Original Article

Effect of Master Apical File Size and Taper on Irrigation and Cleaning of the Apical Third of Curved Canals

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Abstract

Objective: Canal preparation generates a substantial amount of debris and smear layer (SL). The size and taper of the Master Apical File (MAF) affects on penetration of irrigants and subsequently canal cleaning efficacy.
The aim of this study was to evaluate the effect of MAF size and taper on penetration of irrigants to the apical third of curved mesiobuccal (MB) canals of mandibular first molars.
Materials and Methods: Eighty-nine human mandibular first molars were divided into one control group (n=5) without rotary instrumentation and 6 experimental groups (n=14 each) that were prepared with the following RaCe rotary files as MAF: 25.04 (group1), 25.06 (group 2), 30.04 (group 3), 30.06 (group 4), 35.04 (group 5) and 35.06 (group 6). All the experimental groups were rinsed with 2 ml of 17 % EDTA followed by 2 ml of 5.25% NaOCl. Debridement of the MB canals was evaluated using scanning electron microscope (SEM). The data were statistically analyzed using Kruskal-Wallis and Mann-Whitney U tests ($P<0.05$).
Results: Group 6 (MAF=35.06) showed 100% acceptable debridement. This rate was 92.9% for MAF=35.04. In group 4 (MAF=30.06) smear layer (SL) was removed in the three-forth of the samples and debris was removed in 92.9% of them. Acceptable debridement was not achieved in most samples of groups 1 and 2 (25.04 and 25.06, respectively) and the mentioned two groups had statistically significant difference in this respect with the other groups ($P<0.05$).
Conclusion: Based on this study, 30.06 may be considered as the minimum MAF size for acceptable debridement.
Key words: Canal curvature; Debris; Irrigants; Smear layer; Size; Taper

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INTRODUCTION

Successful endodontic therapy requires cleaning and shaping of the root canal system [1]. This procedure is performed using root canal instruments and irrigating solutions [2]. Mechanical preparation with either manual or rotary instrumentations generates a substantial amount of debris and smear layer SL [3].

The SL contains remnants of ground dentin, pulp tissue and odontoblastic processes as well as microbes and bacteria in infected teeth [4]. Despite the controversies regarding SL [5, 6], most clinicians have concluded that the presence of SL contributes to leakage and compromises the seal of root canal filling. It is also a source of nutrients for microorganisms [7, 8]. Currently, a final irrigation sequence with a chelating agent, such as EDTA and NaOCl is recommended to remove the inorganic as well as organic components of the SL [9]. Salzgeber and Brilliant reported that SL and debris removal is less predictable in the apical region as compared with the coronal and middle third of the root [10]. This could be attributed to comparatively smaller apical canal dimensions hindering the penetration of irrigants and resulting in limited contact between canal walls and the irrigants [11] .Bronnec et al [12] reported that improved shaping of the root canals enhanced the flow of irrigants. On the other hand, minimal apical enlargement has been suggested to conserve tooth structure and limit extrusion of filling materials [13].

The extent of apical enlargement, however, has been a matter of debate. A common recommendation is to enlarge the root canal to at least three sizes beyond the initial file [14]. Effects of various sizes and tapers including 20.10 [14], 30.04 [15], 30.06 [16], or 40.04 [17] on debridement of apical debris have been evaluated and reported. The purpose of this study was to evaluate the cleaning efficacy of different sizes and tapers of the MAF for penetration of irrigants to the apical third of curved MB canals of mandibular first molars.

MATERIALS AND METHODS

Sample Collection

One-hundred and eighty-five extracted human mandibular first molars (due to periodontal disease) were collected. The teeth were decontaminated by immersion in 5.25% NaOCl for 1h. After obtaining periapical radiographs, all teeth with external or internal root resorption, open apices, visible cracks, fractures, caries, calcification and previous root canal treatment were excluded.

After preparing the access cavity, presence of the two separate mesial canals was confirmed and patency of MB canal was established by gently inserting a size 10 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) until the tip emerged from the apical foramen. The working length (WL) was calculated by subtracting 1 mm from this length. Any root with an apical foramen placed laterally or an apical constriction diameter wider than a size 15 file was excluded. Degree of curvature was determined for the MB canal according to Schneider [18] (using parallel radiograph in bucco-lingual and mesiodistal directions). Only canals with curvatures of 20º-35º were included. The remaining 89 teeth were decoronated to a standardized root length of 18 mm, with a WL of 17 mm.

Root Canal Instrumentation

After coding the teeth, all the samples were instrumented up to size 20 K-file to the WL; then 5 samples were randomly (simple randomization method) selected as the control group without rotary instrumentation. The remaining teeth were divided into 6 experimental groups of 14. The canals were instrumented passively using RaCe rotary files (FKG, Dentaire, La-Chaux-de-Fonds, Switzerland) and motor controller device (X-SMART, Dentsply, Maillefer, Ballaigues, Switzerland) according to the manufacturer's instructions in the following sequence:

- Coronal pre-flaring for all the samples: 40.10, 35.08 and 30.06, respectively
- Group 1: **25.04**
- Group 2: 25.04 , **25.06**
- Group 3: 25.04, **30.04**
- Group 4: 25.04, 30.04 and **30.06**
- Group 5: 25.04 ,30.04 and **35.04**
- Group 6: 25.04, 30.04, 35.04 and **35.06**

In each group the last instrument was considered the MAF.

A second-year endodontic postgraduate student prepared the canals. Each rotary instrument was used for preparation of five canals and applied for 5s to the WL with an anti-curvature filing method.

After each rotary file, the canal was rinsed with 2ml of 1% NaOCl, delivered by 28-guage needles (Max I-probe, Franklin Park, IL, USA) inserted deeply and passively from coronal to middle third at the end of coronal pre-flaring.

During the apical preparation sequence, the needle penetrated within the apical 3mm. Finally the specimens were rinsed with 2 ml of 17 % EDTA followed by 2 ml of 5.25% NaOCl each for 60s. In controls only 5 ml of normal saline was used. Final flushing with 5 ml of distilled water was done to eliminate the irrigation solutions from the canals.

Root Sectioning and SEM Evaluation

A groove on each of the buccal and lingual aspects of the mesial root was prepared with no entrance into the canal space. The roots were split longitudinally in a buccolingual direction, resulting in 28 samples in each experimental group and 10 control samples.

In addition, two grooves were prepared in the apical 5mm on the mesial and distal walls. The samples were placed in 2% gluteraldehyde for 24 hours and then rinsed 3 times with a sodium cacodylate buffered solution (0.1 M, pH 7.2). After incubation in osmium tetroxide for 1 h, the samples were desiccated with ascending concentrations of ethyl alcohol (30-100%), placed in a desiccator for 24 hours and mounted on a metallic stub. After coating the samples with 20µ of gold, the technician who was blind to the samples provided the SEM photomicrographs using backscatter mode (XL30, Philips, Holland, X2000 and X5000). The amount of debris and SL at the apical third of both root halves of each sample was separately scored according to Schäfer and Schlingemann (Table 1) [19]. Scores 1 and 2 represented acceptable debridement; scores 3, 4 and 5 represented unacceptable debridement. This process was performed by two endodontists who were blinded in relation to the samples. In situation of lack of agreement between the two observers, a third endodontist scored the samples to obtain at least two similar scores out of three. All of the observers were trained to obtain sufficient inter- and intra- observer agreement [20].The scored sections of the canals were selected by chance.

Table1. Scores for *SL* and *debris* removal (Schäfer and Schlingemann classification)

Scores	Smear Layer	Debris
1	No SL, orifices of the dentinal tubules patent	Clean canal wall, only very few debris particles
2	Small amount of SL, some open dentinal tubules	Many conglomerations
3	Homogeneous SL along almost the entire canal wall, with only very few open dentinal tubules;	Many conglomerations, less than 50% of the canal wall covered;
4	The entire root-canal wall covered with a homogeneous SL, with no open dentinal tubules;	More than 50% of the canal wall covered;
5	A thick homogeneous SL covering the entire root-canal wall	Complete or nearly complete covering of the canal wall by debris

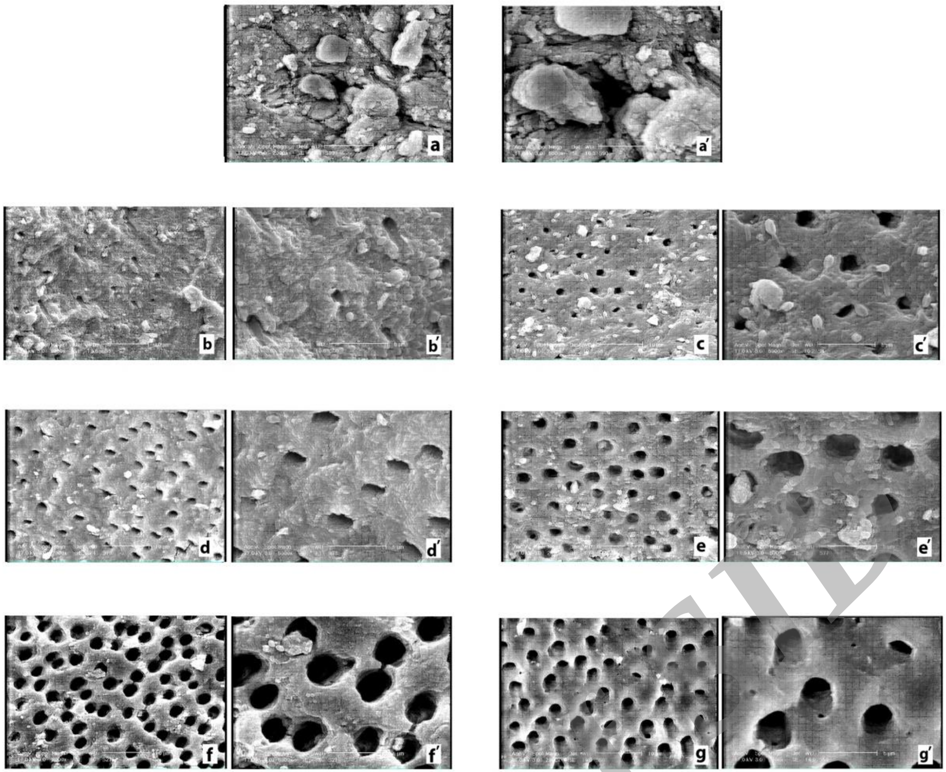

Fig1. SEM photomicrographs of the apical third of canals (×2000 & ×5000). (a,a') control group, (b,b') 25.04, (c,c') 25.06, (d,d') 30.04, (e,e') 30.06, (f,f') 35.04, (g,g') 35.06.

Statistical Analysis

Statistical analysis was performed using the Kruskal-Wallis test among all the groups. Mann-Whitney U test was used for pairwise comparisons at 95% confidence interval and P=0.05. Also, for stabilizing the error type one equal to 0.05, the amount of the P-value was adjusted for each of the multiple comparisons by the Bonferroni method.

RESULTS

The results showed statistically significant differences in the amount of SL and debris among the groups (P<0.01, Table 1). All the specimens in the control group were covered with SL and debris and received a score of 5 (Figures1a and a'). The group of MAF=25.04 showed 14.2% acceptable debridement for debris and no SL removal (Figures 1b and b').

Table 2. Evaluation of debris and SL in the groups(n=5 for control group and n=14 for each of the experiment groups).

Debridement Groups	Debris					Smear Layer				
	Acceptable		Unacceptable			Acceptable		Unacceptable		
	1	2	3	4	5	1	2	3	4	5
Control	0	0	0	0	100	0	0	0	0	100
25 (0.04)	7.1	7.1	7.1	35.8	42.9	0	0	21.4	28.6	50
25 (0.06)	0	14.3	50	21.4	14.3	0	14.3	57.1	14.3	14.3
30 (0.04)	7.1	71.5	21.4	0	0	7.1	35.8	57.1	0	0
30 (0.06)	35.8	57.1	7.1	0	0	28.6	42.8	28.6	0	0
35 (0.04)	42.9	50	7.1	0	0	57.1	35.8	7.1	0	
35(0.06)	57.1	42.9	0	0	0	57.1	42.9	0	0	

The group of MAF=25.06 showed 14.3 % acceptable debridement for both SL and debris removal (Figures 1c and c'). The samples in groups 3 and 4 (30.04 and 30.06, respectively) showed 42.9% and 71.4% acceptable debridement for SL respectively; however these rates were 78.6% and 92.9%, respectively for debris removal (Figures 1 d, d', e and e'). In group 5 (35.04), 92.9% of samples showed acceptable debridement (Figures 1f and f'). The group 6 (35.06) showed 100% acceptable debridement (Figures 1g and g'). Comparisons between each of the two groups using Mann-Whitney U test showed the following statistically significant differences:

25.04 and 25.06 groups with each of the 30.04, 30.06, 35.04 and 35.06 groups (SL and debris removal)

30.04 group with each of the 30.06, 35.04 and 35.06 groups (SL)

There was no significant difference between 25.04 and 25.06 in SL and debris removal.

No deformity or separation of rotary files, and no occurrence of apical perforations were seen during this study.

DISCUSSION

Results of this study showed significant differences between groups 25.04 and 25.06 with the other groups. There were no significant differences between each of the 30.06, 35.04 and 35.06 groups. These groups showed acceptable debridement. Our findings showed that increased size and taper of MAF at WL improved debris and SL removal. One possible explanation is that the increased size/taper allowed for deeper penetration of irrigation, increased volume of irrigant solution and improved flushing of debris. This is in agreement with the studies that have found cleaner canals with larger apical preparations [20, 21].

In the present study, MB canals of mandibular first molars with a similar root curvature (20˚-35˚) were prepared using RaCe rotary files. Mohammadzadeh Akhlaghi et al. [22] used the same curvature with RaCe rotary files.

Paqué et al. [23] reported that RaCe instruments maintain the original direction of curved root canals, retain canal centering and allow preparation to larger sizes. Some studies [14, 21] showed that endodontic errors occurred in narrow and curved canals; whereas Khademi et al. [16] used curvatures of 15˚ to 25˚ and Flexmaster rotary files. Some others did not consider the curvature and used straight files in single roots [15, 17]. Arvaniti and Khabbaz [15] showed that there was significant difference in presence of SL between apical and middle thirds of teeth. Schäfer and Schlingemann [19] reported that debridement of the apical third of the canals was less than the middle and coronal thirds; therefore the apical third of MB canals was evaluated in our study. Previous studies [10, 17, 24] have shown that the volume of irrigant had an influence on debridement of the root canal and the effectiveness of irrigation was a function of the depth of needle.

In our study a flexible needle (28 gauge) was used. SEM has been widely used at different magnifications to score debris and the SL after instrumentation [25-27]. The advantages of this particular type of study have been reported by different investigators [21, 28, 29]. High magnifications can limit the observed field [29]. In accordance with previous studies [19, 30, 31], a five-score index and magnifications of X2000 and X5000 were used in our study because these magnifications offered a detailed image of the canal walls. The issue of apical enlargement size is still a matter of debate. By means of SEM, the cleaning efficacy of curved root canals after chemo-mechanical instrumentation with various sizes and tapers of MAF was compared in our study. Khademi et al [16] also showed that MAF # 30.06 was effective for the removal of debris and SL from the apical portion of root canals. On the other hand, instrumentation to 30.06 caused less dentin removal and decreased the risk of errors like transportation, ledge formation, instrument separation and perforation [14, 32].

Akhlaghi et al. [33] showed that V Taper # 30.10 maintained the canal centering and minimum root thickness in the apical part of curved canals. Brunson et al [17] reported that root canal preparation by using K3 rotary instruments to size 40.04 will allow for tooth structure preservation and maximum volume of irrigation at the apical third of single-rooted teeth when using the apical negative pressure irrigation system. Wu and Wesselink [21] have recommended enlarging the canals to sizes over # 40 file to remove more debris from the canals and achieve better cleaning in the apical thirds of the root canals. Albrecht et al. [14] instrumented the canals with various tapers of ProFile GT files and observed a significantly greater percentage of remaining debris in the apical areas of the canals enlarged to the size 20 compared to 40 in the .04, .06 and .08 taper categories; however when the taper was increased to .10 no significant difference was found between the sizes 20 and 40. Although the results showed that increasing the taper from .04 to .06 in file #30 led to more SL removal, it caused no statistical significance in debris removal. This finding is supported by Arvaniti and Khabbaz [15] who reported that root canal taper can affect debridement only when the final instrument size was smaller than 30. According to the present and some previous studies, file 30.06 may be considered as the minimum size for acceptable debridement. It seems that further investigations are required to evaluate the effect of various sizes and wider tapers from .02 to .10 on SL and debris removal.

CONCLUSION

Under the conditions of the present study, although a complete and ideal debridement was achieved in 35.04 and 35.06 groups, , maintaining the minimum root thickness and increasing the risk of apical transportation should be considered in curved canals. The minimum appropriate and acceptable debridement was achieved with MAF=30.06 in the curved canals.

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REFERENCES

1- Hales JJ, Jackson CR, Everett AP, Moore S. Treatment protocol for the management of a sodium hypochlorite accident during endodontic therapy. Gen Dent 2001;49:278-81.

2- Lumley PJ. Cleaning efficacy of two apical preparation regimens following shaping with hand files of greater taper. Int Endod J 2000;33(3):262-5.

3- Jeon IS, Spangberg LSW, Yoon TC, Kazemi RB, Kum KY. Smear layer production by 3 rotary reamers with different cutting blade designs in straight root canals:a scanning electron microscopic study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:601-7.

4- Dotto SR , Travassos RM, de Oliveira EP, Machado ME, Martins JL. Evaluation of ethylenediaminetetraacetic acid (EDTA) solution and gel for smear layer removal. Aust Endod J 2007;33(2)62-5.

5- Wauters T, Wauters J. [Should the dentin smear layer be preserved or eliminated?(Review of the literature)]. Rev Belge Med Dent 2000;55(2):93-103.

6- Hata G, Hayami S, Weine FS, Toda T. Effectiveness of oxidative potential water as a root canal irrigant. Int Endod J 2001;34(4):308-17.

7- Zand V, Bidar M, Ghaziani P. A comparative SEM investigation of the smear layer following preparation of root canals using nickel titanium rotary and hand instruments. J Oral Sci 2007;49:47-52.

8- Lui JN, Kuah HG ,Chen NN. Effect of EDTA with and without surfactants or ultrasonics on removal of smear layer. J Endod 2007;33(4):472-5.
9- Zehnder M. Root canal irrigants. J Endod 2006;32(5):389-98.
10- Salzgeber RM, Brilliant JD. An in vivo evaluation of the penetration of an irrigating solution in root canals. J Endod 1977;3:394-8.
11- Senia ES, Marshall FJ, Rosen S. The solvent action of sodium hypochlorite on pulp tissue of extracted teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1971;31:96-103.
12- Bronnec F , Bouillaguet S, Machtou P. Ex vivo assessment of irrigant penetration and renewal during the cleaning and shaping of root canals: a digital subtraction radiographic study. Int Endod J 2010;43:275-82.
13- Buchanan LS. The standardized –taper root canal preparation-Part 3.GT file technique in large root canals with small apical diameters. Int Endod J 2001;34:149-56.
14- Albrecht LJ, Baumgartner JC, Marshall JG. Evaluation of apical debris removal using various sizes and tapers of profile GT files. J Endod 2004;30(6)425-8.
15- Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: a scanning electron microscopic study. J Endod 2011;37(6):871-4.
16- Khademi A, Yazdizadeh M, Feizianfard M. Determination of the minimum instrumentation Size for penetration of irrigants to the apical third of root canal systems. J Endod 2006;32(5):417-20.
17- Brunson M, Heilborn C, Johnson D, Cohenca N. Effect of apical preparation size and preparation taper on irrigant volume delivered by using negative pressure irrigation system. J Endod 2010;36(4):721-4.
18- Schneider SW. A Comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1971;32:271-5.
19- Schäfer E, Schlingemann R, . Efficacy 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;36:208-17.
20- Shuping GB, Orstavik D, Sigurdsson A , Trope M. Reduction of intracanal bacteria using nickel-titanium rotary instrumentation and various medications. J Endod 2000;26(12):751-5.
21- 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;79:492-6.
22- Mohammadzadeh Akhlaghi N, Behrooz E, Saghiri MA. Efficacy of MTAD, Glyde and EDTA in debridement of curved root canals. Iranian Endod J 2009;4(2):58-62.
23- Paqué F, Musch U, Hülsmann M . Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. Int Endod J 2005;38:8-16.
24- Nielson BA, Craig Baumgartner J . Comparison of the EndoVac system to needle irrigation of root canals. J Endod 2007;33(5):611-5.
25- 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(1):6-10.
26- Schäfer E, Zapke K. Comparative scanning electron microscopic investigation of the efficacy of manual and automated instrumentation of root canals. J Endod 2000;26:660-6.
27- Ahlquist M, Henningsson O, Hultenby K, Ohlin J. The effectiveness of manual and rotary techniques in the cleaning of root canals: a scanning electron microscopy study. Int Endod J 2001;34(7):533-7.
28- Cameron JA. The choice of irrigant during hand instrumentation and ultrasonic irrigation

of the root canal: a scanning electron microscope study. Aust Den J 1995;40(2):85-90.
29- Williamson AE, Sandor AJ, Justman BC. A comparison of three nickel titanium rotary systems, EndoSequence, ProTaper Universal and Profile GT, for canal-cleaning ability. J Endod 2009;35(1):107-9.
30- Zmener O, Pameijer CH, Banegas G. Effectiveness in cleaning oval-shaped root canals using anatomic endodontic technology, ProFile and manual instrumentation:a scanning electron microscopic study. Int Endod J 2005;38:356-63.
31- Mayer BE, Peters OA, Barbakow F. Effects of rotary instruments and ultrasonic irrigation on debris and smear layer scores: a scanning electron microscopic study. Int Endod J 2002;35:582-9.
32- Card SJ, Sigurdsson S, Orstavik D, Trope M. The effectiveness of increased apical enlargement in reducing intracanal bacteria. J Endod 2002;28:779-83.
33- Akhlaghi NM, Kahali R, Abtahi A, Tabatabaee S, Mehrvarzfar P, Parirokh M. Comparison of dentine removal using V-taper and K-Flexofile instruments. Int Endod J 2010;43:1029-36.