequence: S2, F1 and F2.

Group C: NiTi hand ProTaper file

After exploring the root canal space with a stainless steel size 10 file, the S1 file was inserted to enlarge the coronal two-thirds of the canal. The Sx file was then introduced, but to no more than two-thirds of the canal depth. When pre-enlargement procedures were finished, a size 15 K-file was used to confirm the working length. The files were then inserted to the full working length in the following sequence: S1, S2, F1, F2 and F3.

In all instrumentation groups, the root canals were irrigated with 2 ml each of 5.25% NaOCl between each file. The final irrigation was 2 ml of 5.25% NaOCl, followed by a final rinse with 5 ml of distilled water.

SEM examination

The wax sealing the apical foramen of each root was removed, and the teeth were fixed in 10% formaldehyde. All roots were grooved longitudinally on the surfaces with a diamond disc. Each sample was then longitudinally split along the direction of the curvature with a hammer and chisel, avoiding contamination of the root canal. The two halves were fixed in 2.5% glutaraldehyde in a phosphate buffer solution (pH 7.3) for 48 hours.

The specimens were dehydrated using a series of graded ethanol solutions (70%, 85%, 95%, 100%) for 10 minutes each, critical-point dried, attached to stubs and then coated with 20 nm gold-palladium alloys. All specimens were observed with a scanning electron microscope.

Photomicrographs at ×200 magnification (for debris) and ×1000 (for smear layer score) were taken in the coronal, middle and apical thirds of the canals. Eight microscopic fields at ×200 were randomly assessed in each third of each half of the root for debris, and ten microscopic fields at ×1000 were examined for smear layer. Each field was graded according to the scoring system and the mean score for debris and smear layer were calculated for each region of each half of the root. Evaluation was performed in a blind manner by one observer who was not informed of the nature or purpose of the investigation using the following 5-point scoring system[4]. Evaluation was repeated twice for the first 20 specimens to ensure intra-examiner consistency.

Scoring system

Debris:

- Score 1: no debris was present
- Score 2: debris covering < 25% of the canal wall area
- Score 3: debris covering between 25% and 50% of the root canal wall
- Score 4: debris covering between 50% and 75% of the root canal wall
- Score 5: > 75% of the canal wall was covered with debris.

Smear layer:

- Score 1: no smear layer, dentinal tubules open
- Score 2: small amount of smear layer, most dentinal tubules open
- Score 3: homogeneous smear layer covering the root canal wall, between 50% and 80% dentinal tubules open

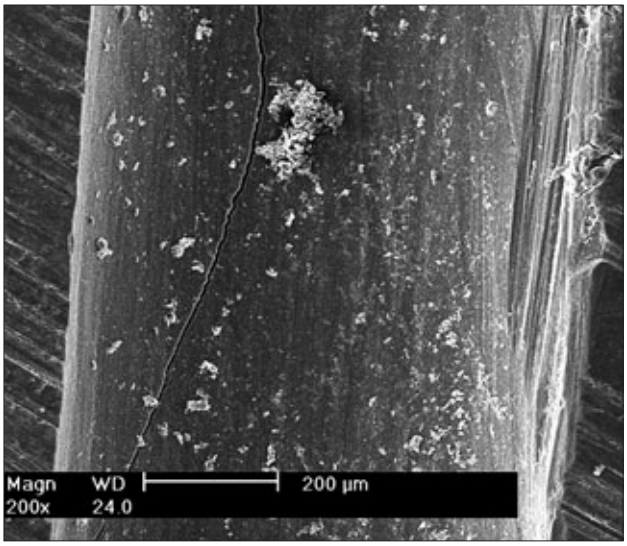

Fig 1 Scanning electron photomicrographs of middle third of root canal prepared by rotary ProTaper (×200).

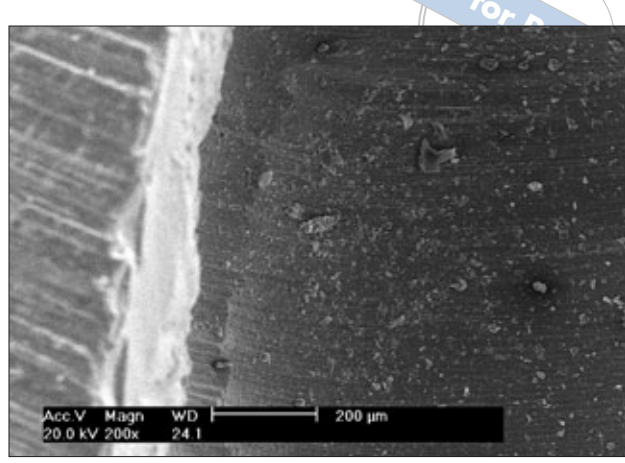

Fig 2 Scanning electron photomicrographs of middle third of root canal prepared by hand ProTaper (×200).

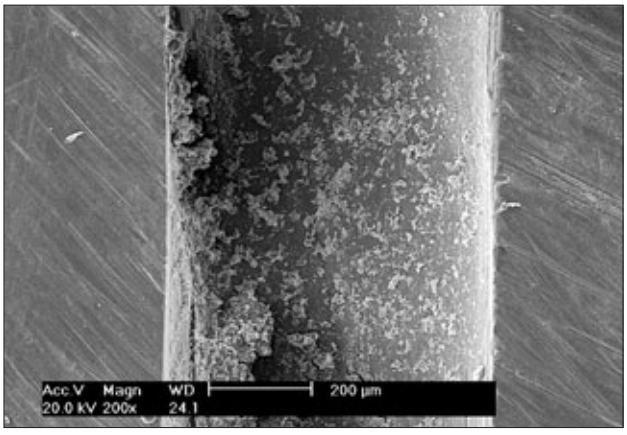

Fig 3 Scanning electron photomicrographs of middle third of root canal prepared by stainless steel K-files (×200).

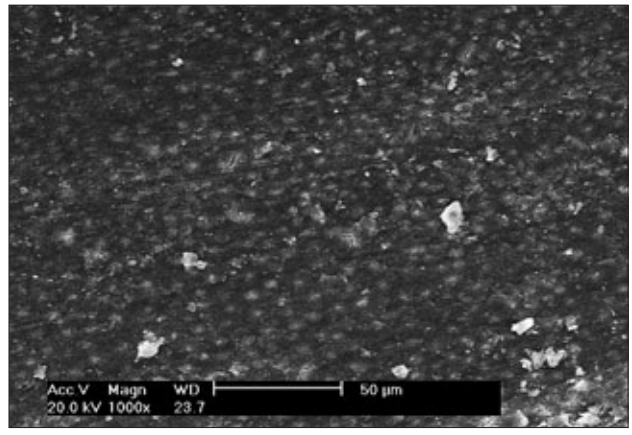

Fig 4 Scanning electron photomicrographs of middle third of root canal prepared by rotary ProTaper (×1000).

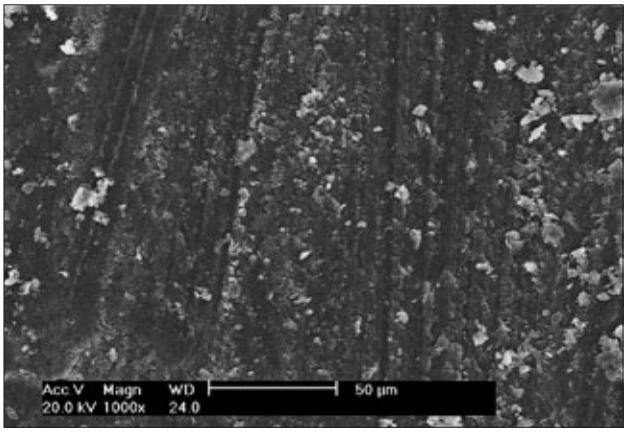

Fig 5 Scanning electron photomicrographs of middle third of root canal prepared by stainless steel K-files (×1000).

- Score 4: homogeneous smear layer covering the root canal wall, less than 50% dentinal tubules open
- Score 5: heavy, non-homogeneous smear layer covering the complete root canal wall.

Statistical analysis

Data were analysed with Walloon's test at a significance level of 0.05 using SPSS 10.0 (SPSS, Chicago, Illinois, USA).

Results

The results for the scoring of the debris and the smear layer are summarised in Table 1 and Table 2, respectively. The two ProTaper groups showed better results in the coronal and middle thirds. No smear layer but scattered

Table 1 Scores of debris in the different regions of the canals wall (n = 20)

Group	Coronal third (SD)	Middle third (SD)	Apical third (SD)
Rotary ProTaper	1.45 (0.46)	1.68 (0.21)	2.65 (0.75)
Hand ProTaper	1.50 (0.32)	1.64 (0.51)	2.74 (0.42)
SS K-file	2.92 (0.57)▲	3.04 (0.51)▲	3.14 (0.14)

▲$P < 0.05$, vs. rotary ProTaper and hand ProTaper

Table 2 Scores of smear layer in different regions of the canal wall (n = 20)

Group	Coronal third (SD)	Middle third (SD)	Apical third (SD)
Rotary ProTaper	1.38 (0.32)	1.45 (0.30)	2.49 (0.36)
Hand ProTaper	1.35 (0.22)	1.52 (0.51)	2.51 (0.22)
SS K-file	2.43 (0.57)▲	2.41 (0.51)▲	2.51 (0.21)

▲$P < 0.05$, vs. rotary ProTaper and hand ProTaper

debris could be viewed on the canal wall. The orifices of the dentinal tubules were open and visible. Statistically significant differences could be found between the K-file group and the ProTaper groups (Figs 1 to 5). There was no significant difference between the NiTi rotary ProTaper and the NiTi hand ProTaper system.

In the apical region, no system of preparation showed a statistically significant difference in either debris or smear layer.

Discussion

Cleaning and shaping was defined as the removal of all contents of the root canal system and the establishment of a specific cavity form[5]. The efficiency of the rotary ProTaper and manual ProTaper system on canal cleanliness was examined in this investigation, and compared with that of the stainless steel K-file.

Irrigation plays an important role in successful debridement and smear layer removal during root canal preparation. Sodium hypochlorite is an irrigant solution widely used because of its antibacterial properties and ability to dissolve organic tissue, but it cannot remove the inorganic smear layer. A combination of NaOCl and EDTA has been reported to be suitable for removing debris as well as smear layer[6]. However, it was recommended that a simple irrigation technique should be used when the aim of the study was to compare the cleaning effectiveness of different instruments[7], thus 5.25% NaOCl alone was used as an irrigant in the present study. It should be considered that the cleaning efficiency of the three instruments might be improved with NaOCl and EDTA.

NiTi instruments are markedly superior to stainless steel instruments in terms of elasticity and strength. They have also been found to be better than stainless steel instruments in maintaining the original anatomy and the shape and position in space of the apical foramen[8]. Among NiTi instruments, the ProTaper system is characterised by multiple and progressive taper, convex triangular cross-section and a non-cutting tip, which allows the instruments to perform smoothly, efficiently and safely[2,9]. In the present study, ProTaper files delivered a better result than K-files in the coronal and middle thirds of the canals. According to Wu and Wesselink[10], there was no difference between crown-down and step-back technique on cleaning efficacy. Thus, one reason for the present result might be the files' tapers and diameters. The ProTaper S1 and S2 files have increasingly larger tapers ranging from 2% to 11%, and 4% to 11.5%, respectively, and the final file F3 has a taper of 0.09. After preparation, the root canal diameters were adequately enlarged to a funnel shape that provided superior penetration of the irrigants. Another reason might be related to the continuously changing helical angle and blade camber (pitch), which effectively allows the blades to move debris out of the canal using an auger-like motion. There was no difference between the NiTi rotary ProTaper and the NiTi hand ProTaper system ($P > 0.05$). A reason for this might be that they share the same design features.

The cleanliness of the apical third is more important clinically than the coronal and middle parts of the canals, because the microorganisms that remain in the apical part of the canal have been considered to be the main cause of

failure[11]. However, the present results revealed no statistically significant differences among the instruments in the apical third of the canals. A similar finding could be found in Bechelli's study[12]. In fact, all hand and mechanical instrumentation methods leave debris within the canal[13]. The importance of providing the optimum cleanliness of the root canal is theoretical. Based on the results, irrigation solutions and related procedures appear to be more critical for sufficient disinfection of the root canal system[14].

References

1. Jeon IS, Spångberg LSW, Yoon TC, Kazemi RB, Kum KY. Smear layer production by 3 rotary reamers with different cutting blade design in straight root canals: a scanning electron microscopic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:601-607.
2. Berutti E, Chiandussi G, Gaviglio I, Ibba A. Comparative analysis of torsional and bending stresses in two mathematical models of nickel-titanium rotary instruments: ProTaper versus Profile. J Endod 2003;29:15-19.
3. Yang G, Wu H, Zheng Y, Zhang H, Li H, Zhou X. Scanning electron microscopic evaluation of debris and smear layer remaining following use of ProTaper and Hero Shaper instruments in combination with NaOCl and EDTA irrigation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:e63-e71.
4. Peters OA, Barbakow F. Effects of irrigation on debris and smear layer on canal walls prepared by two rotary techniques: a scanning electron microscopic study . J Endod 2000;26:6-10.
5. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;18:269-296.
6. Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. J Endod 1987;13:147-157.
7. Schafer E, Schlingemann R. Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 2003;36:208-217.
8. Schafer E. Root canal instruments for manual use: a review. Endod Dent Traumatol 1997;13:51-64.
9. Blum JY, Machtou P, Ruddle C, Micallef JP. Analysis of mechanical preparation in extracted teeth using ProTaper rotary instruments; value of the safety quotient. J Endod 2003;29:567-75.
10. Wu MK, Wesselink PR. Efficacy of three techniques in cleaning the apical portion of curved root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995; 79:492-496.
11. Nair PN, Sjogren U, Krey G, Kahnberg KE, Sundqvist G. Intraradicular bacteria and fungi in root-filled, asymptomatic human teeth with therapy-resistant periapical lesions: a long-term light and electron microscopic follow-up study. J Endod 1990;16:580-588.
12. Bechelli C, Zecchi Orlandini S, Colafranceschi M. Scanning electron microscope study on the efficacy of root canal wall debridement of hand versus Lightspeed instrumentation. Int Endod J 1999;32:484-493.
13. Cunningham WT, Martin H, Forrest WR. Evaluation of root canal debridement by the endosonic ultrasonic synergistic system. Oral Surg Oral Med Oral Pathol 1982;53:401-404.
14. Hülsmann M, Gressmann G, Schäfers F. A comparative study of root canal preparation using FlexMaster and HERO 642 rotary Ni-Ti instruments. Int Endod J 2003;36:358-366.