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Influence of Instrument Size on Root Canal Debridement

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Files of Greater Taper (GT) are rotary nickel-titanium files of three tapers (0.06, 0.08, 0.10) with file tips of sizes 20, 30, and 40. The purpose of this study was to compare in an in situ model the efficacy of root canal debridement in the apical 3 mm when instrumenting to a GT size 20 or a GT size 40 at working length. Twenty matched human cadaver teeth with 32 canals were decoronated at the cementoenamel junction and instrumented with rotary Files of GT to either GT size 20 or GT size 40. Sodium hypochlorite, EDTA, and RC Prep were chemical aids for debridement. The teeth were extracted; decalcified; sectioned at 0.5 mm, 1.5 mm, and 2.5 mm from the apex; and prepared for histologic examination and quantification of remaining debris. No differences were found between each level within each apex size group; however, the GT size 20 group left significantly more debris in the apical third compared with the GT size 40 group. A regression analysis showed that the apical third cleanliness could be predicted mainly by instrument size and to a lesser extent by the canal length. Irrigant volume, number of instrument changes, and depth of penetration of irrigation needle were not likely to explain differences in debridement.

Nonsurgical endodontic treatment is composed of three phases: (a) cleaning/disinfection (debridement of canal contents), (b) shaping of the canals, and (c) obturation of the root canal space. Mechanical debridement may consist of using both hand-driven and engine-driven rotary instruments in filing and reaming motions. In addition, this phase creates adequate shape, which serves as a reservoir for irrigants and allows adequate obturation. Chemical debridement consists of using agents such as sodium hypochlorite (NaOCl) and EDTA that are able to penetrate mechanically inaccessible areas. In addition, irrigants increase the efficacy of mechanical debridement in the main pulp canal space through lubrication. NaOCl is bactericidal through its liberation of hypochlorous ions and has the ability to dissolve organic material (1). EDTA is a chelating agent that, when used in conjunction with NaOCl, removes the smear layer, which results in the cleanest surface, as seen with a scanning electron microscope (2). Proponents of smear layer removal believe that it may serve as substrate for any remaining bacteria still living within dentinal tubules (3). Removal of this smear layer should allow deeper penetration of sealer and gutta-percha, thus entombing bacteria. RC Prep (Premier Dental Products, King of Prussia, PA) is one of several commercially available agents used for lubrication and is an adjunct in chemical debridement because of the presence of EDTA in a methylcellulose vehicle (4).

A study using a scanning electron microscope that compared mechanical and chemical debridement showed marked differences among the coronal, middle, and apical thirds. These differences could have been caused by the inability to deliver agents such as NaOCl and EDTA effectively to the apical third without the risk of extruding the irrigants beyond the apical foramen (5).

In the past 10 years, engine-driven nickel titanium (NiTi) instruments have been introduced. These instruments, used in a crown-down fashion, minimize radicular dentin removal while still allowing good access to the apical third. A crown-down technique minimizes canal transportation and ledging and is helpful in displacing debris coronally (6). Various NiTi files have been introduced with different tapers and flute and radial land designs.

A new NiTi instrumentation system has recently been introduced. The Files of Greater Taper (Tulsa Dental, Tulsa, OK) are files of three tapers, 0.06, 0.08, and 0.10, with file tips of different sizes. The purpose of this study was to compare in an in situ model the efficacy of root canal debridement in the apical 3 mm when instrumenting to a GT size 20 or a GT size 40 at working length.

MATERIALS AND METHODS

Instrumentation Phase

The maxillary and mandibular jaws from four human cadavers with 50 matched pairs of teeth with patent canals were used in this study. The jaws were radiographed using an occlusal size film with a 12-ms exposure with a film object distance of less than 1 cm. The teeth used in this study were chosen based on the following radiographic criteria: (a) the root canals could be traced from coronal third to apical third, (b) the contralateral teeth appeared similar, (c) there was no previous endodontic treatment, and (d) there was no periapical lesion. Based on these criteria, the experimental groups consisted of 34 matched pairs of human teeth. The

teeth were decoronated at the CEJ. Using RC Prep and a #10 stainless steel file (Brasseler Inc., Savannah, GA), patency to the radiographic apex was accomplished without coronal flaring. The clinical length of each pair of teeth was adjusted so that they were always within 0.5 mm of each other.

The right side was designated as the GT size 20 group, and the left side was designated as the GT size 40 group. The method of instrumentation was as follows. A 27-gauge endodontic irrigation needle (Monoject; Sherwood Medical, St. Louis, MO) was placed as deeply as possible without binding into the unflared canal, and the canal was irrigated with 3 ml 5.25% NaOCl. The GT series rotary files (Dentsply, Tulsa, OK) were placed in an ATR electric handpiece (Dentsply, Tulsa, OK) with programmed torque control and speed settings. Each file was lubricated with RC Prep and used for no more than 10 s in each canal. In a crown-down fashion, successively less tapered GTs were used (0.10, 0.08, 0.06, and 0.04; Dentsply). Between every file change, the canals were irrigated with approximately 0.5 ml irrigant, alternating 15% EDTA and 5.25% NaOCl. An attempt was made to keep the total amount of irrigant used per instrument type equal. Patency at working length was confirmed after each series (i.e. 0.10, 0.08, 0.06, and 0.04.) using a #10 stainless steel file. The maximum depth of irrigation needle penetration was recorded, using silicone stops, after each series. Recapitulation through the series was performed several times until the 0.06 GT (silver) was able to penetrate to working length. Once this was achieved, patency was reconfirmed with a #10 file, and the canal was irrigated with 1 ml NaOCl followed by 1 ml EDTA and another 1 ml 5.25% NaOCl. A final flush of 3 ml distilled water was performed to remove any residual effect of the working irrigants. Each file was used in only two canals to minimize instrument fatigue and breakage. The following features of instrumentation were recorded: (a) initial depth of penetration of the irrigation syringe, (b) the number of series of recapitulations required to achieve instrumentation goal (i.e. GT size 20/0.06 versus GT size 40/0.06), (c) amount of irrigant used, and (d) final depth of penetration of irrigation syringe. Once all teeth were instrumented, they were surgically extracted from the cadaver jaws. Using the largest 0.02 NiTi hand file that could just be seen at the apex, the apical size of the canal was gauged, and the length of the root canal was measured.

Histologic Phase

After extraction, the teeth were fixed in 10% formalin for 7 to 10 days. The fixed teeth were then demineralized for 8 to 10 days in Kristenson decalcifying solution (102 g sodium formate, 1500 ml hot tap water, 515 ml formic acid, and 925 ml cold water). A scalpel was used to remove the apical 0.5 mm, and the remaining root was sectioned at 1.0 mm, 2.0 mm, and 3.0 mm. The segments' most apical view was noted such that they could be imbedded in paraffin, allowing horizontal sectioning to be performed at 0.5 mm, 1.5 mm, and 2.5 mm from the apex.

Histologic evaluation was performed in a blinded manner. The slides were viewed with a light microscope at 100× magnification. The images were captured with Adobe Photo Shop 3.0 (Adobe Systems, San Jose, CA), and NIH Image 1.55 (available on the Internet at http://rsb.info.nih.gov/nih-image/ National Institute of Health, Bethesda, MD) was used to calculate the amount of debris, in pixels, left in the canal space. The results from the two groups were statistically compared using matched pair *t* tests and regression analyses.

RESULTS

Methodology

The range of working lengths used was 10 to 17 mm, depending on the tooth type. The radiographic working length resulted in an overestimation of the working length (instrumenting long) in both the GT size 40 apex group (0.40 mm) and the GT size 20 apex group (0.20 mm). When the canals were apically gauged after extraction from the cadavers, both the working length and the largest 0.02 NiTi file that could be taken to working length were recorded. The mean foramen size was 25.65 in the GT size 20 group and 45.16 in the GT size 40 group. The difference between the two apical sizes was statistically significant using a paired *t* test ($p < 0.0001$). Several positive correlations were noted among the measured variables. The total amount of irrigant was related to the number of recapitulations. This relationship was stronger within the GT size 20 group ($r_s = 0.78$) versus the GT size 40 group ($r_s = 0.66$). The GT size 20 group required fewer instrument changes to reach the working length. The amount of irrigant per instrument change was doubled in the GT size 20 group compared with the 40 group to even out this variable. As working length increased, the number of recapitulations needed to reach working length also increased. This relationship was stronger in the GT size 20 group ($r_s = 0.5$) compared with the GT size 40 group ($r_s = 0.4$). There were no separations of NiTi rotary instruments in either the GT size 20 group or the GT size 40 group. Some distortion of GT size 20/0.04 files was noted. Regardless of canal type, all canals were instrumented to a 0.06 taper at working length.

Thirty-six pairs of canals were instrumented and sectioned at three levels, potentially yielding 108 histologic slides (36 from each level). However, some samples were lost as a result of histologic processing errors. Ultimately, 24 sections 0.5 mm from the apex, 23 sections 1.5 mm from the apex, and 19 sections 2.5 mm from the apex, totaling 66, made up the sample subjected to quantitative analysis.

Amount of Remaining Debris

Using the NIH software, the number of pixels representing debris, tissue, or both was quantified, representing *efficacy of debridement*. Because of the nature of the data expressed as *number of pixels*, logarithmic transformation was performed for normalization. The difference in debridement between the GT size 20 group and GT size 40 group at 0.5, 1.5, and 2.5 mm from the apex was computed using a matched pair *t* test. A one-way analysis of variance was performed on the number of pixels representing debris at the three different levels.

There was no difference between the three different levels in the GT size 20 group ($p < 0.315$) or the GT size 40 group ($p < 0.348$); therefore, all levels were combined to compare debridement between GT size 20 and GT size 40. When the levels were combined, the GT size 20 group left significantly more debris in the apical third compared with the GT size 40 group ($p < 0.006$) (Table 1).

The average amount of irrigant used in the GT size 20 group was 11.82 ml, versus 11.91 ml in the GT size 40 group. The difference was not statistically significant. The average working lengths in the GT size 20 group and the GT size 40 group were 12.94 and 12.69, respectively. The difference was not statistically significant. The average number of recapitulations in the GT size 20 group was 3.86, versus 7.3 in the GT size 40 group. The

TABLE 1. Logarithmic expression of average of debris as measured in pixels between GT size 20 and GT size 40

Average Pixels (Log)		Average Pixels (Log)		Difference	
20/0.5	2.55	40/0.5	1.88	0.676	$p < 0.087$
20/1.5	2.28	40/1.5	1.78	0.500	$p < 0.086$
20/2.5	1.94	40/2.5	1.41	0.530	$p < 0.210$
20 combined	2.29	40 combined	1.71	0.580	$p < 0.006$*

* Significantly less apical debris using GT size 40 compared with GT size 20.

difference was statistically significant ($p < 0.0001$). On average, the 27-gauge irrigation needle was able to move passively to within 76.6% of the working length in the GT size 20 group, versus 94.4% in the GT size 40 group. The difference was statistically significant ($p < 0.0001$).

Regression analysis determined that the most important determining factors were the instrument type (GT size 20 versus GT size 40, $p < 0.006$) and the working length of the root canal ($p < 0.017$). Volume of irrigant and number of instrument changes did not contribute to efficacy of debridement in this study. In addition, regression analysis did not find the depth of irrigation needle penetration to contribute to the efficacy of debridement, even though the irrigation needle could be placed significantly deeper in the GT size 40 group than in the GT size 20 group.

DISCUSSION

It was the goal of this study to assess the efficacy of debridement in an in situ model. The benefit of using human cadaver materials was that matched pairs with a variety of tooth types could be used. By irrigating in the presence of a periodontal ligament, an attempt was made to simulate clinical practice. One drawback of using cadaver materials was the influence of the fixative formoalcohol. No studies could be found that assessed the efficacy of EDTA and NaOCl on formalin-fixed tissue; two studies did comment that there might be some effect (7, 8). Numerous histologic sections were lost before it was found that these teeth required longer decalcification times and were also likely to chip during sectioning because they were highly dehydrated. This condition seemed to be related to the way the cadaver tissue was fixed using alcohol and formaldehyde.

The size of the sample also did not permit assessment of cadaver differences. Differences in teeth could be caused by age of specimen, level of secondary and tertiary dentin, presence of existing restorations, and so forth. Even though each tooth was matched with its contralateral, there were two instances in which anatomical variances were present. Use of an electronic apex locator in situ was found to be unreliable; therefore, working lengths were determined radiographically (9). This method resulted in half of the canals treated in both groups being instrumented past the apical foramen. This working length discrepancy ranged from 0.5 to 2.5mm in both groups. For this study, we adhered to the criterion of maintaining apical patency. This criterion was met at the expense of instrumenting 0.5 to 1.0 mm long in many cases. From the data, it could be seen that the GT size 20 apex group was actually an average size 25.65, and the GT size 40 group was 45.16.

Many studies have attempted to determine the efficacy of chemical and mechanical debridement during endodontic therapy. Siqueira et al. (10) found that after five methods of instrumentation, including ultrasonic activation of irrigants, complete debridement was not possible. Baumgartner and Mader (2) found that alternating irrigation with NaOCl and EDTA was the most effective in removing both the smear layer and organic debris when using ideal delivery of the irrigants. Because debridement in the apical third has always been a challenge, this area was the focus of this study. Histologic sections were taken 0.5 mm, 1.5 mm, and 2.5 mm from the anatomic apex. When the amount of debris was compared between the levels within each group, no differences could be seen. Therefore, it was of no benefit to have sections so close together. It is recommended that future studies compare sections more than 2.5 mm apart.

This study found a statistically significant difference in the amount of debris between the use of GT size 20 instruments and GT size 40 instruments. When regression analysis was used, it was found that it was the size of mechanical instrumentation at working length and not the number of flushes of irrigant or the number of instrument changes that contributed to the difference.

In this study, it appears that there may be no advantage in needle penetration beyond 75% of the working length with regards to canal cleanliness. This finding appears to be in disagreement with other studies that found increased canal cleanliness with increased needle penetration (5). The reason for this difference is not apparent. However, our findings show that increased size of canal instrumentation at working length produced an increase in canal cleanliness. With increased size, care must be taken not to force irrigant beyond the root canal. Salzgeber and Brilliant (11) showed that instrumentation beyond a size 35 may allow penetration of irrigant beyond the apex into periapical tissues. The sequela of forcing sodium hypochlorite into periapical tissues may be significant (12).

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