Analysis of the Internal Anatomy of Maxillary First Molars by Using Different Methods

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Abstract

The success of endodontic treatment depends on the identification of all root canals so that they can be cleaned, shaped, and obturated. This study investigated internal morphology of maxillary first molars by 3 different methods: *ex vivo*, clinical, and cone beam computed tomography (CBCT) analysis. In all these different methods, the number of additional root canals and their locations, the number of foramina, and the frequency of canals that could or could not be negotiated were recorded. In the *ex vivo* study, 140 extracted maxillary first molars were evaluated. After canals were accessed and detected by using an operating microscope, the teeth with significant anatomic variances were cleared. In the clinical analysis, the records of 291 patients who had undergone endodontic treatment in a dental school during a 2-year period were used. In the CBCT analysis, 54 maxillary first molars were evaluated. The *ex vivo* assessment results showed a fourth canal frequency in 67.14% of the teeth, besides a tooth with 7 root canals (0.72%). Additional root canals were located in the mesiobuccal root in 92.85% of the teeth (17.35% could not be negotiated), and when they were present, 65.30% exhibited 1 foramen. Clinical assessment showed that 53.26%, 0.35%, and 0.35% of the teeth exhibited 4, 5, and 6 root canals, respectively. Additional root canals were located in this assessment in mesiobuccal root in 95.63% (27.50% could not be negotiated), and when they were present, 59.38% exhibited 1 foramen. CBCT results showed 2, 4, and 5 root canals in 1.85%, 37.05%, and 1.85% of the teeth, respectively. When present, additional canals showed 1 foramen in 90.90% of the teeth studied. This study demonstrated that operating microscope and CBCT have been important for locating and identifying root canals, and CBCT can be used as a good method for initial identification of maxillary first molar internal morphology. *(J Endod 2009;35:337–342)*

Key Words

Anatomic variations, CBCT, maxillary first molars

Knowledge of dental root internal morphology has been a complex and extremely important issue regarding the planning and execution of endodontic therapy. The several anatomic variations that might exist in the root canal system have contributed to endodontic treatment failures (1). Maxillary first molars have exhibited a frequent radicular anatomy of 3 roots and 3 or 4 canals (2). Besides that, their roots could be ovoid, which has increasingly interfered in the visualization and detection of additional canals especially during radiographic procedures. Historically, many studies have assessed the main characteristics of all dental groups; however, maxillary molars have been particularly studied as a result of their more complex root canal morphology.

The occurrence of 2 root canals in the mesiobuccal (MB) root of maxillary molars has been reported as greater than 50% by Pécora et al (2), Weine et al (3), and Pineda and Kutler (4). Although the majority of maxillary molars have exhibited 3 or 4 root canals, the literature has shown differences in this anatomic pattern. Martinez-Berna and Ruiz-Badanelli (5) reported 3 cases in which the maxillary first molars had presented 6 root canals (3 in MB, 2 in distobuccal [DB], and 1 in palatine root). Favieri et al (1) also showed a similar occurrence in the MB root and reported the difficulty of handling such cases. The occurrence of 2 canals in DB roots has been less frequent and has been reported in 3.6% of maxillary molars (4). Palatine root canal variations were well-established by Christie et al (6), who reported the endodontic treatment of maxillary molars with 2 palatine roots and classified these teeth as types I, II, and III, according to root degree of divergence.

Currently, technological advances have been developed and different techniques have been introduced to facilitate the assessment of internal anatomic variations of dental roots. For this purpose, operating microscope usage in daily clinic could potentialize and facilitate the localization and handling of additional canals as a result of a lighter and significantly higher magnification of the field of view (7–9). Magnification could therefore increase the detection of additional canals. Studies have shown that when the operator experience had been increased as a result of regular use of an operating microscope, the prevalence of detection of additional canals increased to 93% (10).

Cone beam computed tomography (CBCT) system was developed for evaluating hard tissues to assist oral and maxillofacial diagnosis and implant planning. On the other hand, this system has been very useful in particular endodontic problems (11) as a result of identification of anatomic features and variations of the root canal system, because endodontic diagnosis and treatment planning have been difficult to handle with 2-dimensional radiographs. Patient's radiation exposure to a conventional CT has been approximately 100–300 microsieverts (μSv) for maxilla and 200–500 μSv for mandible (12). Nevertheless, the radiation exposure (for both maxilla and mandible) to CBCT has been 34–102 μSv, which has depended on the exposure time and scan resolution (13). Accordingly, CBCT has exhibited a low effective dose and produced undistorted 3-dimensional information of the maxillofacial skeleton as well as

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TABLE 1. *Ex Vivo*, Clinical, and CBCT Frequency of the Number of Root Canals in the Maxillary First Molars

No. of canals	*Ex vivo* frequency (140)	Clinical frequency (291)	CBCT frequency (54)
2			1 (1.85%)
3	45 (32.14%)	134 (46.04%)	32 (59.25%)
4	94 (67.14%)	155 (53.26%)	20 (37.05%)
5		1 (0.35%)	1 (1.85%)
6		1 (0.35%)	
7	1 (0.72%)		

CBCT, cone beam computed tomography.

3-dimensional images of the teeth and their surrounding tissues. The relationship among anatomic structures such as the maxillary sinus and inferior dental nerve regarding root apices, root fractures, and root canal anatomy could be clearly visualized (14).

The aim of this study was to evaluate internal morphology of maxillary first molars by *ex vivo* and clinical assessments by using operating microscope and CBCT.

Material and Methods

Ex Vivo Assessment

One hundred forty maxillary first molars were randomly selected and collected among several thousand extracted teeth from the Dental School's teeth bank of Positivo University and stored in 1% thymol solution until usage. Initially, root canal access was performed, and canals were negotiated by using #08 and #10 K-files (Maillefer, Ballaigues, Switzerland). The morphologic features (location and number of canals) were analyzed by an endodontist who used an operating microscope at 18× magnification and were recorded by photographs and radiographs. All additional canals were recorded, even if they could not be negotiated up to complete root length. In this case, these canals were classified as difficult to negotiate.

Some specimens that showed uncommon anatomic characteristics were selected and further investigated. For this purpose, the specimens were placed into a container with 5% sodium hypochlorite, which was changed daily, for 4 days. After that, the specimens were washed in tap water and placed into a 5% hydrochloric acid solution for decalcification, which was also changed daily, for 4 days. After decalcification, the specimens were again washed in tap water and submitted to dehydration in alcohol (80%–100%). Next, a mixture of gelatin and India ink was injected into the root canals, and specimens were cleared in methylsalicylate. Finally, the specimens were subjected to anatomic assessment to confirm the number of canals and foramina by using an operating microscope under 4× magnification.

Clinical Assessment

In the clinical assessment, the records of the endodontic treatments performed by undergraduate students from the Dental School of Positivo University during 2006 and 2007 were used. All students enrolled in the project were monitored by an endodontist. Operating microscope was only used for detecting root canal number and morphology. Two hundred ninety-one first molars were submitted to endodontic treatment (127 right and 164 left). During these treatments, radiographic and photographic records of all teeth and patients were completed. During data assessment, the number of canals and their locations and variations were evaluated. The root canals that fused after cleaning and shaping were also registered.

CBCT

This assessment sample comprised the patients who had undergone CBCT analysis (i-CAT; Imaging Sciences International, Hatfield, PA) by using axial, coronal, and sagittal images because of several dentistry reasons, mainly implant planning. Therefore, the date of the laboratory was examined, and from several thousand exams, 54 maxillary first molars without endodontic treatment were randomly selected (25 right and 29 left). These assessments were performed by a dental radiologist.

To access data reliability, an intraexaminer calibration based on anatomic diagnosis of CBCT images was previously performed. The dental radiologist, who was helped by an experienced endodontist, examined 10 different CBCT images of maxillary first molars. These images were previously selected and showed first maxillary molars with different morphologies (3, 4, and 5 root canals). The dental radiologist evaluated the images twice, with a 1-week interval between the assessments. Reliability data were accessed by kappa test.

The CBCT unit of this study used a gray scale of 12 bits and had a voxel size of 0.2 mm. During this assessment, the number of canals and their locations and variations were recorded.

Results

Because each method used a different sample of maxillary first molars, data were only submitted to descriptive statistical analysis.

Ex Vivo Assessment

Table 1 shows the frequency of the number of root canals found in the 140 maxillary first molars. The most frequent number found was 4 canals followed by 3 canals, which represented 67.14% and 32.14%, respectively, of all teeth studied. Only 1 tooth showed 7 root canals. Table 2 presents the characteristics of the additional canals. These canals were preferentially located in the MB root (92.85%), whereas 7.15% were located in DB and palatine roots. When the additional canal was present, 70.40% had only 1 foramen, whereas 12.25% had 2 foramina. In 17.35% of the maxillary first molars, the MB2 could not be negotiated up to the whole root length. Two teeth showed 2 palatine roots, and 2 canals showed 2 independent foramina. In the molar that presented 7 canals, 3 MB canals, 3 DB canals, and 1 palatine canal (Figs. 1 and 2) were identified; however, all roots showed 1 foramen each.

Clinical Assessment

Table 1 shows the number of root canals in the 291 maxillary first molars. Four and 3 canals were again the most frequent pattern found, which represented 53.26% and 46.04%, respectively, of all teeth studied in this assessment. Two molars showed both 5 and 6 canals, which represented 0.70% of all teeth. Table 2 presents the characteristics of additional canals. These were preferentially located in MB root (95.63%), whereas 4.37% were located in DB and palatine roots. When the additional canal was present, 63.12% showed only 1 foramen, whereas 9.37% showed 2 foramina. In 27.50% of the teeth, the MB2 could not be negotiated up to the whole root length. In the tooth that showed 6 canals, 2 canals were located in MB root, 2 in DB root,

TABLE 2. *Ex Vivo*, Clinical, and CBCT Characteristics of the Additional Canals in the Maxillary First Molars

Root canals	*Ex vivo* (98)	Clinical (160)	CBCT (22)
MB2 foramina	10 (10.20%)	14 (8.75%)	1 (4.55%)
MB, 1 foramen	64 (65.30%)	95 (59.38%)	20 (90.90%)
DB, 1 foramen	5 (5.10%)	6 (3.75%)	
Palatine, 2 foramina	2 (2.05%)	1 (0.62%)	1 (4.55%)
MB, difficult to negotiate	17 (17.35%)	44 (27.50%)	
Canals fused after cleaning and shaping		35 (21.88%)	
Total MB	91 (92.85%)	153 (95.63%)	21 (95.45%)
Total, 1 foramen	69 (70.40%)	101 (63.12%)	
Total, 2 foramina	12 (12.25%)	15 (9.37%)	2 (9.10%)

CBCT, cone beam computed tomography.

and 2 in palatine root, and only the P root presented in independent foramina. In the tooth that showed 5 canals, 2 canals were located in MB root, 2 in DB root, and 1 in palatine root (Figs. 3 and 4).

CBCT Study

Kappa test values for intraexaminer variability were greater than 0.78. Table 1 shows the number of root canals found in the 54 maxillary first molars. The most frequent pattern found was 3 canals followed by 4 canals, which represented 59.25% and 37.05%, respectively, of all teeth in this assessment. Two anatomic variations (2 and 5 canals) were found (3.7%). Table 2 presents the location of additional canals. These were preferentially located in MB root (95.45%), whereas 4.55% were located in the palatine roots. When an additional canal was present, 90.90% showed only 1 foramen, whereas 9.10 % showed 2 foramina. In the tooth that presented 2 canals, one canal was located in buccal root and the other one in palatine root (Fig. 5). However, in the tooth that showed 5 canals, 2 canals were located in MB root, 1 canal in DB root, and 2 canals in palatine root (Fig. 6).

Discussion

Prevalence of additional root canals has been reported and discussed by several authors, and a variety of study methods that has included radiographs, magnification, clinical evaluations, dye injection, tooth sectioning, and scanning electron microscopy have been used (15–17).

Regarding *ex vivo* assessment, Smadi and Khraisat (16) found a presence of 63.9% of 2 root canals in the MB root of molars (MB2), which was similar to the 67.14% found by this *ex vivo* assessment (92.85% in the MB2). Another important characteristic in MB root configuration has been the presence of 2 foramina, which were found in 12.25%, 9.37%, and 9.10%, respectively, of the teeth of this study's *ex vivo*, clinical, and CBTC assessments. These assessment results were discordant from those of Smadi and Khraisat, who reported a high frequency of the Vertucci (18) classification type IV (2 foramina) followed by type II (1 foramen). Still regarding the number of additional canal foramina, Degerness and Bowles (19) reported the frequency of accessory canals in MB roots of maxillary molars as well as the isthmus presence in these roots. These authors showed that 80% of MB accessory root canals were located within 3.6 mm of the tooth apex, and the incidence of type I isthmus (root without isthmus tissue) was most noticeable close to the apex. Furthermore, these findings could corroborate the data of the present study, because the apical tendency has been toward a more rounded shape; consequently, dental roots have shown 1 canal and foramen.

Regarding clinical assessment, Corcoran et al (20) evaluated the effect of the operator experience on the localization of additional canals in maxillary molars. Their results showed that the percentage of 4 canals that had been located by junior and senior residents was 37.1% and 62.1%, respectively. These were different from the results of this study (53.26%); however, the endodontic treatments of this research were performed by undergraduate students. Still regarding clinical assessment, 95.63% of the additional canals were presented in MB root, which was concordant to literature (8, 21).

In the CBCT assessment, the frequency of additional canals was 37.05%, and 95.45% were located in MB root, and 90.90% exhibited only 1 foramen. Matherne et al (17) reported the superiority of CBCT over other diagnostic methods and suggested the simultaneous use of the operating microscope and CBCT in further studies. On the

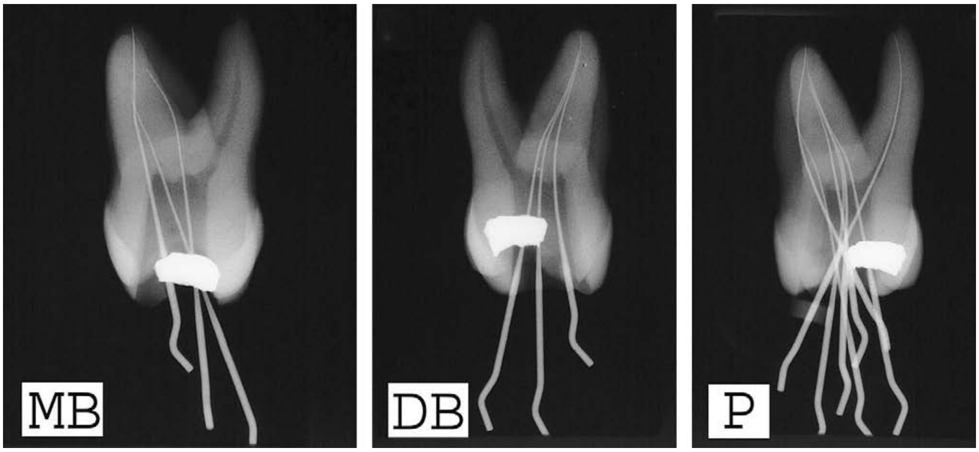

Figure 1. Maxillary first molar with 7 canals. Radiographic examination shows 3 canals in the MB root, 3 canals in the DB root, and 1 canal in the palatine root.

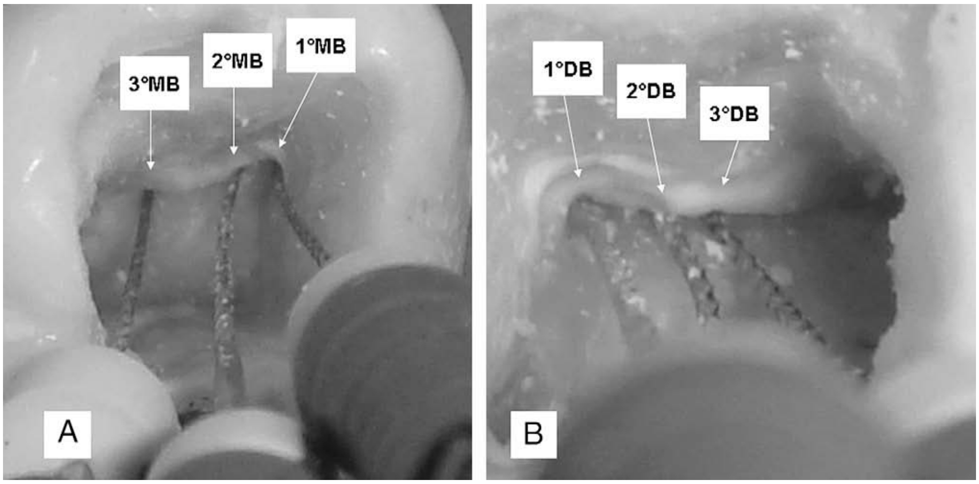

Figure 2. Maxillary first molar with 7 canals. (*A*) 3 canals in the MB root; (*B*) 3 canals in the DB root.

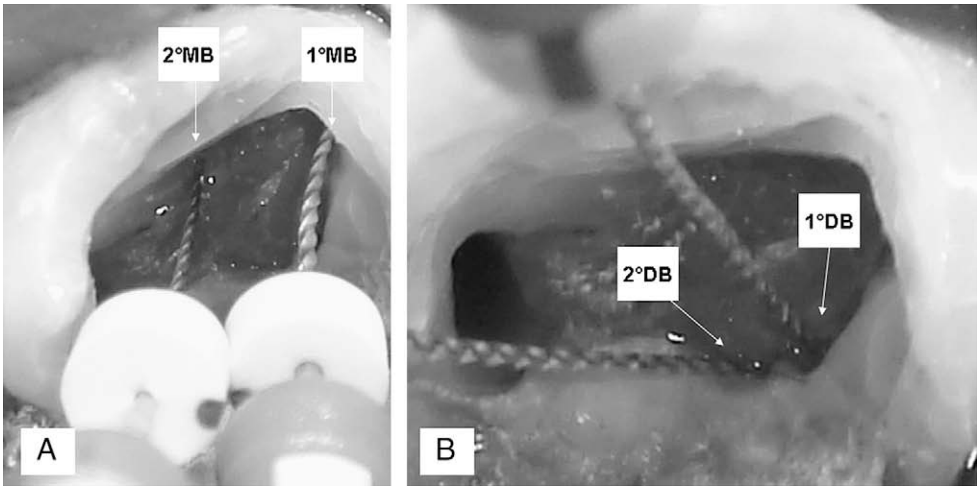

Figure 3. Maxillary first molar with 5 canals. (*A*) 2 canals in the MB root; (*B*) 2 canals in the DB root.

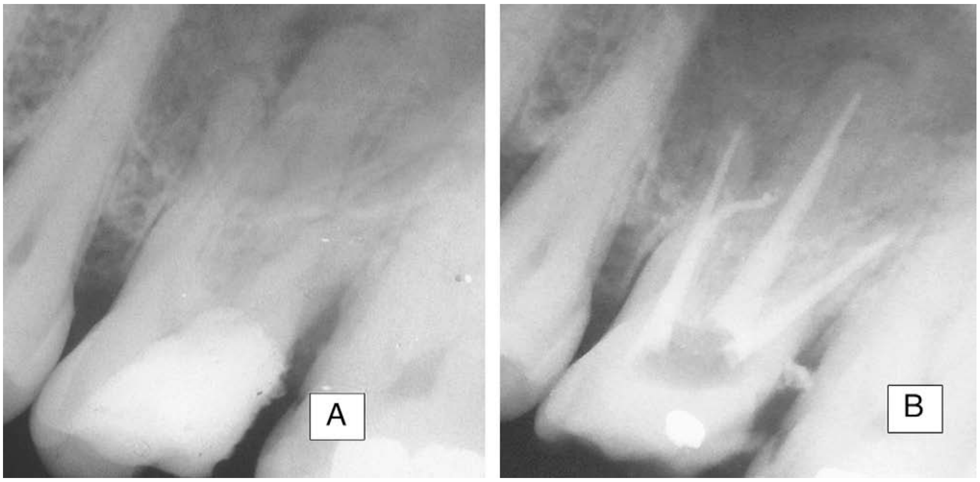

Figure 4. Maxillary first molar with 5 canals. (*A*) Initial radiograph; (*B*) final radiograph.

Figure 5. Maxillary first molar with 2 canals; CBCT's axial section.

basis of this idea, the use of this technology in patient's initial examination, as routine and/or in scientific studies similar to this present one, could probably increase the clinical findings, because intraoral radiographs have been relatively inaccurate for the assessment of the presence of additional canals in maxillary molars (15). Similarly, to increase the *ex vivo* assessment results, the association of a 3-dimensional computerized microtomography and the operating microscope would be more appropriate because this technology could provide more details of the root canal system (22).

Another relevant aspect of this present study was that the outcomes of root canals classified as difficult to negotiate were shown (presence of 17.35% in *ex vivo* assessment and 27.50% in clinical assessment). These outcome types have been normally excluded from research; however, they are important because such patterns occur in daily clinic practice and usually interfere with endodontic therapy. The difference exhibited between the *ex vivo* and clinical assessments could be explained by the fact that it was easier to manipulate an extracted tooth than to clinically handle it.

Figure 6. Maxillary first molar with 5 canals; CBCT's axial section.

Although variations in the fourth canal presence in DB root have been less frequent, they might be present (23), and they were also verified in this investigation. Therefore, such variations were found in 5.10% and 3.75%, respectively, of the cases in the *ex vivo* and clinical assessments. These results were very close to the 3.6% rate found by Pineda and Kutler (4).

In the *ex vivo* assessment, an uncommon morphology was also found in 1 tooth, which exhibited 7 canals. Similarly, the clinical assessment showed 2 uncommon teeth, one that had 5 canals and other with 6 canals. CBCT assessment showed one tooth with 5 canals and other where only 2 canals were found. Favieri et al (1), Beatty (24), and Ferguson et al (25) reported a maxillary first molar morphology that revealed 5 root canals (3 canals in MB root). Bond et al (26) also reported a maxillary first molar that showed 6 root canals (2 canals in MB root, 2 in DB root, and 2 in palatine root). These canal distributions were similar to the *ex vivo*, CBCT, and clinical assessments of this study.

Christie et al (6), Peikoff et al (27), Di Fiore (28), and Baratto Filho et al (29) stated that variations of maxillary molars' palatine root canals have had a relatively high frequency in the literature, and they could vary from 1–2 roots and 1–3 canals, as shown by Wong (30) and Maggiore et al (31). In this study's *ex vivo* assessment, 2 teeth that presented 2 palatine canals were found, whereas in clinical and CBCT assessments, only 1 tooth showed this variation. However, all these root canals could be classified as type I by Christie et al (6).

Within the limitations of this study, it can be concluded that the maxillary first molar teeth showed significant variations of their root canals. The location and identification of the root canals were facilitated by using an operating microscope and CBCT.

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