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Relationship between Files that Bind at the Apical Foramen and Foramen Openings in Maxillary Central Incisors - A SEM Study

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Considering that instrumentation of the apical foramen has been suggested for root canal infection control, this study analyzed the relationship between the files that bind at the apical foramen and the foraminal openings in 50 maxillary central incisors. After preparation of the pulp chamber, access to the canal was obtained with #1 and 2 LA Axxess and K-files with tip cut were inserted up to the apical foramen until binding was felt. The files were fixed with methyl cyanoacrylate and the tooth-file sets were cross-sectioned 10 mm short of the apex. Scanning electron microscopic analysis was carried out and files and foraminal areas were measured using Image Tool software. Statistically significant difference ($p<0.0001$) was found between files and the apical foraminal areas. The mean foraminal area was 3.8 times larger than the mean file area. The results of this study suggest that it would require 4 files of greater size beyond the one that bound to the foramen in order to allow a better relationship between files and apical openings of maxillary central incisors.

Key Words: Apical foramen, apical patency, infection control, root canal instrumentation.

INTRODUCTION

Inaccessibility to apical constriction and preoperative presence of periradicular lesion are significant factors related to outcome, increasing the risk of root canal therapy failure (1).

Debridement of the root canal by instrumentation and irrigation is considered the most important single factor in the prevention and treatment of endodontic diseases (2). Instrumentation should go apically enough to eliminate or at least reduce bacterial load (3).

The presence of microorganisms in the cemental canal and their participation in the development of periapical lesions has been well demonstrated (4,5) and therefore this part of the radicular anatomy should not be overlooked during root canal therapy.

Apical patency consists of the passive use of a small size file through the apical constriction without enlarging this region (6). Despite the fears in the past with apical foramen handling (7), this has been recently proposed (7,8).

While some authors (3,7,9) believe that apical patency promotes cleaning of the cemental canal, others (10,11) raised the question of how can this procedure clean properly using an instrument with smaller diameter than that of the apical foramen.

With the understanding that cleaning should involve mechanical action on the walls of the cemental canal, the question of which file could play this role arises. It is possible that an appropriate instrument would

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be the one that binds at the apical foramen.

There is no information on this topic in endodontic literature. The aim of this study was to analyze the relationship between the files that bind at the apical foramen and the apical foramen openings in maxillary central incisors by scanning electron microscopy.

MATERIAL AND METHODS

Fifty human maxillary central incisors with complete root formation from the tooth bank of the Dental School of the Bahiana School of Medicine and Public Health were used. Inclusion criteria were lack of complex anatomy, acute curves, incomplete root formation and apical resorption, observed by means of direct examination and periapical radiographs. This study was approved by the Ethics Committee of the University of Ribeirão Preto (Protocol #124/09).

Access and preparation of the pulp chamber were carried out with a #3 carbide round bur (KG Sorensen, Cotia, SP, Brazil) and Endo-Z bur (Maillefer, Ballaigues, Switzerland). Root canals were explored with a size 15 K-file (MMDF, Burges, France) with watch-winding motion until the tip was visible at the apical foramen and root length was determined at this stage.

Line access was performed with #1 and 2 LA Axxess (SybronEndo, Glendora, CA, USA), which correspond to 20/.06 and 35/.06 file tips, 4 mm short of root length with concomitant irrigation with 1 mL 2.5% sodium hypochlorite (Q-Boa; Indústrias Anhembi S/A, Osasco, SP, Brazil). Foraminal patency was re-established with a #15 K-file, and an ascending size sequence of K-files (MMDF) was inserted within the root canal with gentle watch-winding movements until the file would feel fitting snugly at the apical foramen. Size was recorded, the instrument was removed and the tip cut and flattened at D1 with a double-face diamond disk (KG Sorensen) to allow better conditions of area measurement. Files were maintained close to the respective teeth.

Roots were cross-sectioned 10 mm short of the apex and the respective files re-inserted until they reached the foramen. The files were fixed to the roots with methyl cyanoacrylate and following setting they were cut at the same level of the roots.

Roots were fixed in stubs and gold sputtered, as previously reported (12), and a scanning electron microscope (Philips XL-30; Philips, Eindhoven, Netherland) was used at 140× magnification to map the contour of the foramen together with the flattened tip of the file. Images were captured digitally and analyzed by one observer, which performed 3 measurements of each file tip area and other 3 measurements of each apical foramen area, at different day intervals, using the Image Tool software (The University of Texas Health Science Center, San Antonio, TX, USA) (Fig. 1). The mean values were recorded.

Statistical analysis was run using InStat software (GraphPad Software Inc., San Diego, CA, USA), and normal distribution was confirmed by Kolmogorov-Smirnov test. Student's t-test was performed at α=0.01.

RESULTS

The files that fitted at the apical foramina

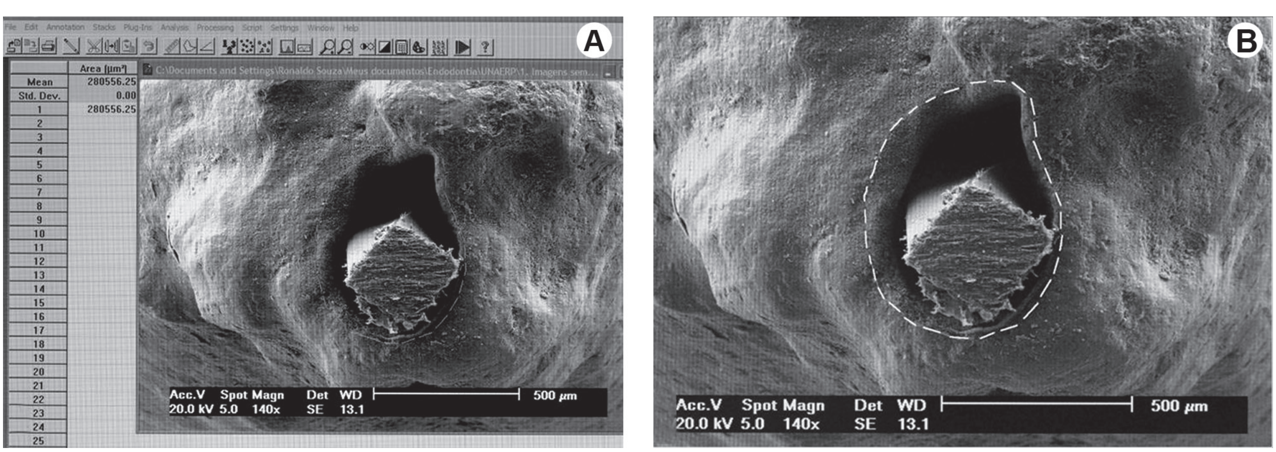

Figure 1. Measurement of the apical foramen area using the Image Tool Software. A= Observe the line demarcating the foraminal area; B= Same image as in A seen in detail.

presented great discrepancy in relation to the foraminal openings (Fig. 2).

Table 1 shows the mean values of the area for each apical foramen opening and file tip cross-section and the discrepancy between them (μm^2). As these mean values were obtained from 3 measurements for each foraminal area and 3 for each file area, Lin's Concordance Correlation Coefficient was used to verify their reproducibility. High concordance was obtained. The coefficient was superior to 0.99 in all comparisons.

Table 2 shows the mean values for file tips and apical foramina, with standard deviation, as well as the range of values and the medians. The mean area of foraminal opening was 281,341 μm^2, 3.8 times greater than the file mean area, which was 76,129 μm^2 (Table 2). Comparison of mean values by the Student's t-test demonstrated significant difference ($p<0.0001$). The mean discrepancy between the areas of foraminal opening and file tip was 205,212 μm^2 ± 80,293.

DISCUSSION

Constriction area or CDC junction is the site where working length is ideally set (13,14). It is also known as minor foramen (15). Beyond CDC junction, cemental canal diverges its walls and ends at the external root portion, the foraminal opening, where it reaches its greater diameter. For this reason, it is also known as major foramen (13,15). The apical foramen is the round or circumferential extreme of the root, acting as a funnel or crater, which differentiates from the terminus of the cemental canal of the root surface (15).

Current literature demonstrates that instruments that bind at the apical constriction actually do not express

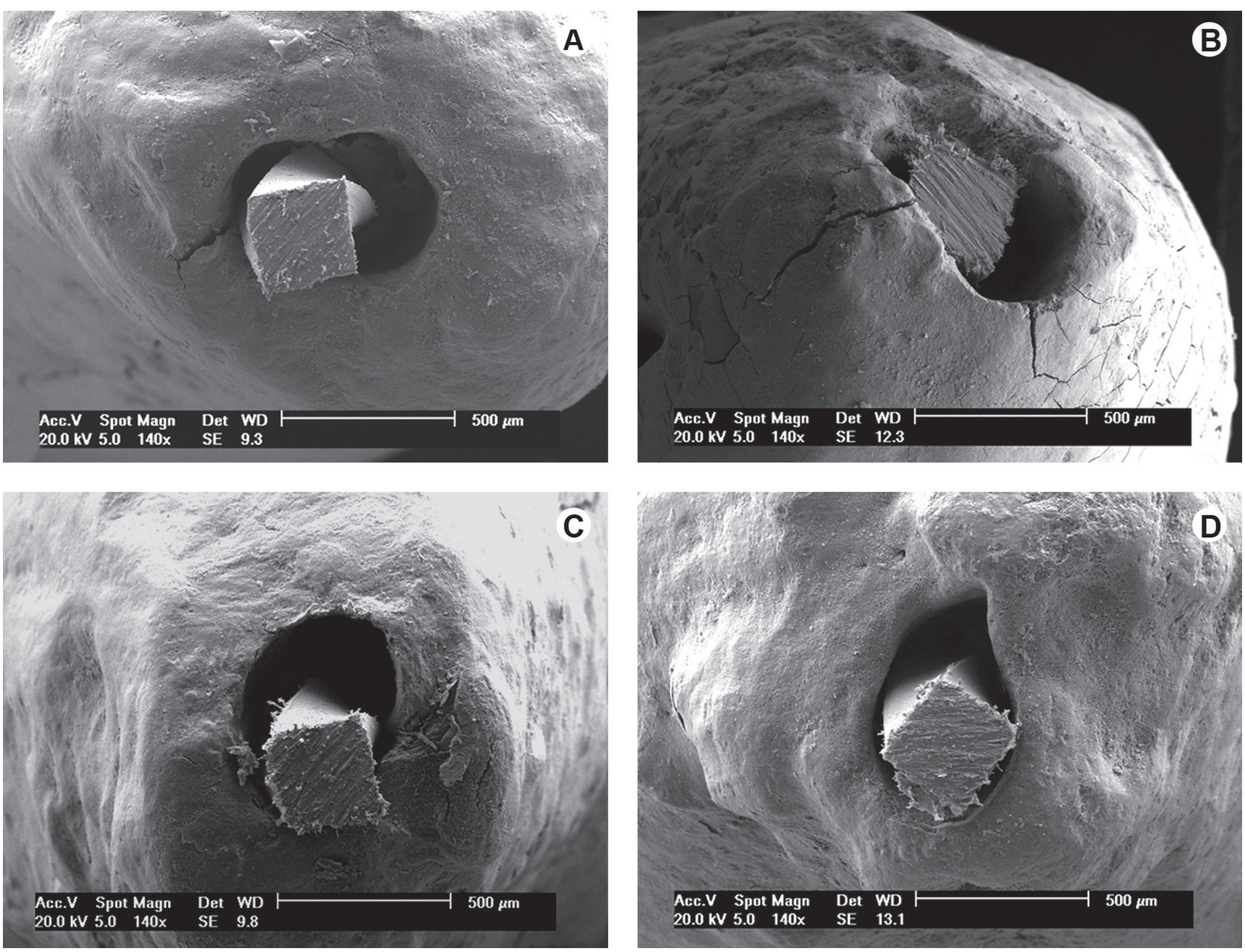

Figure 2. SEM micrographs of the files in the apical foramen. A-D = Note the great discrepancy between K-files and foramina (Original magnification 140×). The tips of files were cut at D1 for area measurement.

its real anatomic diameter. On the contrary, a discrepancy will exist between them (16).

If the instruments that bind at the apical constriction (minor foramen) actually show discrepancy with the convergent walls of the dentinal canal, when they reach the cemental canal there is a tendency to enhance this discrepancy because of its divergent walls, particularly at the apical foraminal opening (major foramen). This discrepancy can be observed in Figure 2 and Tables 1 and 2.

The tips of the files were cross-sectioned at D1 in this study to allow more reliable measurements. If the discrepancy was great at D1 (Fig. 2), it can be speculated that it would be even greater at D0. In the clinical condition it is the final 1 mm of the file that will be in the cemental canal.

Enlargement of the root canal is justified for mechanical (shaping) and biological (cleaning) reasons (17-19). The apical foramen instrumentation may be more favorable to the healing of chronic periapical lesions (20) because, exerting a mechanical action on cemental canal walls, it probably reduces bacteria load from the apical foramen and promotes a better infection control, the basis for success in Endodontics.

Considering that the files that bind at the apical foramen do not touch the divergent walls of the cemental canal (Fig. 2), it is possible that infection control is not properly carried out in some cases. Therefore, apical patency does not represent an effective foraminal cleaning procedure, as assumed by some authors (3,7,9), and the patency file would not remove significant amount of debris (13).

According to Butler (21), the apical foramen

Table 1. Areas of each apical foramen opening and file tip cross-section and discrepancy between them (µm²).

Tooth	Foramen	File	Discrepancy	Tooth	Foramen	File	Discrepancy
1	177,312	35,355	141,957	26	233,527	60,526	173,001
2	340,439	40,370	300,069	27	209,901	68,490	141,411
3	129,883	30,417	99,466	28	273,435	73,030	200,405
4	100,205	36,259	63,946	29	206,449	92,338	114,111
5	202,218	37,387	164,831	30	283,151	93,506	189,645
6	184,545	62,098	122,447	31	327,799	88,735	239,064
7	173,465	64,281	109,184	32	320,594	73,774	246,820
8	232,615	47,309	185,306	33	317,543	95,158	222,385
9	250,354	44,516	205,838	34	325,093	94,484	230,609
10	235,252	53,183	182,069	35	316,650	87,223	229,427
11	258,793	52,129	206,664	36	280,201	88,578	191,623
12	206,411	53,707	152,704	37	263,429	91,528	171,901
13	131,331	53,740	77,591	38	297,795	65,503	232,292
14	330,717	52,783	277,934	39	271,024	93,964	177,060
15	200,318	51,733	148,585	40	519,178	104,271	414,907
16	277,604	62,108	215,496	41	284,553	98,318	186,235
17	157,588	64,706	92,882	42	339,843	101,899	237,944
18	235,990	69,868	166,122	43	424,405	108,330	316,075
19	271,507	72,667	198,840	44	391,722	92,512	299,210
20	242,166	75,891	166,275	45	307,832	104,791	203,041
21	247,291	66,467	180,824	46	421,181	125,574	295,607
22	301,207	72,137	229,070	47	555,559	117,455	438,104
23	202,338	70,536	131,802	48	409,432	135,827	273,605
24	202,697	67,428	135,269	49	440,601	115,822	324,779
25	256398	75,540	180,858	50	497,498	122,201	375,297

Table 2. Mean values and standard deviations of foraminal area and file tip area (µm²).

	Mean (SD)	Range	Median
Foramen	281,341 ± 98,205	100,205-555,559	271,266
File tip	76,129 ± 25,677	30,417-135,827	72,402

should be instrumented with a file that fits closely the constriction of the canal and be followed by the next two of its type in series and size. However, as in dentinal canal, instrumentation of the cemental canal should not follow rigid pre-established principles, but rather, each clinical situation should be individually examined (22).

The results of this study suggest that it would require 4 files of greater size beyond the one that bound to the foramen in order to allow a better relationship between files and apical openings of maxillary central incisors. However, these results apply to maxillary central incisors and further research including other groups of teeth is needed.

RESUMO

Uma vez que a instrumentação do forame apical tem sido sugerida para o controle de infecção do canal radicular, este estudo analisou a relação entre as limas que se ajustam no forame apical e a abertura foraminal em cinquenta incisivos centrais superiores. Após o preparo da câmara pulpar, foi feito o acesso radicular com as brocas LA Axxess #1 e 2 e limas K com a ponta cortada foram inseridas até que oferecessem a sensação tátil de ajuste no forame apical. Foram fixadas com cianoacrilato de metila e o conjunto dente-lima foi seccionado a 10 mm aquém do ápice. Foi feita a microscopia eletrônica de varredura e as áreas das limas e dos forames foram medidas por meio do Image Tool software. A análise estatística demonstrou diferença significante entre as áreas das limas e dos forames ($p<0,0001$). A média da área dos forames apicais foi 3,8 vezes maior que a das limas. Os resultados deste estudo sugerem que seriam necessários 4 instrumentos de calibre maior além do que se ajustou para que haja melhor relação entre as limas e as aberturas foraminais nos incisivos centrais superiores.

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