

Research Article

Research on Anatomy of the Pulp Chamber Floor of the Maxillary Second Permanent Molar in CBCT

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Abstract

Objective: The objective of this study was to examine the pulp chamber floor anatomy of the maxillary second permanent molar in Chinese individuals by using Cone-Beam Computed Tomography (CBCT). These data may facilitate endodontic treatment success.

Methodology: A total of 2505 CBCT images of maxillary second permanent molars were studied to evaluate the shape of the pulp chamber floor, the types of developmental root fusion lines (DRFLs), the number of canal orifices and their possible relationships.

Results: Three pulp chamber floor shapes were identified: triangular (50.3%), rhomboid (34.3%) and oval (15.4%). The shape of the DRFLs and the number of canal orifices on the pulp chamber floor were variable. The frequency of non branching DRFLs was 63.8%, followed by branching DRFLs (33.6%). The I-shaped DRFL group had more variations in the number and location of canal orifices.

Conclusion: The anatomy of the pulp chamber floor of the maxillary second permanent molar in Chinese individuals is diverse. Knowledge of variations in pulp chamber shape, types of DRFLs and canal orifice number of the maxillary second permanent molar can help reduce the risk of missing root canals in endodontic treatment.

Keywords: Maxillary second molar; CBCT; Pulp chamber floor; DRFL; Canal orifice

Introduction

A satisfactory outcome of Root Canal Treatment (RCT) is achieved after complete cleaning, shaping and obturating the root canal system. To accomplish this goal, a systematic understanding of pulp chamber floor anatomy and the root canal system is necessary [1]. The maxillary second permanent molar is located in the posterior corner of the dental arch. Variations in tooth morphology, a complicated root canal system, deposition of secondary dentin and limited operation space increase the difficulty of RCT. Anatomical variations in terms of morphology and number of roots and canals have been reported [2-22]. However, analysis of the pulp chamber floor anatomy of the maxillary second permanent molar is inadequate. Since the pulp chamber floor is the first impression of the root canal system, the study of the anatomy of the pulp chamber floor can help clinicians precisely locate the canal orifices and reduce the risk of missing root canals.

There are two approaches to studying the morphology of teeth, namely, invasive and noninvasive procedures. The number of samples associated with invasive procedures is limited, and teeth cannot be reused for further research. Conventional two-dimensional radiography is an important noninvasive tool for investigating root canal morphology and pulp chamber position. However, it is difficult to identify the number of canal orifices, the location of canal orifices on the pulp chamber floor and variations in the morphology of the root canal system with two-dimensional radiographs [2-6].

Currently, noninvasive and three-dimensional imaging approaches for studying tooth anatomy are widely performed. Cone-Beam Computed Tomography (CBCT) is one of the most favored methods for studying tooth morphology because the images produced by CBCT are as accurate as those obtained by clearing and modified staining methods [6], and they are produced with relatively lower doses of radiation and shorter working times [23].

The anatomy of the pulp chamber floor in multirouted teeth is complex. The canal orifices present as a dark mark with a funnel shape on the pulp chamber floor. The canal orifices are interconnected by grooves on the pulp chamber floor. These grooves were first described as "subpulpal grooves" and "depressions of the pulp chamber floor" [24]. Krasner and Rankow described subpulpal grooves as "Developmental Root Fusion Lines" (DRFLs), which are darker than the pulp chamber floor color. DRFLs may present as deep or shallow grooves, and the law of color change in the pulp floor is a better method for identifying DRFLs and orifices located on the pulp floor [25]. DRFLs are observed during direct observation of the pulp chamber floor and can be regarded as important trace marks for orifice location.

Although studies have noted the anatomical variations in the pulp chamber floor in the maxillary second permanent molar [2-22,26], the correlation between DRFLs and the orifice location on the pulp chamber floor has not been studied. The aim of this study was to investigate the shape of the pulp chamber floor of the maxillary

Table 1: Distribution of shapes of pulp chamber floor in maxillary second permanent molar.

Shape of pulp chamber	Triangular	Rhomboid	Oval
N (%)	1261 (50.3)	857 (34.3)	387 (15.4)

second permanent molar with CBCT and evaluate the types of DRFLs, the number of canal orifices and their possible relationships.

Materials and Methodology

A total of 2505 CBCT images of the maxillary second permanent molar from 1789 patients were obtained from the medical image center of ××Hospital of Stomatology, ××University, ××, P.R. China. The 3D Accuitomo CBCT machine (MCT-1[EX-2F], J. Morita Manufacturing Corp, Kyoto, Japan) used for the study produces images of 14-bit grayscale, 0.125 mm voxel size and 1 mm thickness. The teeth included had a closed apex, no restoration, and a history of RCT or periapical surgery. Examination of coronal, axial and sagittal sections of images was performed by moving the toolbar from the crown to the apex of the root to identify the shape of the pulp chamber, shape of the DRFLs, and site and number of root canal orifices on the pulp chamber floor. One-volume Data Viewer software (J. Morita Manufacturing Corp) was used by two endodontists to inspect the images.

Results

The age of the patients included in the study was between 15 and 84 years old, with an average age of 39.79 years. Among the 1789 patients, 871 (48.7%) were male, and 918 (51.3%) were female.

Shape of the Pulp Chamber Floor of the Maxillary Second Permanent Molar

The shape of the pulp chamber floor was studied at the level of the Cemento Enamel Junction (CEJ). Three shapes of the pulp chamber floor, namely, triangular, rhomboid and oval, were identified (Figure 1). The presence of a triangular-shaped pulp chamber floor was

found at a higher frequency (50.3%) than those for rhomboid-shaped (34.3%) or oval-shaped (15.4%) floors (Table 1).

Types of Drfls in the Maxillary Second Permanent Molar

1. The dark line on the pulp chamber floor was described as the DRFL. In this study, DRFLs were found in 2441 cases. According to their appearance, the DRFLs were divided into three types and six subtypes. **No DRFL:** a tooth without a DRFL because there was only one canal orifice in the chamber floor (Figure 2).

2. **Nonbranching DRFL:** A line starting from the palatal canal orifice end in the buccal orifice without producing any distributions. The line is identified as an I-shaped DRFL when it is a straight line from the palatal canal orifice to the buccal canal orifice (Figure 3A). If the line has some degree of angulation while passing forward, it is identified as a 7-shaped DRFL (Figure 4A) or inverted U-shaped DRFL (Figure 4F).

3. **Branching DRFL:** a line proceeding toward the buccal direction that splits into branches and passes forward to join the respective canal orifices, similar to a Y shape (Figure 5). While in the teeth with two palatal canal orifices, the two proceeding lines from each palatal canal orifice join together and divide or may proceed as a single line in the buccal direction to end in respective buccal canal orifices as an X-shaped DRFL (Figure 6A) and an inverted Y-shaped DRFL (Figure 6D).

The distributions of the different types of DRFLs on the pulp chamber floor in the maxillary second permanent molar are shown in Table 2. DRFLs were not found in 64 cases, which had only one canal orifice in the center of the chamber floor. Most teeth had a nonbranching DRFL (63.8%, 1598/2505), while 33.6% of all the cases showed a branching DRFL on the pulp chamber floor. For the nonbranching DRFLs, the 7 shape was found in the highest frequency (68.1%), followed by the I shape (31.0%) and inverted U shape (0.9%). Nearly 97% of the cases of branching DRFLs were Y-shaped DRFLs.

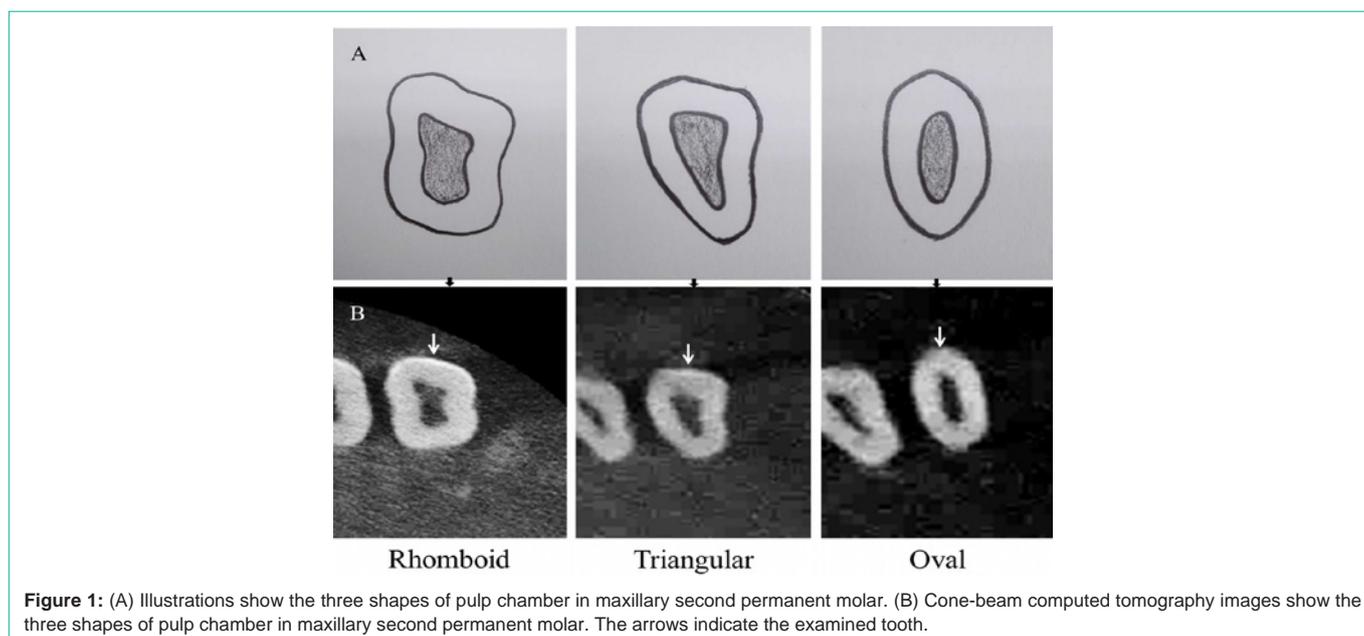


Figure 1: (A) Illustrations show the three shapes of pulp chamber in maxillary second permanent molar. (B) Cone-beam computed tomography images show the three shapes of pulp chamber in maxillary second permanent molar. The arrows indicate the examined tooth.

Table 2: Distribution of different types of DRFL on Pulp chamber floor in maxillary second permanent molar.

		Rhomboid	Triangular	Oval	Total	
No DRFL	64 (2.6%)	5	24	35		
Nonbranching DRFLs	1598 (63.8%)	I-shaped DRFL	97	127	271	495 (19.8%)
		7-shaped DRFL	504	561	24	1089 (43.4%)
		Inverted U-shaped DRFL	10	3	1	14 (0.5%)
Branching DRFLs	843 (33.6%)	Y-shaped DRFLs	215	546	56	817 (32.6%)
		X-shaped and Inverted Y-shaped DRFL	26			26 (1.0%)

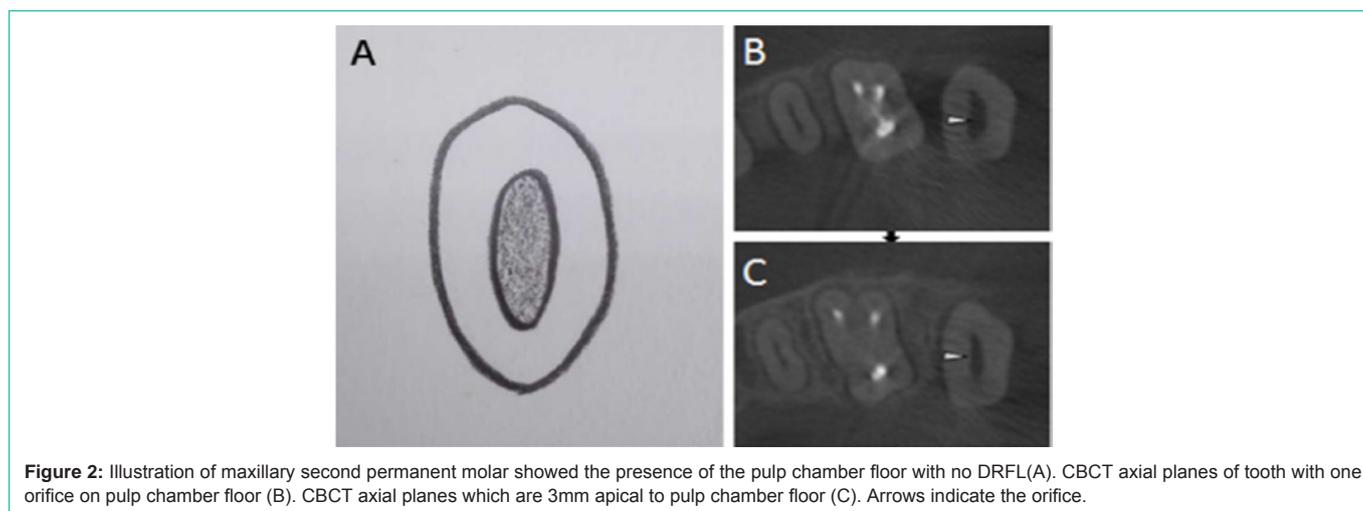


Figure 2: Illustration of maxillary second permanent molar showed the presence of the pulp chamber floor with no DRFL(A). CBCT axial planes of tooth with one orifice on pulp chamber floor (B). CBCT axial planes which are 3mm apical to pulp chamber floor (C). Arrows indicate the orifice.

Table 3: The distribution of Root Canal orifice in subtypes of DRFL.

	O1 (%)	P1 (%)				P2 (%)		
		B1	B2	B3	B4	B1	B2	B3
I-shaped DRFL		263 (53.1)	173 (35.0)	59 (11.9)	-	-	-	-
7-shaped DRFL		-	668 (61.3)	421 (38.7)	-	-	-	-
Inverted U-shaped DRFL	-	-	-	-	-	-	13 (92.9)	1 (7.1)
Y-shaped DRFL		-	710 (86.9)	106 (13.0)	1 (0.1)	-	-	-
X-shaped Inverted Y-shaped DRFL	-	-	-	-	-	1 (33.3)	22 (95.7) 2 (66.7)	1 (4.3)
Single orifice (no DRFL)	64 (100)							

O1: One canal orifice; P1: One palatal canal orifice; P2: Two palatal canal orifice; B1: One buccal canal orifice; B2: Two buccal canal orifices; B3: Three buccal canal orifices; B4: Four buccal canal orifices.

The chamber floor shape of all the cases with X-shaped and inverted Y-shaped DRFLs were classified as rhomboid. The 7-shaped and Y-shaped DRFLs were commonly present in cases of triangular-shaped pulp chambers. The chamber floors of more than 50% of the cases with I-shaped DRFLs and without DRFLs were identified as oval shaped.

Distribution of Root Canal Orifices in Cases of Different Types of Drfls

No DRFL

A single orifice was present in the center of the pulp chamber floor. For this case, there was only one canal orifice (Figure 2).

Nonbranching DRFL

I-shaped DRFL: The buccal end of the DRFL had variable numbers of canal orifice(s): either one buccal orifice (Figure 3D and

3E), two buccal orifices (Figure 3F and 3G) or three buccal orifices (Figure 3H and 3I). The canal orifices at the buccal end were close to each other. The palatal end had only one palatal canal orifice in this type. I-shaped DRFLs with a single buccal orifice had the highest prevalence (53.1%), followed by two buccal orifices (35%) and three buccal orifices (11.9%) (Table 3).

7-shaped DRFL: This type was subdivided into two categories noted by capital letters. A. The Mesiobuccal (MB), Distobuccal (DB) and Palatal (P) canal orifices were connected by deep grooves (Figure 4B and 4C), which were identified in 61.3% of the cases (Table 3). B. The 7-shaped DRFL consisted of the second Mesiobuccal (MB2)

Table 4: Number of Root Canal orifices in Maxillary second permanent molar.

The number of orifice	1	2	3	4	5
N (%)	64 (2.5)	263 (10.5)	1552 (62.0)	623 (24.9)	3 (0.1)

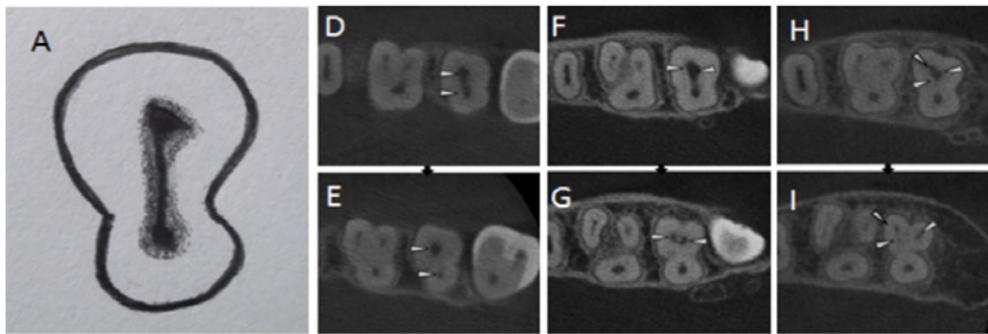


Figure 3: Illustration of maxillary second permanent molar showed the presence of I-shaped DRFL on pulp chamber floor (A). CBCT axial planes of tooth with four sub-types of I-shaped DRFL on pulp chamber floor (D, F, H). CBCT axial planes which are 3mm apical to pulp chamber floor for each of the sub-type (E, G, I). Arrows indicate the orifice and canal.

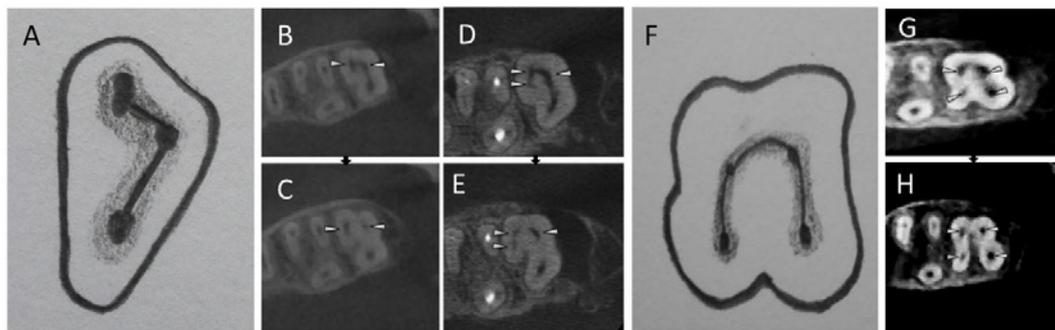


Figure 4: Illustration of maxillary second permanent molar shows the presence of 7-shaped DRFL (A) and inverted U-shaped DRFL (F) on pulp chamber floor. CBCT axial planes of tooth with two sub-types of 7-shaped DRFL (B, D) and inverted U-shaped DRFL (G) on pulp chamber floor. CBCT axial planes which are 3mm apical to pulp chamber floor for each of the sub-type (C, E, H). Arrows indicate the orifice and canal.

canal orifice as well as the MB, DB and P canal orifices (Figure 4D and 4E). According to our data, 38.7% of the cases showed three buccal orifices on the pulp chamber floor.

Inverted U-shaped DRFL

The second palatal orifice was present in all cases of this type (Figure 4F). A tooth with the second palatal (P2) canal orifice had a palatal bulge on the external surface of the tooth (Figure 4G and 4H). Therefore, all the cases with inverted U-shaped DRFLs had two palatal orifices. Most cases (92.9%) showed two buccal orifices. Only one case presented three buccal orifices.

Branching DRFL

A. Y-shaped DRFL: This DRFL passes from the palatal canal orifice and divides into mesial and distal branches. All the cases in this group had only one palatal canal orifice (Table 3). However, the ends of the buccal branches had a variable number of canal orifices. This group was subdivided into three categories noted by capital letter. The MB, DB and P canal orifices were connected by Y-shaped superficial (Figure 5B) or deep grooves (Figure 5E). A total of 86.9% of the cases in the Y-shaped DRFL group had two buccal orifices.

B. Four distinct canal orifices (MB, MB2, DB and P) were present on the pulp chamber floor. The location of the MB2 canal orifice was variable: it was located close to the MB canal orifice (Figure 5H and 5I) or at the junction of the line joining the MB and DB canal orifices (Figure 5J and 5K). A total of 13.0% of the cases in

the Y-shaped DRFL group had three buccal orifices.

C. Five canal orifices [MB, MB2, DB, second distobuccal (DB2) and P] were present on the pulp chamber floor. However, only one case in the Y-shaped DRFL group had four buccal orifices.

X-Shaped and Inverted Y-Shaped Drfls

In the X-shaped DRFL type, two palatal canal orifices (P and P2) were present on the pulp chamber floor. DRFLs stretch from both palatal canal orifices and join together before reaching the buccal side and connect the MB and DB canal orifices (Figure 6B and 6C). In some of the cases, the MB and DB canal orifices were located close to each other or were connected by deep grooves, and this type of DRFL formed an inverted Y-shaped pattern (Figure 6E). Most of the cases with the X-shaped and inverted Y-shaped DRFLs showed two buccal orifices and two palatal orifices. However, only one case in the X-shaped DRFL group had three buccal orifices, and one case in the inverted Y-shaped DRFL group had one buccal orifice (Table 3).

Most of the teeth had three canal orifices (62.0%, 1552 of 2505), followed by four canal orifices (24.9%, 623 of 2505) (Table 4). Among the teeth with four canal orifices, the incidences of the MB2 and P2 canal orifices were 94.1% (586/623) and 5.9% (37/623), respectively. The two canal orifice cases were all observed in the I-shaped DRFL group. In addition, there were three cases with five canal orifices on the pulp chamber floor. One of them had two root canal orifices in the mesial aspect (MB and MB2 canal orifices), two distal aspects (DB

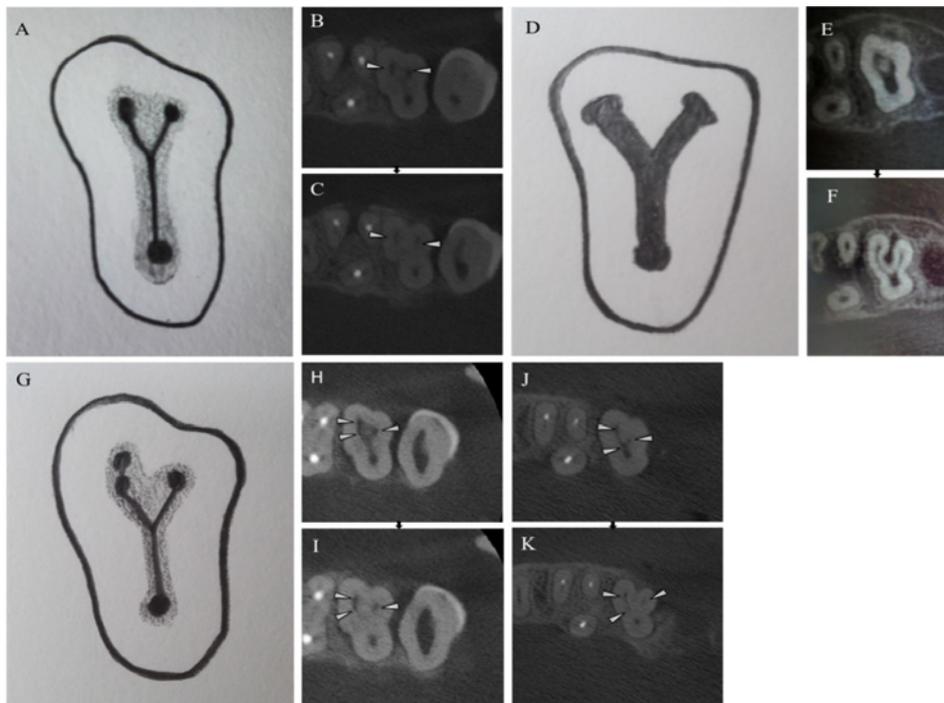


Figure 5: Illustration of maxillary second permanent molar shows the presence of Y-shaped branching DRFL on pulp chamber floor (A,D,G). CBCT axial planes of tooth with two sub-types of Y-shaped DRFL on pulp chamber floor (B,E,H,J). CBCT axial planes which are 3mm apical to pulp chamber floor for each of the sub-type (C,F,I,K). Arrows indicate the orifice and canal.

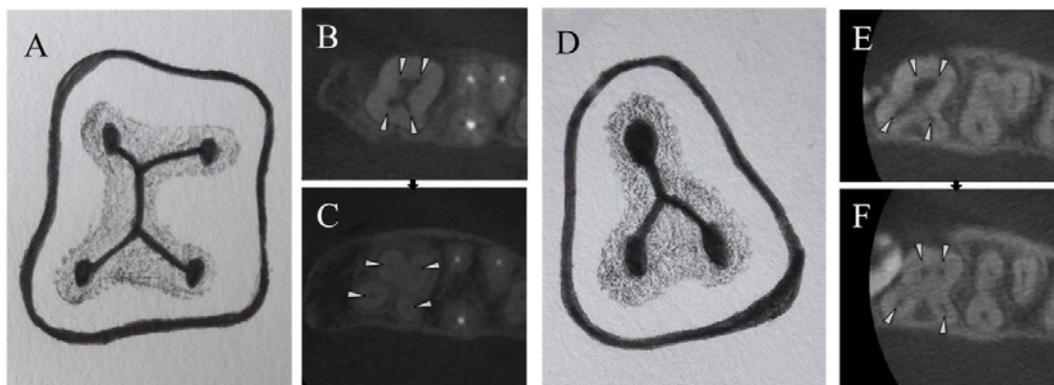


Figure 6: Illustration of maxillary second permanent molar shows the presence of X-shaped branching DRFL on pulp chamber floor (A). CBCT axial planes of tooth with X-shaped (B) and inverted Y-shaped (E) on pulp chamber floor. CBCT axial planes which are 3mm apical to pulp chamber floor for each of the sub-type (C,F). CBCT axial planes of tooth showing the bulge on cemento-enamel junction at palatal side indicate the presence of second palatal canal orifice on pulp chamber floor (B,E). Arrows indicate the orifice and canal.

and DB2 canal orifices) and one palatal canal orifice. The other two cases had one MB canal orifice, two distal canal orifices (DB and DB2) and two palatal canal orifices (P and P2).

Discussion

The objective of root canal therapy, eradication of bacteria from the root canal system and restoration of tooth function, can be achieved through cleaning, shaping and obturating the root canal system. Therefore, access preparation is the first and most important aspect of RCT. The ideal access provides an unimpeded passageway for an instrument to reach the apical foramen through the root canal of the tooth, which can facilitate adequate cleaning and shaping and

minimize the risk of instrument separation in the root canal during the procedure. The shape of the pulp chamber determines the shape of the access opening. It has been reported that the shape of the pulp chamber is 1, rhomboid shaped in teeth with four canal orifices, 2, triangular shaped in teeth with three canal orifices and 3, oval shaped in teeth with buccal and palatal canal orifices [27]. The findings of this study are consistent with our data in terms of the shape of pulp chambers. However, the CBCT images of the maxillary second molars in our study show the variable number of canal orifices on the floor of all three shapes of pulp chambers.

The correlation between DRFLs and canal orifice location on the pulp chamber floor of the maxillary second permanent molar has not

been reported before. The data in this study show a close relationship between DRFLs and the location of canal orifices. This relationship highlights the need to explore canal orifices on the pulp chamber floor along the DRFL during RCT. When a complete DRFL cannot be found during treatment, a canal may have been missed.

The number of canal orifices on the pulp chamber floor is variable in maxillary second permanent molars. According to our study, three canal orifices were present in 62% (1552/2505 cases) of the cases. Almost all three canal orifice cases showed two buccal orifices and one palatal orifice, except 1 case with one buccal orifice and two palatal orifices. This result is consistent with a previous study [26]. The most frequently encountered extra canal orifice was the MB2 canal orifice. MB2 was present in 23.4% (586/2505 cases) of the cases in our study, and this frequency is within the range of previously published papers [10-22]. These prevalence differences among different studies could be due to the type of study approach (in vivo vs. in vitro), the technique of studying root canal morphology (CBCT examination, modified canal staining and clearing technique, spiral computed tomography, and plain and contrast medium-enhanced digital radiography), or an ethnic difference.

The presence of a P2 canal orifice is a rare phenomenon, but its existence cannot be overlooked. The frequency of a P2 root canal in the maxillary second molar has been reported, and its prevalence ranges from 0.4% to 2.08% [7-9,28]. In this study, the P2 canal was only found in inverted-U-, X- and inverted-Y- shaped DRFL types and accounted for 1.6% (39/2505 cases) of all the cases. The pulp chamber of the maxillary second molar with two palatal canal orifices is wider on the palatal side, and the access opening must be rectangular in shape [29]. The preparation of conventional oval- or triangular-shaped access openings is a possible reason for missing the second palatal canal orifice during RCT. Therefore, knowledge about variation in pulp floor morphology is valuable for successful RCT. The presence of a third palatal canal has been reported once by Pasternak et al. [4]. In our study, no case with three palatal canals was found, but this possibility cannot be ignored during endodontic practice.

The preoperative analysis of the root canal system was performed by studying the intraoral radiographs. The radiograph produces a two-dimensional image, and the image of the tooth structure is frequently overlapped by adjacent tooth structures, increasing the possibility of misinterpretation of the image and misleading diagnosis. Studies have shown that more canal orifices can be located with magnification aids than with the naked eye [30-32], and CBCT images are free of limitations posed by conventional radiographs [33]. The CBCT scanner used for this study provides high-resolution images that are most suitable for the study of root canal orifice sites and morphology of the root canal system. Thus, the adoption of newer technologies and a better understanding of the anatomy of the pulp floor can ensure the success of RCT.

Conclusions

The maxillary second molar has variations in the shape of the pulp chamber floor, types of DRFLs, and location and number of canal orifices on the DRFLs. Our data can help locate the canal orifices of the maxillary second permanent molar and achieve good endodontic treatment results.

Acknowledgement

The authors deny any conflicts of interest.

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