Influence of Root Canal Taper on Its Cleanliness: A Scanning Electron Microscopic Study

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Abstract

Introduction: Taper is a factor that determines final root canal dimensions and, consequently, the dimensions of the space for the cleaning action of irrigants. Therefore, the aim of the present study was to investigate the influence of taper on root canal cleanliness. **Methods:** Root canals of 45 mandibular incisors were divided into 3 groups and prepared with GT rotary files to apical preparation size 30 and final taper 0.04, 0.06, and 0.08, respectively. Irrigation with 2.5% NaOCl was performed after each file. The final irrigation sequence was 10 mL 17% ethylenediaminetetraacetic acid, followed by 10 mL 2.5% NaOCl and 10 mL saline solution. The presence of debris and smear layer on root canal walls was evaluated under the scanning electron microscope with the use of a 4-category scale system. **Results:** The presence of debris was minimal in all groups. Statistical analysis for the presence of smear layer showed no significant differences between the groups, whereas a significant difference was detected between the apical and middle thirds of each group. **Conclusions:** Under the conditions of this study, root canal preparation with tapers 0.04, 0.06, or 0.08 did not affect canal cleanliness. Debris removal was almost complete for all tapers, whereas smear layer was not removed, especially from the apical part of the canals. *(J Endod 2011;37:871–874)*

Key Words

Debris, EDTA, root canal preparation, root canal taper, rotary NiTi instruments, smear layer

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The research was funded by the Athens University Research Fund (code number 70/4/56.90.5782).

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0099-2399/$ - see front matter

doi:10.1016/j.joen.2011.02.025

After its mechanical preparation, root canal is a space where the irrigation fluids are placed to express their cleaning action. The dimensions of this space determine the irrigants' volume and, consequently, their efficacy. In 1965, Wandelt (1) stated that only a small and ineffective volume of a chelator can be placed in narrow root canals. In a recent study, Brunson *et al* (2) confirmed Wandelt's statement, showing that an increase in root canal dimensions leads to an increase in the mean volume of irrigant inside the canal. The clinician has the ability to alter root canal dimensions by changing the final apical preparation size and/or its taper.

In the era of ISO manufactured endodontic instruments, keeping the apical preparation as wide as possible was believed to be the only way for the irrigation fluids to reach and reduce the microbial population from the critical apical 3 mm of the root canal, thus increasing its cleanliness (3–7). Today, the manufacturers of nickel-titanium rotary systems believe that apical preparation should be kept as narrow as possible while increasing root canal taper. This decreases the preparation errors and makes root canal obturation easier and more efficient, but it also creates a greater deposit for the irrigation fluids and at the same time leads to cutting a larger amount of dentin from the canal walls, thus producing a cleaner root canal (8). Although this hypothesis seems reasonable, it has little scientific evidence; it is not yet proven whether an increase in taper leads to cleaner root canals. In a recent study, Brunson *et al* (2) showed that the increase in apical preparation size and taper leads to an increase in mean irrigant volume inside the canal. However, these investigators did not study the effect of increased irrigant volume on root canal cleanliness. Therefore, the purpose of the present study was to investigate the influence of taper on root canal cleanliness, which was assessed by the presence of debris and smear layer in the middle and apical thirds of canals prepared with 3 different tapers. The null hypothesis was that the increase in taper does not affect root canal cleanliness.

Materials and Methods

Forty-five freshly-extracted mandibular incisors stored in 10% formalin were used for this study. Before preparation, all teeth were radiographed in buccolingual direction to ensure they had 1 straight root canal. The teeth were cut perpendicularly to their long axis by using a diamond disk 10 mm from the root tip. Patency of the root canals was ensured by using #10 K-file (Dentsply/Maillefer, Ballaigues, Switzerland). Finally, a small amount of Carbowax (Dow Chemical Co, Midland, MI) was placed on each root tip.

The roots were randomly divided into 3 experimental groups (n = 15). Root canal instrumentation was performed with GT rotary files Series 20 and 30 (Dentsply/Maillefer), placed in the handpiece of an Endo IT motor (Aseptico, Woodinville, WA) with programmed torque control and speed settings. Different protocols were used in a way that final root canal taper was 0.04, 0.06, and 0.08 for groups A, B, and C, respectively. Working length was 9 mm. The instrumentation details were as follows.

In group A (taper 0.04), GT files Series 30 were used in a crown-down manner. Files 30/0.10, 30/0.08, and 30/0.06 were placed 2, 5, and 7 mm inside the canal, respectively, and file 30/0.04 at working length. In g roup B (taper 0.06), root canals were instrumented as in group A, and at the end of preparation, files 20/0.08 and 30/0.06 were placed at working length. In g roup C (taper 0.08), root canals were instrumented as in group B, and at the end of preparation, files 20/0.10 and 30/0.08 were placed at working length.

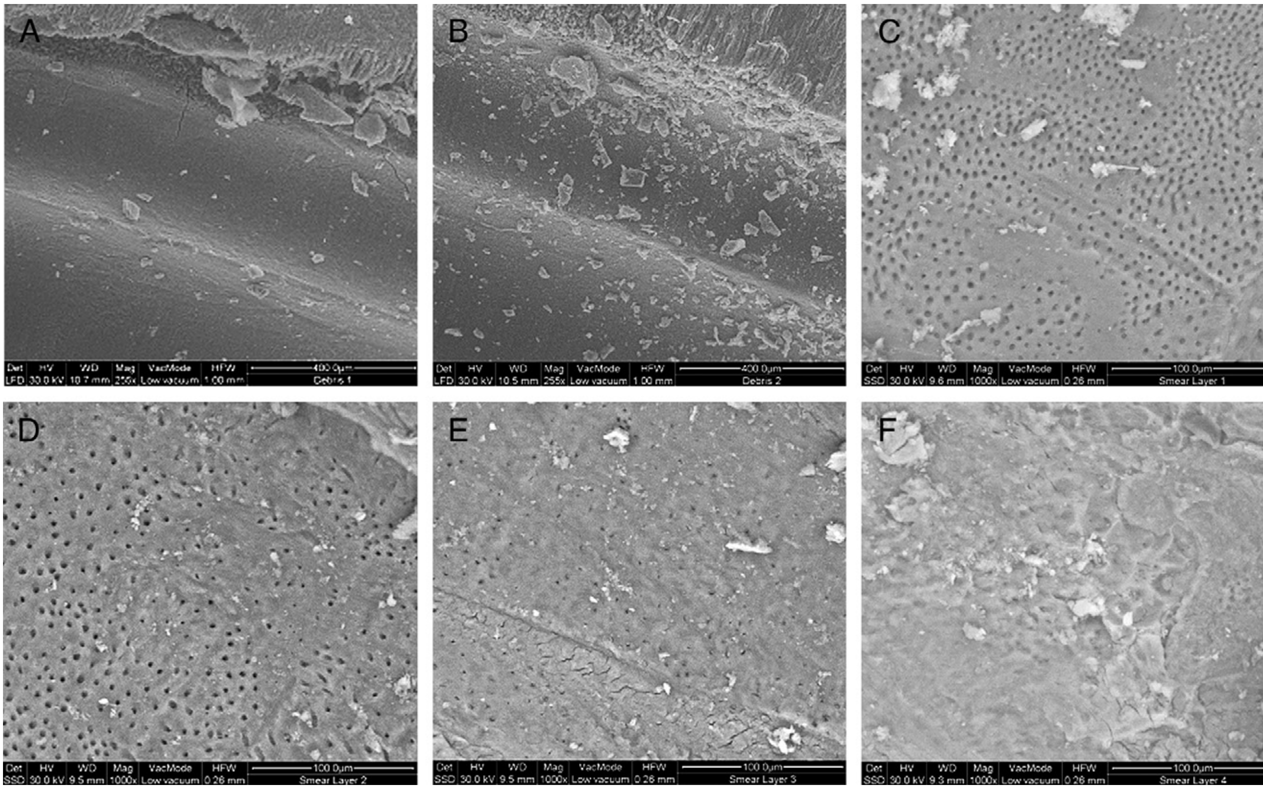

Figure 1. Representative scanning electron microscopy photos of debris and smear layer scores. (*A*) Debris score 1; (*B*) debris score 2; (*C*) smear layer score 1; (*D*) smear layer score 2; (*E*) smear layer score 3; (*F*) smear layer score 4. No representative photos of debris scores 3 and 4 were taken because no root canal surface covered by debris more than 50% was found. This was explained to the examiners before scoring.

Between every file change, patency at working length was confirmed by using #10 K-file, and the canals were irrigated with 2.5% NaOCl. Irrigation was performed with a 27-gauge blind-ended endodontic irrigation needle (Hawe Max-I-probe; Kerr-Hawe, Bioggio, Switzerland). The volume of irrigant flushed after each file was 3 mL for group A, 2 mL for group B, and 1.5 mL for group C. The final irrigation sequence was 10 mL of 17% EDTA (Vista Dental Products, Racine, WI) for 3 minutes, followed by 10 mL of 2.5% NaOCl and 10 mL saline solution. The total amount of irrigants used in each canal was 42 mL.

After instrumentation the roots were split longitudinally with a diamond disk in a buccolingual direction. The presence of debris and smear layer was evaluated by scanning electron microscopy at 255× and 1000× magnification, respectively. A 4-category scale system was used for debris and smear layer as follows: score 1, presence of debris/smear layer that covers 0%–25% of the surface examined; score 2, presence of debris/smear layer that covers 25%–50% of the surface examined; score 3, presence of debris/smear layer that covers 50%–75% of the surface examined; and score 4, presence of debris/smear layer that covers 75%–100% of the surface examined.

Representative photos of each score taken in a pilot study were given to the examiners before scoring (Fig. 1).

The scoring procedure was performed by 3 examiners and was double-blinded. First, the apical end of preparation was found at low magnification, and then every millimeter of the apical (0–3 mm) and middle (4–6 mm) thirds of the root canal wall was scanned at 255× and 1000× magnification and scored.

Statistical analysis with the nonparametric Kruskal-Wallis test was performed to detect any statistical differences in the presence of debris and smear layer between the 3 groups. In addition, the nonparametric Friedman test was used to assess the differences between the apical and middle thirds of the root canals of each group. The level of significance was set at $P \leq .05$.

Results

Debris

The presence of debris in the apical and middle thirds of the root canals was found to be minimal, with a mean score of 1.1 for all groups. For this reason, debris was excluded from the statistical analysis.

Smear Layer

Mean scores for the presence of smear layer in groups A, B, and C are shown in Table 1. No statistically significant differences could be found between the groups. However, a statistically significant difference between the apical and the middle thirds was detected in all groups, with the former showing the worst results (Table 2).

Discussion

The objective of the present study was to evaluate the influence of taper on root canal cleanliness. To achieve this, the canals studied should have the same apical preparation size but different tapers. Therefore, the experimental protocol for the use of System GT files was

TABLE 1. Mean Scores for the Presence of Smear Layer

	Group A	Group B	Group C
Mean score ± standard error	3.3 ± 0.14	3.2 ± 0.2	3.08 ± 0.17

No statistically significant differences were found between the groups ($P > .05$).

TABLE 2. Mean Scores for Presence of Smear Layer in Middle and Apical Thirds of the Root Canals

	Group A	Group B	Group C
Mean score ± standard error			
Apical third	3.81 ± 0.08	3.44 ± 0.22	3.55 ± 0.10
Middle third	2.84 ± 0.25	2.86 ± 0.25	2.64 ± 0.28

There was a statistically significant difference between apical and middle thirds in all groups ($P \leq .05$).

designed in a way that at the end of preparation, the apical and middle thirds of the canals had a constant taper of 0.04, 0.06, or 0.08 mm/mm. In all groups, the last GT file gave its taper to the middle and apical thirds of the canals, because its flute diameters were greater than those of the former file placed at working length.

Irrigation was another factor that was controlled, because it affects root canal cleanliness. The total volume of irrigants in each tooth was 42 mL. Because the number of instrument changes differed between groups, this was achieved by flushing a different volume of irrigant after every instrument in each group. In this way, the only variable was the frequency of irrigation. However, the influence of this factor on root canal cleanliness has not yet been studied thoroughly. A pertinent study showed that the number of instrument changes and, consequently, the frequency of irrigation did not contribute to the efficacy of debridement (9).

The first finding of our study was that root canal taper did not affect its debridement. This result can be compared with those of some previous studies. Lee *et al* (10) and van der Sluis *et al* (11) prepared root canals with GT files Series 20 and studied the influence of root canal taper on debris removal. According to their results, the increase in taper led to better debridement. Albrecht *et al* (12) reported that when canals were prepared with GT files size 20, the increase in taper led to better debridement, whereas when the apical preparation size was 40, taper had no influence on debris removal. It was concluded that root canal debridement is mainly affected by final instrument size and to a lesser extent by canal taper. The influence of final instrument size on root canal cleanliness was also studied by Usman *et al* (9), who reported that root canal instrumentation with GT file 40/0.06 led to significantly better debris removal than with GT file 20/0.06. In our study, root canals were prepared with GT files size 30, and no statistically significant differences were found between groups of different taper. If this result is combined with the above findings, we could conclude that root canal taper can affect its debridement only when final instrument size is smaller than 30. However, this conclusion needs further investigation.

Our second finding was that root canal taper did not influence smear layer removal. This result cannot be confirmed, because studies regarding the influence of taper on root canal cleanliness do not deal with smear layer removal (9–12). Our study was based on early findings by Wandelt (1), according to which the effectiveness of a chelator is very much dependent on root canal's width. We made the hypothesis that the increase in taper would lead to an increase in the volume of the chelator, making it more effective in smear layer removal. Although this was not confirmed by our findings, it is an issue that requires further investigation.

In each group, a statistically significant difference in the presence of smear layer was found between the apical and middle thirds of the canals. This is in accordance with the results of most studies regarding smear layer removal (13–18). This finding seems reasonable, because the apical is the narrowest part of the canals.

To further study the dimensions of this narrowest part, we considered that after their mechanical preparation, the apical third of the canals was a truncated cone, which for all groups had a standard height of 3 mm and a small base diameter of 0.30 mm (the same as the tip diameter of a GT file Series 30), but it differed in its large base diameter, which was 0.42, 0.48, and 0.54 mm for tapers 0.04 mm/mm, 0.06 mm/mm, and 0.08 mm/mm, respectively. According to the formulas for the calculation of the surface area and the volume of the truncated cone, the apical dentin surface was 3.4 mm^2 for group A, 3.7 mm^2 for group B, and 4 mm^2 for group C, whereas the volume of the apical third was 0.0003, 0.00037, and 0.00041 mL for groups A, B, and C, respectively. However, according to early findings by Fraser (19), 2 mL of ethylenediaminetetraacetic acid is needed to decalcify a dentinal surface area as small as 0.35 mm^2. Consequently, the volume-to-surface ratio in our study was extremely low for the chelator to be effective in smear layer removal.

Finally, root canal cleanliness can also be assessed by the presence of bacteria after chemomechanical preparation. Because an increase in taper leads to cutting a greater amount of dentin from the canal walls, it would be interesting to repeat the present study to investigate the influence of taper on root canal's bacteriologic population before and after chemomechanical preparation.

Conclusions

Under the conditions of the present study, root canal preparation to apical size 30 and tapers 0.04, 0.06, or 0.08 did not affect canal cleanliness. The removal of debris was almost complete for all tapers, whereas smear layer was not completely removed in any of the groups, with no statistically significant differences between them ($P > .05$). In all groups, the middle third was the cleanest part of the canal, with a statistically significant difference from the apical third ($P \leq .05$).

Acknowledgments

This article was adapted from a thesis submitted by Dr Ioanna S. Arvaniti in partial fulfillment of the requirements for the MS degree in Endodontics at University of Athens School of Dentistry.

We acknowledge Dr Konstantinos Kalogeropoulos for his assistance in scoring the root canals under the SEM.

The authors deny any conflicts of interest related to this study.

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