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ORIGINAL RESEARCH

To determine whether the First File to bind at the Working Length corresponds to the Apical Diameter in Roots with Apical Curvatures both before and after Flaring using Two Rotary Systems: An *in vitro* Study

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ABSTRACT

Aim: To Investigate the discrepancies between the diameter of the canal and the first file to bind at apex before and after preflaring in teeth with apical curvature.

Materials and methods: A total of 80 mesial canals of lower first and second molars with complete apical formation and patent foramen were selected. The samples were randomly divided into 2 groups of 40 canals each. Diameter of canal and the first file to bind at working length were observed for each tooth before and after flaring using Gates–Glidden and ProTaper.

Results: The mean diameter of first file fitting at apex before flaring (FFFAb) and first file fitting at apex after flaring (FFFAa) was 12.30 ($\pm$4.31)$\times 10^{-2}$ mm and 18.83 ($\pm$5.91)$\times 10^{-2}$ mm respectively, for group 1.

The mean diameter of FFFAb and FFFAa was 10.58 ($\pm$2.56)$\times 10^{-2}$ mm and 18.25 ($\pm$5.94)$\times 10^{-2}$ mm respectively, for group 2.

The p values in both group before and after flaring is < 0.001, which is statistically significant.

Conclusion: Cervical preflaring plays an important role in reducing the discrepancy between initial apical file diameter and apical canal diameter.

Keywords: Apical canal diameter, Cervical preflaring, Endodontic working width, File size, Instrument type.

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INTRODUCTION

The primary goal of root canal treatment is to minimize the number of microorganisms present in the root canal system. In the course of cleaning and shaping the root canal system, the clinician must determine 3 critical parameters: The length of canal, the taper of preparation, and the horizontal dimension of the preparation at its most apical extent.[1] Many studies have demonstrated that widely accepted endodontic cleaning and shaping techniques are inadequate. It was found that mechanical preparation of root canal to two sizes larger than the original was still not adequate.[2] Further, it was shown that often canals are improperly cleaned.[3] They attributed this inadequate instrumentation to the fact that the root canal diameter is larger than the instrument caliber used in each particular case. This finding suggests that each canal should be calibrated independently before instrumentation so that proper preparation can be achieved. One histological study showed that canals that were instrumented to three sizes larger still were not thoroughly cleaned.[4] Recent *in vitro* investigations concluded that stainless steel and nickel-titanium (NiTi) rotary instrument were not able to clean the root canal satisfactorily. In the absence of a study that defines what the original width and optimally prepared horizontal dimensions of canal are, clinicians are making treatment decision without any support of scientific evidence.

Root canal morphology is a critically important part of conventional and surgical endodontics. Many *in vitro* studies have recorded the scales and average sizes of root canals, but there have been few clinical attempts to determine the working width (WW). It is difficult to section all levels of the teeth and make the section plane exactly perpendicular to the canal curvature. Therefore, most morphometric studies can not show the true picture of the horizontal dimension of the root canal system. Until recently, most investigations have involved counting the number of canals and foramina and categorizing how the canals join or split. Current studies pay more attention to the shape of the canal systems and its clinical implications than to the actual preoperative size of the canal. The detection of apical constriction and the determination of the first file that binds at working length are based on the tactile sense of the clinician. This premise is based on the false belief that the root canal is narrower in apical portion and that the file would pass without interference until this narrow point. However, it is demonstrated that the sensation of the file fit does not necessarily occur because of contact at apex as is assumed but may instead be a result of interference in coronal and middle thirds of canal. Irregularity of walls/curvature of root applies false pressure against the file and interference with the clinician's ability to determine contact and tightness at apex. Further continued dentine formation is responsible for an increased thickness of dentin at the floor of pulp chamber and for progressive constriction of the canal space.[5]

In histological sections of infected teeth, bacteria were found in the dentinal tubules adjacent to the pulp chamber.[6] It is therefore considered appropriate to remove the most heavily infected layer of dentin. Since the diameter of apical canals varies greatly in all tooth groups, no standard size is available for the apical enlargement. One recommended approach is to enlarge apical root canal to three sizes larger than the first file bind.[7] The concept behind this approach is that first file to bind reflects the diameter of the apical canal; by using three successively larger files to the same working length, the layer of heavily infected dentin should be removed from all regions of the apical canal wall. Another purpose of this approach is to create an apical stop that was supposed to facilitate reduced leakage and material extrusion. On the other hand, taking successively larger files to the same length in a curved root canal can predispose to apical laceration or ledging.[8] There has been minimal development of concepts, techniques, and technology to measure WW (first file that binds at working length).

One common method of deciding on the size of the apical preparation is to first determine the preoperative canal diameter by passing consequently larger instrument to the working length until one binds. This initial file estimation is referred as initial WW.

There are so many factors as mentioned earlier which affect initial WW determination. To minimize the influence of these affecting factors, early coronal flaring is recommended.

One of the most commonly used rotary instruments for early coronal flaring is a Gates–Glidden (GG) drill; however, new NiTi instruments like ProTaper are also available for this use. This study focused on posterior teeth only because these teeth impose the greatest challenge in root canal treatment. Present study regarding horizontal morphology of root canal system can help to solidify concepts and improve techniques of cleaning and shaping of root canal system. Thus, this study was conducted with the aim to determine whether the first file to bind at working length corresponds to the apical diameter in roots with apical curvatures both before and after flaring.

MATERIALS AND METHODS

Tooth Selection

A total of 40 mesial roots of mandibular first and second molars having patent root canals and fully formed apices were selected. Teeth with complicated anatomy, external resorption, or extreme root curvature were discarded. These 40 roots yielded 80 canals for the use in this evaluation. All the teeth were ultrasonically cleaned to remove any surface debris. They were stored in saline at room temperature.

The distal root of each tooth was sectioned away at the furcation with a #169L fissure bur. A preoperative radiograph was taken for each sample from clinical and proximal view. Caries and restoration were removed and standard access cavities were cut. The pulp tissues were removed with an extra fine barbed broach. Care was taken to ensure that the barbed broach engaged only the pulp tissue without contacting the apical third of the root canal. Canals were then irrigated with copious 2.5% sodium hypochlorite solution. Apical patency was determined by inserting a size #6 k-file into the canal until the tip of the file was visible at the apical foramen. Working length was established by subtracting 1 mm from this full canal length. Cusp tips were used as reference points. Both the working length and the reference of each individual canal were recorded.

Sizing of Canals

Files were inserted passively into the canal with light watch-winding action and care was taken to avoid any force during sizing. Measurement was undertaken starting from ISO size 8. Apical fit was considered to have occurred when largest file reached the apex and passage beyond that depth was not possible. In both groups, the largest file that could fulfill the criteria and reach the working length was determined. In all instances, a larger file was tried to ensure that it could not reach the same depth (i.e., working length). Once satisfied that the largest file has been chosen, radiographs were taken from the proximal and clinical view. These radiographs verified that the file had reached the working length and fit the canal correctly. The size of file was recorded as first file fitting at the apex (FFFA) before flaring (FFFAb).

Coronal and Middle Third Flaring

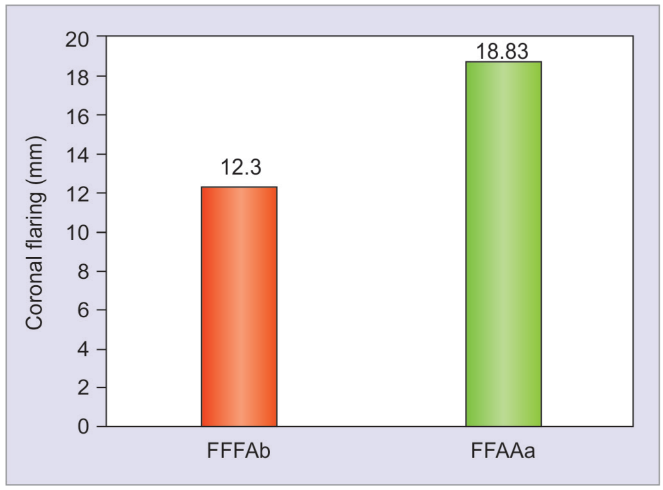
Coronal flaring and middle third flaring were done with ProTaper rotary and GG instruments using crown-down approach to eliminate all interferences. Flaring was terminated 4 mm short of the working length so that the apical third region remained unprepared.

Group 1

In this group, GG drills were used to flare the body of each canal. Flaring began with a GG #6. This drill was used to enlarge the orifice and transport it toward the mesial–facial or mesial–lingual corner of the pulp chamber. The canal was irrigated with 2 mL of a freshly prepared 2.5% solution of sodium hypochlorite and flaring continued with a GG #5 extending the shaping 2 mm further apically and again transporting the shaping toward the mesial–facial and mesial–lingual corners. The entry into the canals was always from the distal toward the mesial and removal applied pressure toward the mesial respective corner. This methodology maintained transporting force away from the furcation and furcation concavity. Irrigation was repeated after each GG and patency tested with a small file. Gates–Glidden #4, GG #3, GG #2, and GG #1 were used to complete flaring, each penetrating 2 mm deeper than preceding drill. No transporting motions were used with these three sizes; however, canal patency was checked and irrigation continued (Graph 1 and Table 1).

Group 2

In this group, early flaring was conducted with rotary Pro Taper. ProTaper instruments were used in a crown-down manner according to the manufacturer's instructions using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt and changed for the next instrument. The instrumentation sequence is as follows: First make a glide path using 15 K-file. S1 was taken into the canal just short of the depth at which the hand instrument was taken previously. Then, the SX instrument was used to move the coronal aspect of canal away from the furcal danger and to improve radicular access. This step was continued with SX until about two-thirds of the overall lengths of the cutting blades were below the orifice. This was followed by S1 and S2 files.



Graph 1: Comparison of pre- and postcoronal flaring (mm) in Gates Glidden group. FFFAa: First file fitting at apex after flaring; FFFAb: First file fitting at apex before flaring

Table 1: Distribution of the FFFAb and FFFAa: Group 1 (GG)

	FFFAb		*FFFAa*	
File site	*Fr*	*Rf*	*Fr*	*Rf*
8	9	0.22	1	0.02
10	14	0.35	3	0.07
15	11	0.27	16	0.40
20	4	0.10	8	0.20
25	2	0.05	10	0.25
30	–	–	1	0.02
35	–	–	1	0.02
40	–	–		
45	–	–		
Total	40	1.0	40	1.0

FFFAb: First file fitting at a pen before flaring; FFFAa: First file fitting at a pen after flaring; Rf: Relative frequency; Fr: Frequency; GG: Gates–Glidden

After early flaring was completed, a new evaluation for the FFFA was done. This was accomplished in the same manner as previously described. Radiographs were made using the clinical and proximal view as before. This file was recorded as FFFA after flaring (FFFAa) (Table 2).

RESULTS

In group 1 from FFFAb, only 3 canals (7.5%) kept the same size after flaring, rest 37 canals (92.5%) showed increase in file diameter (Table 3).

In group 2 from FFFAb, only 5 canals (10%) kept the same size after flaring, rest 35 canals (90%) showed increase in file diameter.

The mean diameter of FFFAb and FFFAa was 12.30 ($\pm$4.31)$\times 10^{-2}$ mm and 18.83 ($\pm$5.91)$\times 10^{-2}$ mm respectively, for group 1.

Table 2: Group 2 (ProTaper)

	FFFAb		FFFAa	
File size	*Fr*	*Rf*	*Fr*	*Rf*
8	11	0.27	–	–
10	20	0.50	5	0.12
15	9	0.22	16	0.40
20	–		10	0.25
25	–		8	0.20
30	–		–	–
35	–		–	–
40	–		1	0.01
45	–		–	–
Total	40	1.0	40	1.0

FFFAb: First file fitting at a pen before flaring; FFFAa: First file fitting at a pen after flaring; Rf: Relative frequency; Fr: Frequency

Table 3: Increment frequency of increase in file size per group

	Frequency	
Increment	*Group 1*	*Group 2*
None	3	5
1	22	13
2	11	14
3	3	6
4	1	1
5	–	–
6	–	1

Note: Each increment = one file size

The mean diameter of FFFAb and FFFAa was 10.58 (±2.56)$\times 10^{-2}$ mm and 18.25 (±5.94)$\times 10^{-2}$ mm respectively, for group 2 (Table 4).

The p value in both groups before and after flaring is <0.001, which is statistically significant.

DISCUSSION

Success of endodontic therapy depends on the thorough chemomechanical preparation and three-dimensional (3D) obturation of the root canal. Adequate instrumentation not only removes the superficial infected layer but also acts as a reservoir for irrigation and produces a shape that facilitates sealing. Thorough instrumentation of the apical region has long been considered to be an essential component in cleaning and shaping as it is recognized as the critical zone of instrumentation. Several authors have attempted to quantify the horizontal dimension of the apical constriction, but most of the studies could not give the true picture of horizontal dimensions as they did not take into consideration all variable such as age, curvatures, apical shape, etc.

Canal enlargement has the aim of allowing sufficient space to act as a reservoir for irrigation, of removing the superficial layer of infected dentin, and to produce a shape that facilitates sealing. In terms of removal of infected dentin, Sequeria et al[9] in 2001 found in 62% of the roots more than 50,000 CFU/gm in the dentin layer close to the cementum. This may suggest that instrumentation is not able to remove infected dentin. On the other hand, Nair et al[10] and Card et al report that reduction of the bacterial population in the root canal may be achieved through instrumentation. In general, the classic parameter for enlargement of the apical region at working length is still the use of three file sizes greater than the first file that fits at the apex as recommended by Grossman,[11] Ingle and Bakland,[12] and Weine.[13]

However, determination of real anatomical diameter WW at working length is difficult.

This study was in the mesial roots of mandibular molars, which is considered to have the most complicated root canal system. To enhance clinical success, dental practitioners must be aware of root canal morphology, including the configuration and degree of curvature. This information is necessary not in a mesial to distal direction, as seen in a clinical view radiograph but also in a buccal to lingual direction (proximal view radiograph). Although canal curvature in the proximal view is unseen by the clinician with routine radiographic techniques, it can play a significant role in the cleaning and shaping process. According to Cary J Cunnigham et al, curvatures were found in 100% of the canals of mandibular mesial root. This magnitude of curvature is reduced by coronal flaring as reported by Roane et al.[14] Leseberg and Montgomery studied canal transportation at the level of the curve and documented the distal and axial (toward the midline) movement of the original canal. This canal transportation is caused by a combination of forces resulting from clinical as well as proximal

Table 4: Statistical analysis

	Group	*N*	*Mean*	*Std. deviation*	*Median*	*Min*	*Max*	*t-value*	*p-value*
FFFAb	Gates–Glidden	40	12.30	4.31	10.00	8	25	2.176	0.033
	ProTaper	40	10.58	2.56	10.00	8	15		
FFFAa	Gates–Glidden	40	18.83	5.91	17.50	8	35	0.434	0.666
	ProTaper	40	18.25	5.94	15.00	10	40		

	Group	*Paired differences*	*Mean*	*Std. deviation*	*t-value*	*p-value*
	Gates–Glidden	FFFAb − FFFAa	–6.52	4.06	–5.411	<0.001
	ProTaper	FFFAb − FFFAa	–7.68	5.91	–5.188	<0.001

FFFAb: First file fitting at a pen before flaring; FFFAa: First file fitting at a pen after flaring curvature, which produces a vector distally and axially. From their study, it would appear that the greater the proximal curvature, the faster the transportation would progress toward the distal concavity. This could result in strip perforation. So this coronal flaring procedure by reducing the degree of canal curvature reduces chance of strip perforation also.

In this study, GG drills is used for coronal flaring in one group as it is the most commonly used instrument. It has a history of use of more than 100 years. Gates–Glidden instruments are manufactured in a set and number 1 to 6 with corresponding diameter of 0.5 to 1.5 mm. Gates–Glidden drills are side-cutting instruments with a safety tip and can be used to cut dentin as they are withdrawn from the canal (i.e., on outstroke).

It is important to note that the technique used with the GG flaring was crown-down in this study and progressed from large to small through the canal, sequence #4, #3, #2, and #1. This nuance altered the insertion axis for the small drills (#4, #3, and #2) and allowed the smaller drills to shape 2-mm increments of each canal. This method provides deeper access with the smaller drills and limits the possibility of instrument failure. As stated earlier, when used adequately, GG instruments are inexpensive, safe, and clinically beneficial tools.

ProTaper instruments were used in the second group for coronal flaring, which is a NiTi rotary system. Two properties of the NiTi alloy are of particular interest in endodontics: Super elasticity and high resistance to cyclic fatigue. ProTaper instruments were recently introduced and embody two new concepts. First in cross section, instruments do not have a U-file design and second the instrument shaft has variable taper along its cutting surface. This concept minimizes the number of instruments per set and is claimed to decrease tortional loads by reducing the friction, thereby increasing cutting efficiency. Originally ProTaper sets included 5 instruments, shaping files 1 and 2 and finishing files 1 to 3. However, additional instrument (shaper X and finishing files 4 and 5) were subsequently introduced whose task is to relocate canal orifices and shape the coronal part of canal and for F4, F5 apical preparation in a wide canal respectively. This is nowadays the commonly used NiTi rotary system having the advantage over conventional stainless steel GG drills of super elasticity chances of strip perforation and less canal transportation. In the present study, coronal flaring was completed with Sx, S1, and S2 files.[15]

In the present study, both groups used "Crown-down Pressureless" technique which was first advocated by Marshall and Pappin. A primary purpose of this technique is to minimize or eliminate the amount of necrotic debris that could be excluded from the apical foramen during instrumentation. This will help to prevent post-treatment discomfort, incomplete cleansing, and difficulty in achieving a biocompatible seal at apical constriction. One of the major advantages of step-down preparation is the freedom from constraint of the apical enlarging instruments. By first flaring the coronal two-thirds of the canal, the final apical instruments are unencumbered through most of their length. This increased access allows greater control and less chance of zipping near apical constriction. In addition, it provides coronal escapeway that reduces the "Piston in a cylinder effect" responsible for debris extrusion from the apex. It also provides a better penetration of root canal irrigants.

The result of this study showed that 37 canals in group 1 (92.5%) and 35 canals in group 2 (90%) showed change in apical first file diameter. Only 3 canals in group 1 (7.5%) and 5 canals in group 2 (10%) kept the same size after flaring. In group 1, mean diameter of FFFAb was 12.30×10^{-2} (±4.31) mm which changed to 18.83 $(\pm5.91)\times10^{-2}$ mm after flaring, whereas in group 2, mean diameter of FFFAb and FFFAa was 10.58 $(\pm2.56)\times10^{-2}$ mm and 18.25 $(\pm5.94)\times10^{-2}$ mm respectively. In both group, the file size increased by approximately one file size after flaring. This is in accordance with a study previously reported by Tan and Messer[16] who used 121 canals from 60 extracted intact human maxillary and mandibular premolars and molars and showed that flaring of the cervical and middle thirds of the canal had an impact on apical sizing with an average increase of 5.3×10^{-2} mm. Results of this study are also supported by Pecora et al[17] where they concluded that preflaring of the cervical and middle thirds of the root canal improved anatomical diameter determination.

Results of our study suggested that by removing the cervical interference, it was possible to insert a larger file size to the apical constricture. This was also confirmed by a previous finding of Leeb[18] where human maxillary and mandibular molars were used to determine the effect of orifice enlargement prior to biomechanical canal preparation and who found that when this was accomplished, a larger file could be passed to apex and comparatively more easily. This was attributed to the canal interference and the curvature, factors that govern a clinician's ability to sense apical diameter with file.

In our study, out of 80 canals, the diameter of canal at WW before flaring was in the range of #8 to #15 k-file size in 74 canals, i.e., 92.5% cases, whereas after flaring it was in the range of #15 to #25 K-file size. Based on this result, it can be attributed that coronal flaring helps in proper determination of WW. If one considered that canals tend to be less than round, it is appropriate to enlarge at least a couple of file sizes in an effort to clean and shape the entire space.

Data from this study suggest that mesial canals of mandibular molars should be enlarged more than previously accepted. The increase in file size after flaring can be explained realizing that within a canal, irregularities and curvature produce contact with the file and interfere with its progression toward the apex. Early flaring, regardless of the method used, removes these contacts, opens the space, and reduces file contact, thus a file progresses more easily toward the apex after flaring. After flaring, a file comes to stop only when the diameter of the canal begins to apply pressure against the instrument. Early flaring allows the operator to sense the canal size near the apex, not curvature and irregularities. This better sense of apical diameter provides information that should result in better control of biomechanical preparation. Early flaring offers several clinical advantages and it can be accomplished either by manual or by mechanical means. Mechanical (rotary) flaring reduces treatment time. Overenthusiastic use, inappropriate size, and excessive depths can result in lateral perforations, ledges, and instrument breakage.

Data revealed that coronal flaring is similar with GG and ProTaper system. This indicates that shaping files used in ProTaper system is as efficient as GG. This is in accordance with a study done by Contreras et al[19] where they used GG drills and Rapid Body Shapers for coronal flaring on mesial root of 50 mandibular molars. This observation is explained by the fact that both systems shape the coronal two-thirds of the canal and remove contacts that when present provide resistance and change the operator's ability to pass a file to the apex. Both systems remove canal interference and allow the file to contact mostly in apex and give the clinician a different sense of resistance plus an ability to place a larger file to the apex.

Early coronal flaring not only allows better sense of apical constricture and diameter, it may also facilitate cleaning by allowing the irrigants to work deeper, more quickly, and more effectively into the apical third region. The concept of apical enlargement is still poorly understood. To date, no study has shown the influence of apical enlargement on the success and failure of endodontic treatment. The feasibility of larger apical third preparation, especially in molars, should be investigated. Questions, such as whether the canals are cleaner with larger preparation and whether the roots are weaker if they are further enlarged still remain to be answered. No procedural errors like lateral perforations, ledges, or instrument failure were experienced in this study.

CONCLUSION

Within the limitation of this *in vitro* study, it can be concluded that cervical preflaring plays a vital role in reducing the discrepancy between initial file diameter and apical canal diameter. Traditional method of apical size determination may lead to a substantial underestimation of actual canal size. Early coronal preflaring offers substantial advantages for more accurate apical sizing, with clinical implications regarding the adequacy of apical enlargement and debridement. Both ProTaper and GG drills are equally effective in coronal preflaring.

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