

A Comparison of Weights of Debris Extruded Apically by Conventional Filing and Canal Master Techniques

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Sixty extracted human teeth were divided into three groups of 20 each. Apically extruded debris and irrigant were collected, dried, and weighed by the following three instrumentation techniques: (a) group 1, filing 1 mm short of the foramen; (b) group 2, Canal Master instrumentation to the foramen; and (c) group 3, filing to the foramen (for a relative comparison). The results indicated that all three groups were significantly different from one another. Group 1 had the least amount of debris extruded. Of the two groups instrumented to the foramen, group 3 had twice as much debris extruded as group 2. An apical dentinal plug was frequently found in group 1 and was probably a major reason why this group had the least amount of extruded debris. The significance of this dentinal plug and possible indications for instrumentation to the foramen are discussed.

The flare-up phenomenon during endodontic treatment has been a persistent problem over the years (1-6). It is most often associated with pain and swelling during or after completion of root canal therapy. Seltzer and Naidorf (1) discussed several factors that possibly trigger this process, including: (a) a quiescent chronic inflammatory periapical lesion which reacts violently when root canal therapy is initiated and introduces infective debris into the lesion and (b) immunological phenomena, either cell mediated or humoral, that respond to foreign material or antigens in the area. Naidorf (2) also postulated that a certain minimal amount of inoculum is needed to initiate these types of responses. Ingle and Beveridge (3) illustrated a "worm" of necrotic debris which was forced through the foramen of an instrumented tooth. They stated that this material potentially contained millions of bacteria which would act as a nidus for an acute apical abscess.

Over the past 20 yr, a number of studies have confirmed that debris is indeed forced out the apical foramen during canal instrumentation and that some instrumentation techniques may extrude less material than others (5-10). In 1968, Chapman et al. (5) verified the expulsion of infective material from the root canal system during endodontic instrumentation. In that same year Seltzer et al. (6) showed that periapical tissue reactions occurred whether instrumentation was con-

finned within the canal space or was extended beyond the apical foramen. In 1975, Vande Visse and Brilliant (7) demonstrated that instrumentation with irrigation produced significantly more extruded debris than did instrumentation without irrigation. However, other inherent problems existed with dry instrumentation and irrigation was deemed essential. In 1982, Martin and Cunningham (8) showed that endosonic instrumentation produced less apically extruded material than did hand filing. Four instrumentation techniques were compared by Fairbourn et al. (9) in 1987 to assess debris extrusion during instrumentation. They found that sonic, ultrasonic, and cervical flaring techniques produced less apical debris extrusion than did a conventional hand instrumentation technique. Ruiz-Hubard et al. (10), in an extrusion study with silicone models, found that a crown-down pressure-less instrumentation technique had significantly less apical debris extrusion than did a typical step-back technique. The recent study of McKendry (11) indicated that an endosonic technique extruded significantly more debris than did the "balanced force" technique. One common theme through each of these studies was that, despite the technique, in the presence of irrigant, some debris was always apically extruded.

Recently a new root canal instrument, the Canal Master (CM) (12), was introduced. Two aspects of its unique design are a reduced cutting segment (from 16.0 to 1.0 to 2.0 mm) and a thinner, smooth, constant-diameter, flexible shaft. These two variations from the previous instrument design could conceivably facilitate debris removal in a coronal direction, thereby reducing the amount of material pushed apically. To date, no studies have been done to determine the amount of debris extrusion with this instrument.

The purpose of the study reported here was to compare the amount of apical debris extrusion and the frequency of plug formation during biomechanical instrumentation by using two different techniques: (a) conventional hand filing with Flex-R files in a step-back fashion and (b) rotary motions with CM instruments.

MATERIALS AND METHODS

Specimen Selection

Sixty extracted human teeth with mature apices were used. Teeth were limited to maxillary lateral incisors and mandibular premolars with a single canal and a single apical foramen.

This was verified by viewing their radiographs and examining them under a stereomicroscope. Next, the following measurements were made and recorded: (a) the degree of apical curvatures, by using the method of Schneider (13); (b) the estimated canal lengths (CL) as measured from the radiographs; (c) the largest diameter and (d) the smallest diameter of the apical foramina measured by using a stereomicroscope with a screw micrometer eyepiece. These four criteria were covariates and were submitted to a statistician who entered them into a computer which randomly assigned the teeth to one of three groups (20 each) while keeping the covariates as equally distributed as possible among the groups.

The buccal cusp/incisal edge of each tooth was then flattened as a reference point, a conventional access preparation was made, and the canal was broached to remove the bulk of the soft tissue. The roots were scaled with a curette and further cleaned with a stiff #11 Robinson bristle brush rotating in a slow-speed handpiece. CL was determined by a #8 Flex-R file (Union Broach, New York, NY) being placed into the canal until the tip was flush with the apical foramen, a rubber stop being placed flush with the flattened reference point, and then the distance from the stop to the file tip being measured.

Canal Instrumentation

Three groups were selected for this study. In group 1 (controls), the canals were instrumented with a conventional filing technique 1 mm short of the CL length (14, 15). A #10 Flex-R file was used to circumferentially file the canal to the preestablished CL. This was then followed by circumferential filing with #15 through #40 Flex-R files 1 mm short of the CL. Hedstrom files #45 through #55 were then used in a step-back fashion to file the middle and cervical thirds of the canal. The #40 Flex-R was placed back to the working length between each Hedstrom file. Before instrumentation, the canal was flooded with 2 ml of distilled water and between each file size an additional 1 ml was delivered through an endodontic irrigation needle for canal irrigation. The needle tip was placed no closer than 8 mm from the foramen opening in all teeth, and it was never allowed to bind. This same irrigation procedure was used for groups 2 and 3.

Group 2 was instrumented with CM instruments to the CL as directed by the videotape and instructions enclosed by the manufacturer (12). Initially, #10 and #15 Flex-R files were used in a circumferential manner until the #15 file fit passively at canal length. Rotary CM #50, 60, 70, and 80, were then used to prepare the cervical and middle thirds of the canal down to the curve or to a point no closer than 5 mm from the apical foramen. The apical portion of the canal was then prepared with CM #20 through #40 to the CL by using a continuous 30- to 45-degree rotary motion in each direction. A step-back procedure in 1-mm increments was done by using CM #45 through #55 with recapitulation with the last apical instrument between each larger size. Irrigation with distilled water was used as in group 1.

Because the first two groups involved two different techniques and two different working lengths, a third group was used to provide a relative comparison between the two techniques with the same working lengths. Group 3 canals were instrumented by using the same filing technique as in group

1 but were instrumented to the canal length, as were the canals in group 2. Irrigation was accomplished in the same fashion as in the previous groups.

Debris Collection

Each tooth was secured for instrumentation and debris collection by the root being forced through a precut hole in a #1 rubber stopper. A 15- × 45-mm glass shell vial (Kimble, Toledo, OH) was used as the collecting container for any debris or irrigant extruded during instrumentation. This vial was placed into a glass flask (20-ml scintillation vial; Kimble) with the rubber stopper fitted securely into the mouth of the flask. The apex of the root was suspended below the upper rim of the collection vial (Fig. 1). The use of the collection vial was a modification of the technique used by Fairbourn et al. (9) for debris collection. A 25-gauge needle was placed alongside the stopper during insertion to equalize the air pressure inside and outside the flask. The flask was then held securely in a rubber-jawed vise, and a rubber dam was placed to obscure the flask so that the root could not be observed during instrumentation. All instrumentation was done by the same person. After canal instrumentation, any debris visually adherent to the root end was scraped off with the inner edge of the collection vial and the root apex was flushed with 0.1 ml of distilled water to wash any remaining debris into the vial. Once the debris was removed from the root surface, the presence of an apical plug was determined by viewing the foramen area through a stereomicroscope.

Unexpectedly, a significant amount of irrigant was frequently present in the collection vials. A clean vial was filled with irrigant in 0.5-ml increments and marked at each level. The volume of extruded irrigant was measured by placing the collection vials next to this calibrated vial. The vials were then immediately placed into a dessicator (with CaCl₂ crystals) to drive off all moisture before a dry weight was obtained. The dessicator was kept in a warm room (85°F) until the vials were dry and was then kept at room temperature for 24 h before the final weighing.

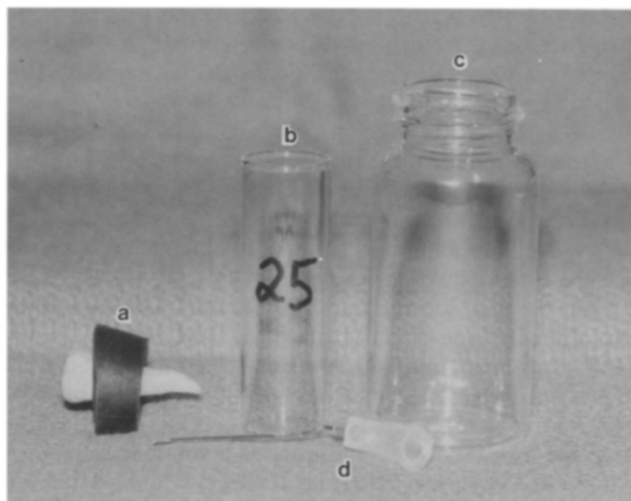


FIG 1. Tooth in stopper (a), collection vial (b), flask (c), and vent (d) before assembly.

Weighing Debris

The collection vials were cleaned, labeled, desiccated over CaCl₂ for 24 h, and brought to constant weights before being used as collection devices. All weighing was done on a Mettler balance (model #H54AR; Mettler Instrument Corp., Hightstown, NJ), and at least two weights were recorded before and after debris collection to verify that a constant weight was achieved. The vials were handled with clean cotton forceps at all times.

Six control vials were taken by the same precollection procedures as outlined above. Two to three milliliters of distilled water were placed in each of these, and they were then dried and weighed to see if the distilled water (used as the irrigant) left any residue.

Statistical Analysis

The mean dry weights of the three groups were compared to determine if any significant differences existed among them. Single-factor analysis of variance and Student-Newman-Keuls procedures were used to evaluate the data.

RESULTS

Debris Extruded

Of the 60 teeth used in this study, two had to be discarded because a #8 file could not be placed to the foramen before instrumentation. The mean dry weights and the range of debris collected for each group are presented in Table 1. According to analysis of variance, the difference among groups was significant ($p = 0.0001$). Furthermore, the Student-Newman-Keuls test showed that all three groups were significantly different from one another at the 0.05 level. The group instrumented short of the foramen had significantly less debris extruded than the other two groups. Of the two groups instrumented to the foramen, the CM group extruded significantly less debris.

Apical Plug Formation

Apical plugs were seen in 16 of 19 (84.2%) teeth instrumented 1 mm short of the foramen whereas they were seen in only 4 of 39 (10.3%) teeth instrumented to the foramen. All four of the latter group occurred in teeth with an abrupt apical curve which may not have been instrumented with the larger file sizes.

The two diameters of the apical foramina, the canal lengths, and canal curvatures were all considered as covariates in this study (Table 2). A stepwise regression analysis showed that only the CL had a significant correlation with the amount of debris extruded (longer CL, more extrusion). However, since the CL group means differed very slightly, the results of the significance tests among groups remained unchanged. In addition, no significant difference was noted when comparing the two types of teeth used within each group.

Some samples in each of the three groups had some irrigant present in the collection vial after instrumentation (Fig. 2). The majority of these occurred in the two groups instru-

mented the entire length of the canal (Table 3). Although a correlation was suspected between the volume of irrigant collected and the final mean dry weights, statistical analysis showed otherwise—there was no significant correlation between these two observations.

Controls

Of the six distilled water controls, five of the collection vessels weighed within ± 0.01 mg before and after the irrigant

TABLE 1. Extruded debris (mg) and apical plugs

Group	n*	Mean \pm SD	Range	Plugs
1 (Filing 1 mm short)	19	0.22 \pm 0.17	0.01–0.69	16
2 (CM)	20	0.78 \pm 0.40	0.01–1.74	1
3 (Filing to foramen)	19	1.58 \pm 1.16	0.14–4.02	3

* Total number of teeth in each group.

TABLE 2. Mean values for covariates by group

Group	Apical Foramina		CL (mm)	Canal Curvature (degrees)
	Largest Diameter (mm)	Smallest Diameter (mm)		
1	0.33	0.26	20.9	14.5
2	0.33	0.26	21.1	16.3
3	0.33	0.23	20.9	12.3



Fig 2. A drop of irrigant (a) suspended from the apical end of the root in the assembled apparatus before falling into the collection vial (b). Flask (c).

TABLE 3. Collected irrigant by group

Group	No. of Samples	Mean Volume (ml)	Range (ml)
1	5	0.79	0.50–1.50
2	13	2.25	0.30–5.20
3	17	1.77	0.20–3.70

was placed. The sixth weighed 0.03 mg heavier after the irrigant was dried out. These findings indicated the irrigant did not contribute any significant residue to the dry debris weights.

DISCUSSION

The results of this study appear to correlate well with those of previous debris extrusion studies (Table 4). Three previous studies (8, 9, 11) each included a group filed 1 mm short of the CL. The results for this group ranged from a mean low of 0.22 mg (this study) to a mean high of 0.53 mg (8). These differences may be attributed to a variety of factors, including operator technique, debris collection methodology, amount of apical instrumentation before collection of debris, size and types of files used, etc. Despite these variables, the results appear reasonably consistent.

Only one previous study (8) has involved debris collection during instrumentation to or beyond the foramen. As in the study presented here, the amount of extruded debris was significantly higher when the entire CL was instrumented. In the study reported here, great care was used to instrument to the foramen (and not beyond this point) in groups 2 and 3. When these groups were compared, the CM technique resulted in significantly less debris extrusion than did the filing technique. This difference may perhaps be attributed to the design features of the CM instruments. The smaller cutting head probably produces less dentinal debris than did a conventional file. Additional room provided by the reduced shaft may facilitate the removal of dentinal debris from the cutting flutes. Avoiding clogged flutes may, therefore, aid in reducing the amount of debris physically pushed forward in the canal. The use of filing motions as opposed to rotary motions may have been another factor determining the amount of extruded debris. Further research is needed to see if instrument design or instrumentation technique has a greater impact in this area.

Another observation noted in some studies was a possible correlation between CL and the amount of extruded debris. This observation was noted in studies which involved instrumentation short of the foramen (7, 9). However, in neither of these studies was this correlation found to be statistically significant. In the study presented here, the correlation was found to be significant and may have been attributed to the fact that instrumentation of two of the three groups went to the foramen.

McKendry (11) noted that there appeared to be a few instances where the amount of debris extruded is substantially

larger than the mean amounts observed. Some studies deleted these values from the statistical analysis as outliers (9, 11) under the assumption that the data followed an ideal normal distribution. However, because of the consistent presence of these outliers throughout these similar studies, the data may not occur in such an ideal distribution. In this study, all data were included for statistical analysis for this reason. Perhaps, as McKendry noted, the few clinical flare-ups that occur may be correlated to the excessive debris in these few outliers.

An interesting observation was the amount of irrigant which passed through the canal into the collecting vessel. An observable amount of irrigant was seen in 30 of 39 (76.9%) canals instrumented to the foramen, whereas it was seen in only 5 of 19 (26.3%) canals instrumented short of the foramen. This may have been attributed to: (a) absence of an apical plug or natural bone/tissue barrier; (b) the entire canal being kept patent to the foramen; and (c) gravity carrying irrigant out through the foramen in the *in vitro* design used. Volumes of irrigant as high as 3.5 to 5.0 ml were collected in some specimens. The amount of irrigant that passes out through the foramen is not known clinically. Salzgeber and Brilliant (16) found in an *in vivo* study that: (a) in vital cases, the irrigant was found only in the space created by instrumentation whether it was confined to the canal space or whether it extended into the periapical area and (b) in necrotic cases, the irrigant was not necessarily confined only to those areas which had been instrumented. When it did penetrate into the periapical tissues, the irrigant appeared to be randomly distributed in the apical lesion. Clinically then, the tissues surrounding the apex appear to act as a natural barrier, so one must wonder how much debris actually passes out into the periradicular tissues when the canal is instrumented to the foramen. Would this barrier be equally effective against the compacted worm of debris forced out when instrumentation is short of the foramen? If both situations resulted in extruded material, which scenario would be handled better by the periapical tissues—debris suspended in irrigant or debris compacted into a condensed mass, i.e., the apical worm?

A reassessment of the apical dentinal plug should be considered. During instrumentation, neither method gave any indication if plug formation was occurring. In a short-term scenario, the benefits of this plug appear numerous: it seems to limit the amount of debris which is extruded, thereby reducing the chances of potential flare-ups, it probably prevents overinstrumentation of the periapical tissues, and it probably helps to prevent the extrusion of the obturating materials. Long-term prognosis, however, could possibly be compromised, especially in teeth with necrotic pulps, because

TABLE 4. Comparison of extrusion studies*

	Filing	Ultrasonic	Sonic	Other	Filing	CM
Vande Visse	—	—	—	0.41†	—	—
Fairbourn	0.30	0.20	0.12	0.18‡	—	—
Martin	0.53	0.22	—	—	1.39¶	—
McKendry	0.46	0.60	—	0.25§	—	—
Myers	0.22	—	—	—	1.58¶	0.78¶

* Values are milligrams of debris.

† ¼ turn and pull.

‡ Cervical flaring.

§ Balanced force.

¶ Instrumentation to foramen.

the plug is inside of the canal where it is difficult for host defenses to remove it.

Holland et al. (17) showed that if infected dentin chips are accumulated between the filling material and the periapical tissues, the healing process may be impaired. Root canals plugged with contaminated dentin chips responded much more poorly than did canals where plugs were absent. Studies involving vital pulps have shown favorable results (18–20) when an apical plug was created. It was found that: (a) plugging of the canal was fairly easily accomplished (18); (b) fewer instances of periapical inflammation occurred when plugs were formed (19); (c) plugs provided an effective barrier against which to obturate (20); and (d) a calcific barrier with an appearance similar to cellular cementum could develop adjacent to these apical plugs (20). Follow-up periods in these studies ranged from 95 days to 12 months. Which then, is a more desirable end result: (a) a canal instrumented short, with an apical plug and possibly a lower incidence of treatment-related flare-ups or (b) a canal instrumented to the foramen with no plug and possibly a better long-term prognosis (although short-term flare-ups might occur more frequently)? This is a clinical dilemma which should be the subject of future research.

In necrotic cases, complete instrumentation of the entire CL seems desirable. Finding a technique which extrudes the least amount of debris under these conditions is then desirable, and the CM technique appears to be a significant improvement in this regard. Further studies are needed to compare: (a) other techniques taken to the foramen; (b) effects of multiple foramina; (c) effects of different irrigants; and (d) differences in an apical barrier consisting of healthy tissue or a periapical lesion.

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We thank Dr. Chen Yuan for statistical and computer analysis and Dr. David Carnes for his assistance in the research design and materials.

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References

1. Seltzer S, Naidorf IJ. Flare-ups in endodontics I. Etiological factors. *J Endodon* 1985;11:472–8.
2. Naidorf IJ. Endodontic flare-ups: bacteriological and immunological mechanisms. *J Endodon* 1985;11:462–4.
3. Ingle J, Beveridge E. *Endodontics*. 3rd ed. Philadelphia: Lea & Febiger, 1985:170–80.
4. Matusow RJ. The flare-up phenomenon in endodontics: a clinical perspective and review. *Oral Surg* 1988;65:750–3.
5. Chapman CE, Collee JG, Beagrie GS. A preliminary report on the correlation between apical infection and instrumentation in endodontics. *J Br Endod Soc* 1968;2:7–11.
6. Seltzer S, Soltanoff W, Sinai I, Goldenberg A, Bender IB. Biologic aspects of endodontics. Part III. Periapical tissue reactions to root canal instrumentation. *Oral Surg* 1968;26:534–46, 694–705.
7. Vande Visse JE, Brilliant JD. Effect of irrigation on the production of extruded material at the root apex during instrumentation. *J Endodon* 1975;1:243–6.
8. Martin H, Cunningham WT. The effect of endosonic and hand manipulation on the amount of root canal material extruded. *Oral Surg* 1982;53:611–3.
9. Fairbourn DR, McWalter GM, Montgomery S. The effect of four preparation techniques on the amount of apically extruded debris. *J Endodon* 1987;13:102–8.
10. Ruiz-Hubard EE, Gutmann JL, Wagner MJ. A quantitative assessment of canal debris forced periapically during root canal instrumentation using two different techniques. *J Endodon* 1987;13:554–8.
11. McKendry DJ. Comparison of balanced forces, endosonic, and step-back filling instrumentation techniques: quantification of extruded apical debris. *J Endodon* 1990;16:24–7.
12. Wildey WL, Senia ES. A new root canal instrument and instrumentation technique: a preliminary report. *Oral Surg* 1989;67:198–207.
13. Schneider SW. A comparison of canal preparations in straight and curved root canals. *Oral Surg* 1971;32:271–5.
14. del Rio C, Canales ML. A sophomore pre-clinical laboratory course manual. San Antonio: The University of Texas Health Science Center, 1981:40–60.
15. Grossman LI, Oliet S, del Rio CE. *Endodontic practice*. 11th ed. Philadelphia: Lea & Febiger, 1985:196–206.
16. Salzgeber RM, Brilliant JD. An in vivo evaluation of the penetration of an irrigating solution in root canals. *J Endodon* 1977;3:394–8.
17. Holland R, De Souza V, Nery MJ, de Mello W, Bernabé PFE, Otoboni Filho JA. Tissue reactions following apical plugging of the root canal with infected dentin chips. *Oral Surg* 1980;49:366–69.
18. Tronstad L. Tissue reactions following apical plugging of the root canal with dentin chips in monkey teeth subjected to pulpectomy. *Oral Surg* 1978;45:297–304.
19. Patterson SM, Patterson SS, Newton CW, Kafrawy AH. The effect of an apical dentin plug in root canal preparation. *J Endodon* 1988;14:1–6.
20. Pitts DL, Jones JE, Oswald RJ. A histological comparison of calcium hydroxide plugs and dentin plugs used for the control of gutta-percha root canal filling material. *J Endodon* 1984;10:283–93.