

# Evaluation of Apical Debris Removal Using Various Sizes and Tapers of ProFile GT Files

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**The purpose of this study was to evaluate the effect of preparation taper using size #20 or size #40 ProFile GT files on the ability to introduce irrigant and remove debris from root canals. Forty-eight bilaterally matched pairs of extracted teeth were instrumented using .04-, .06-, .08-, and .10-tapered files with one tooth of each pair enlarged to size #20 and the other to size #40. The teeth were sectioned at 1 mm and 3 mm from the apex, and the amount of remaining debris was calculated as a percentage of the total lumen area. The following variables were evaluated: apical preparation size, preparation taper, total volume of irrigation, depth of irrigation needle penetration, and number of instrument changes needed to reach working length. Compared with the size #40 preparations, a significantly greater percentage of remaining debris was observed in the size #20 preparations at the 1-mm level for all tapers except the .10 taper group in which there was no significant difference ( $p = 0.982$ ). There were no significant differences between any groups at 3 mm. Results suggest that debris is more effectively removed using .04, .06, and .08 ProFile GT instruments when the apical preparation size is larger (size #40) compared with size #20 apical preparations. When a taper of .10 can be produced at the apical extent of the canal, there is no difference in debris removal between the two preparations sizes.**

The goals of endodontic instrumentation include thorough debridement and disinfection of the root canal system in addition to creating a suitable shape for complete obturation. This should be accomplished without iatrogenic damage or compromising the structural integrity of the root. There are varying philosophies with regard to the optimal size and shape of root canal preparations necessary to satisfy these goals.

It has been established that instrumentation alone is inadequate for disinfection of root canals in the majority of cases, necessitating the addition of chemical irrigation (1, 2). Sodium hypochlorite (NaOCl) is commonly used as an intracanal irrigant because of its antimicrobial and tissue-dissolving properties (3–5). Baker et al.

(6) demonstrated the benefits of using a greater volume of irrigant during root canal instrumentation. However, the ability to introduce NaOCl into the apical extent of root canals has been questioned. Senia et al. (4) reported that NaOCl was effective as a pulp tissue solvent up to but not beyond the apical 5-mm level. Salzgeber and Brilliant (7) reported that irrigation solution penetrated to the full depth of instrumentation 79% of the time when the root canals were prepared to a size #35 and flared with a #2 Gates Glidden drill. Shuping et al. (8) found a better antibacterial effect during nickel-titanium (NiTi) instrumentation when NaOCl was used, but only after instrumentation exceeded ISO size #30 to #35.

To overcome the potential limits of irrigation in the apical area, enlargement of this area has been advocated for better cleansing (8–11). 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 to bind (12). Studies have shown, however, that initial binding files often do not correspond to the actual size of the foramen, because the instruments are actually binding more coronally (13–15). Minimal apical enlargement, on the other hand, has been suggested to conserve tooth structure and limit extrusion of filling materials (16, 17). Schilder (18) proposed creating a continuously tapering preparation while maintaining the apical foramen as small as possible.

The influence of irrigation needle penetration on cleaning root canals also has been studied. Chow (19) found that the effectiveness of irrigation was a function of needle penetration depth and that the distribution of solution beyond the tip of the needle was much less than expected. Other studies have demonstrated that removal of canal debris was dependent on canal size, diameter of irrigating needle, and its depth of penetration into the root canal (4, 20–22).

The ProFile GT system of instruments (Dentsply, Tulsa, OK) incorporates NiTi rotary files with varying tapers, allowing for a range of final preparation shapes. It is proposed that greater file taper allows for the introduction of irrigant and subsequent removal of debris while keeping the apical foramen small. The purpose of this study was to evaluate the effect of preparation taper using size #20 or size #40 ProFile GT files on the ability to introduce irrigant and subsequently remove debris from the apical extent of root canals.

## MATERIALS AND METHODS

A total of 104, bilaterally matched, freshly extracted, human teeth were collected and stored in saline. The collection protocol was approved by the institutional review board at Oregon Health &

Science University. The teeth were comprised of maxillary and mandibular incisors, canines, and bicuspids. All teeth demonstrated complete root formation with fully formed apices. Forty-eight pairs were divided into four groups, attempting to equally distribute the different types of teeth in each experimental group. The occlusal one-half of each crown was removed with a high-speed handpiece and tapered diamond bur to create a flat surface for easier access to the pulp chamber and to facilitate length measurement of the canal. The pulp chambers were accessed, and the teeth were examined using  $\times 12.5$  magnification to verify the presence of pulp tissue. All instrumentation was performed by the same operator. Canals were initially negotiated with a size #10 K-file with Glyde lubricant (Dentsply Maillefer, Tulsa, OK) followed by a size #15 K-file. Gates Glidden drills #1–4 (Dentsply Maillefer) were then used to flare the coronal one-half of the root with each successively larger drill taken 1 to 2 mm short of the previous size. The #4 Gates Glidden drill was only used to the depth of the cutting flutes. Flaring was followed by irrigation with 1 ml of 5.25% NaOCl delivered in a Monoject syringe with a 28-gauge needle (Max-i-Probe, Dentsply MPL, Elgin, IL). Working length was then determined by inserting a size #15 file until it was just visible in the apical foramen, then retracting it 0.5 mm. Each tooth was radiographed with the size #15 K-file in place from the buccal and proximal views to assess root curvature. Only relatively straight roots were included. Shallow horizontal grooves were cut on the external surface of the root, and each tooth was mounted in polyvinyl siloxane impression material expressed into 1-inch segments of clear rubber surgical tubing. The impression material served to simulate the periodontal ligament, and the grooves helped retain the teeth.

Next, each canal was instrumented up to a size #20 K-file to working length using a combination of filing and reaming in the presence of Glyde and NaOCl. Rotary NiTi ProFile GT files were used in an electric handpiece (Aseptico Endo ITR, Tulsa Dental, Tulsa, OK) set to 300 rpm and a torque setting of two for completion of the instrumentation. Each of the four groups of teeth was instrumented with files of different taper. Group 1 was instrumented with .04-tapered instruments, group 2 with .06-tapered instruments, group 3 with .08-tapered instruments, and group 4 with .10-tapered instruments. One tooth of each bilaterally matched pair was prepared to size #20 at the apex, and the other to size #40 within each taper category. Four pairs of teeth received no instrumentation after verification of the presence of pulp tissue and served as positive controls.

Instrumentation of the experimental groups was performed using a crown-down technique beginning with the final objective file. For example, in the .10 taper size #40 group, the .10-40 file was the first instrument introduced. If the file would not advance to working length, a lower taper or size would be attempted. A typical sequence for the .10-40 group was as follows: .10-40 to resistance using light pressure followed by .10-30, .10-20, .08-20, .06-20, etc. until working length was reached with a size 20 instrument. The canal was then enlarged to size 30 and 40 using instruments of that same taper. Preparation continued with the size #30 and #40 files of sequentially larger tapers until the .10-40 was achieved. Canals were irrigated with 1 ml of 5.25% NaOCl after every third file. The irrigation needle was placed as far apically as possible without binding in the canal. The total number of instrument changes necessary to reach working length with the final instrument was recorded as well as the total volume of irrigant. Instruments were replaced after instrumenting six teeth or if any sign of deformation was observed. Once the desired shape was achieved, the canals

were rinsed with 2 ml of 15% EDTA for 30 s followed by 2 ml of 5.25% NaOCl for 30 s. The depth of irrigation needle penetration during the final irrigation was measured and recorded. Canals were dried with paper points, and the teeth were removed from the impression material mounting. The roots were marked with a sharp pencil at 1 mm and 3 mm from the apex using a millimeter ruler. Next, using  $\times 12.5$  magnification, small indentations were created on the buccal or lingual surface of the root using a 1/2 round bur in a high-speed handpiece corresponding to the pencil marks. These indentations served as markers during sectioning. The canal was then passively filled with 10% formalin using a Monoject syringe and 28-gauge needle, followed by immersion in 10% formalin for a minimum of 24 h.

The teeth were then decalcified in Kristenson's decalcification solution (102 g of sodium formate, 515 ml of 88% formic acid, and 2425 ml of water) for 1 week. The root ends were cut horizontally with a razor blade between the 1 and 3 mm marks, and 5- $\mu$ m sections were created that included the indentations for histologic exam. The sections were stained with hematoxylin and eosin, and viewed with a light microscope under  $\times 100$  magnification. Each section was assigned a randomization number, allowing blinded evaluation. An image of each section was captured using Adobe Photoshop (Adobe Systems Inc, San Jose, CA), and the amount of debris remaining in the canal was quantified using the NIH Image V1.56 software program. This program allowed transformation of the canal contents to black or white pixels, which were then counted and compared. The remaining debris was expressed as a percentage of the lumen area.

### Statistical Analysis

A paired *t* test was used to compare remaining debris at 1 and 3 mm, depth of irrigation needle penetration, number of instrument changes, and total volume of irrigant used between the matched teeth in each taper category. The mean percentage of debris remaining at 1 and 3 mm for all size/taper combinations was compared using ANOVA. A linear-regression model was used to test whether there was a significant relationship between any of the tested variables and percentage of debris at 1 and 3 mm. Statistical significance was set at  $p < 0.05$ .

### RESULTS

A total of 204 sections were evaluated. Four sections were lost during the sectioning process. The mean percentage of debris remaining in experimental groups is shown in Fig. 1. All experimental groups showed significantly less debris than the uninstrumented control teeth at both the 1-mm and 3-mm levels ( $p < 0.01$ ). The paired *t* test revealed a significantly greater percentage of debris remaining in the size #20 preparations compared with size #40 in the .04-, .06-, and .08-taper categories at the 1-mm level (Table 1). There was no statistically significant difference in the .10-taper category at this level. At the 3-mm level, there were no statistically significant differences in percentage of remaining debris between size #20 and size #40 in all four taper categories (Table 1).

The irrigation needle penetrated to  $< 1$  mm from working length in the .06-, .08-, and .10-taper categories when prepared to size #40. This was significantly further compared with the size #20 preparations in these taper categories (Table 2). The .04-taper

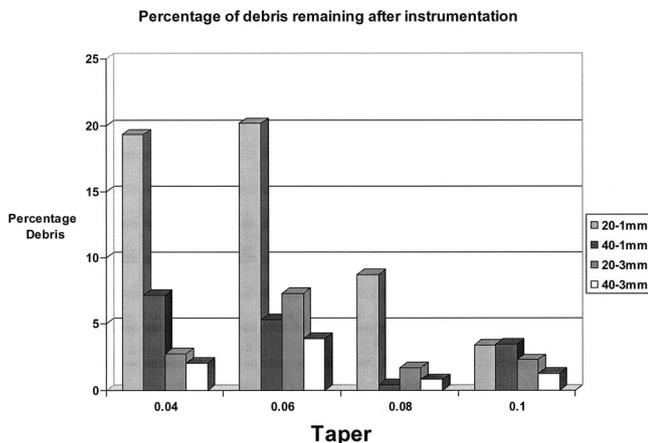


Fig 1. Remaining debris at 1 and 3 mm.

category only allowed needle penetration to within 2.25 mm when prepared to size #40. This was not significantly different from the size #20 preparation, which demonstrated needle penetration to within 3.25 mm. Within the size #20 group, the needle penetrated to within 1.50 and 1.29 mm in the .08- and .10-taper categories, respectively. Each was significantly closer to the apex compared with the .04 and .06 groups.

The number of instrument changes necessary to reach working length was significantly greater for the size #40 preparations in all taper categories (Table 2). Only one instrument was needed for all of the size #20 preparations except the .10-taper category, which required slightly more than one instrument. A total of 5.0 ml of NaOCl was used to irrigate each of the size #20 preparations, whereas 5.5 to 5.9 ml was used to irrigate the size #40 preparations. This difference was statistically significant.

When comparing remaining debris percentages between different taper categories, ANOVA revealed significant differences at the 1-mm level. The most debris was found in the size #20 preparations with .04 and .06 tapers. These two categories showed significantly more debris than all other combinations. There were no significant differences between any of the other combinations. At the 3-mm level, the .06-20 combination exhibited the most debris, which was significantly greater than all other combinations

except the .04-20 and .06-40. There were no other significant differences at this level.

A linear-regression model revealed a significant relationship between percentage of remaining debris at the 1-mm level and the two variables of apical size and taper ( $p < 0.001$ ). At the 3-mm level, only the needle to apex variable was significant ( $p = 0.026$ ). No other variables were found to be significantly related to remaining debris at either level.

DISCUSSION

The results of this study show that the size #40 preparations resulted in less residual debris compared with the size #20 preparations in the .04-, .06-, and .08-taper categories. This is in agreement with other studies that have found cleaner canals with larger apical preparations (8–11). However, when the taper was increased to .10, no significant difference was found between the size #20 and #40 preparations. One possible explanation is that the increased taper allowed for deeper penetration of the irrigation needle and improved flushing of debris. Abou-Ross and Piccinino (22) found that for the irrigant to be effective, the needle delivering the solution must come in close proximity to the material to be removed. Chow (19) found that the effectiveness of irrigation was a function of the depth of the needle and advocated using smaller, more flexible 30-gauge needles. Within the size #20 preparations, needle penetration in the .10- and .08-tapered groups was significantly greater than the .04- and .06-tapered categories. The diameter of the 28-gauge needles used in this study was 0.40 mm. Interestingly, the needle to apex distance in the size #40 preparations with .04 taper was 2.25 mm, well short of working length. A possible explanation for this is that the parallelism of the walls in the .04-tapered canals combined with a slight degree of curvature may have created enough resistance to inhibit complete penetration of the needle.

The total volume of irrigant used during instrumentation differed depending on the number of instrument changes needed to complete the shaping. In a clinical setting, longer instrumentation times or more rotary instrument changes would result in more opportunity for canal irrigation. This also would influence the total treatment time, a variable not evaluated in this study but worthy of consideration. The size

TABLE 1. Comparison of remaining debris at 1 and 3 mm

Taper	% debris at 1 mm, size 20	% debris at 1 mm, size 40	Significance*	% debris at 3 mm, size 20	% debris at 3 mm, size 40	Significance*
.04	19.30	7.13	0.043	2.74	2.06	0.744
.06	20.15	5.29	0.013	7.31	3.90	0.236
.08	8.74	.41	0.048	1.70	0.79	0.550
.10	3.41	3.48	0.982	2.28	1.28	0.629

\* Paired t test, significance set at  $p < 0.05$ .

TABLE 2. Comparison of needle penetration and instrument changes

Taper	Needle to apex distance, size 20 (mm)	Needle to apex distance, size 40 (mm)	Significance*	Instrument changes, size 20	Instrument changes, size 40	Significance*
.04	3.25	2.25	0.082	0	3.17	<0.001
.06	2.83	0.71	<0.001	0	3.33	<0.001
.08	1.5	0.33	<0.001	0	4.5	0.001
.10	1.29	0.21	0.001	0.17	4	<0.001

\* Paired t test, significance set at  $p < 0.05$ .

#40 preparations required more instrument changes than the size #20 preparations in all taper categories ( $p \leq 0.001$ ). As a result, the total volume of irrigant used during preparation to size #20 was 0.5 ml less in the .04 and .06 groups and 0.9 ml less in the .08 and .10 groups compared with the size #40 preparations. Despite the statistical significance, it would be difficult to conclude that these relatively small differences in volume significantly influenced the amount of remaining debris. The differences in remaining debris were most likely the result of the different instrument size/taper combinations. Baker et al. (6), on the other hand, emphasized the importance of irrigant volume; therefore, its potential influence on remaining debris also must be considered.

It must be recognized that achieving deep shape or flare is not always practical. The teeth used in this study all had relatively straight roots. Curved canals, frequently encountered clinically, are more difficult to clean and shape (23, 24). Achieving a .10 tapered preparation in curved roots may be impractical in the majority of cases and more likely to involve procedural mishaps such as instrument separation or root perforation. With this in mind, good clinical judgment must be used when considering the optimal shape for each canal.

Whether apical enlargement is necessary is still controversial. No study to date has shown a definitive relationship between apical enlargement and clinical success or failure. Proponents of larger apical preparations suggest this as the most predictable way to clean and disinfect. However, it has been shown that irrigating with EDTA followed by sodium hypochlorite is capable of producing clean dentin surfaces that are free of debris on uninstrumented surfaces of root canals (25). The necessity to instrument all surfaces of dentin in the apical extent of root canals is therefore brought into question. If irrigants can be introduced into these areas in sufficient volume, more conservative apical preparations may be sufficient.

In conclusion, the results of this investigation suggest that debris is more effectively removed using .04, .06, and .08 ProFile GT instruments when the apical preparation size is larger (size 40) compared with size 20 apical preparations. When a taper of .10 can be produced at the apical extent of the canal, there is no difference in debris removal between the two preparation sizes. This may be because of increased penetration of the irrigation needle and subsequent improvement in the effectiveness of irrigation.

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