Original Article

Root canal anatomy of maxillary first molars in a Turkish population using cone-beam computed tomography

Ömer Demirtaş[1], Şuayip Burak Duman[2]

Abstract

Objective: This study aimed to assess canal morphology of maxillary first molars by analyzing cone beam computed tomography (CBCT) images.

Methods: A total of 324 maxillary first molars were collected from the Turkish population and scanned using the in vitro CBCT method. The number of roots and canals, root canal configuration, canal shape, the presence of a C-shaped canal, apical delta, and lateral canal, as well as the distance between radiographic and anatomic apices were examined.

Results: The majority of the samples (97.9%) had 3 separate roots; while the remaining teeth had two or four roots (1.5% and 0.6% respectively). CBCT results showed 2, 3, 4, and 5 root canals in 0.3%, 47.9%, 50.3% and 1.5% of the teeth, respectively. All distobuccal (DB) and palatal (P) roots had one canal. The mesiobuccal (MB) roots frequently showed a second mesiobuccal canal (MB2). The most common canal morphology in the MB roots was type I (33.1%), followed by type II and type III (29.0% and 9.8%, respectively). The P and DB roots commonly showed a type I canal configuration. C-shaped canals were rare. The mean distances between radiographic and anatomic apices in MB, DB, and P roots were 0.77 ± 0.45, 1.68 ± 0.9 and 0.91 ± 0.46 mm, respectively.

Conclusions: The MB roots of maxillary first molars showed greater variations in their canal anatomy than other roots. These anatomical differences, potentially attributable to ethnic variations, should be considered when performing surgical or nonsurgical root canal treatments on maxillary molars.

Keywords: Cone beam computed tomography, Endodontic, Lateral canal, Maxillary molar, Root canal, Tooth root

Introduction

Understanding variations in root canal anatomy is critical for the successful treatment of endodontic cases. Inadequate knowledge of root canal morphology can lead to improper instrumentation, which results in suboptimal cleaning, ledge creation, possible instrument fracture within the root canal, inadequate obturation, and ultimately compromised healing (1). Hence, dental practitioners need to pay special attention to potential anatomical variations of first molars. Failure in root canal therapy of maxillary molars often results from the inability to identify and adequately clean the second mesiobuccal canal (MB2) (2). MB2 in maxillary first molars has a reported prevalence ranging from 38.5% to 64.76% (3).

Another anatomical feature that poses challenges during root canal treatment is the C-shaped canal, which is seen in the maxillary first molars at rates between 0.12% and 1.1% (4). Conventional X-rays are limited in their ability to determine the complexities of C-shaped root canals (5). Evidence indicates that cone-beam computed tomography (CBCT) offers precise detection of various dental anatomical features, including MB2 and C-shaped canals (6).

Overextension of root-filling materials, due to discrepancies between the anatomical and radiographic apices has been observed to afflict healing of the periapical tissue (7). The average distance between the anatomical apices and apical foramina in maxillary molars ranges from 0.35 to 0.62 mm (8).

Variability in the root canal system morphology in maxillary first molars may be influenced by the population under study (9). Dental research has indeed documented a variety of root and canal configurations in maxillary first molars (10). To our knowledge, no study has evaluated the position of the anatomical apex or root canal configuration in maxillary first molars using CBCT scans in the Turkish population. Moreover, there is a discernible data gap concerning root canal shapes in the coronal, middle, and apical sections. Therefore, this

[1] Department of Oral and Maxillofacial Radiology, School of Dentistry, Bingol University, Bingol, Turkey.
[2] Department of Oral and Maxillofacial Radiology, School of Dentistry, Inonu University, Malatya, Turkey.

Corresponding Author: Şuayip Burak Duman
Department of Oral and Maxillofacial Radiology, School of Dentistry, Inonu University, Malatya, Turkey.
Email: suayipburakduman@gmail.com

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study aimed to delineate the canal configurations and shapes and the presence of apical delta and lateral canals, as well as to determine the location of the anatomical apex in maxillary first molars within the Turkish population, using CBCT scans.

Materials and Methods

Study design and sample collection

The research protocol for this in vitro study was approved by the ethics committee of Inonu University under registration number 21-2022/3758. A total of 324 extracted permanent maxillary first molars from an Anatolian population were obtained from Inonu University's Dental School. Information about the patient's age, gender, and reasons for tooth extraction was not available. Teeth with root canal fillings, posts, fractures, internal/external resorption, or immature apices were excluded from the study.

Obtaining and analyzing the CBCT scans

We conducted radiographic examinations of the teeth using the Newtom 5G CBCT device (QR SRL, Verona, Italy). The CBCT scans were assessed using the built-in software (NNT) on a Dell Precision T5400 workstation (Dell, Round Rock, TX, USA). The images were assessed on a 20-inch LCD screen boasting a resolution of 1280 x 1024 pixels within a darkroom. An experienced radiologist conducted the procedure following the manufacturer's recommended protocol, ensuring the minimum exposure time necessary for satisfactory image quality. Tube potential and tube current were automatically determined by the CBCT machine from scout views. To optimize visualization, the contrast and brightness of the images were adjusted using the software's image processing tool. The CBCT device's voxel size was set at 75 µm. Two radiologists reviewed the images. The evaluation of the CBCT images encompassed the following aspects:

1. Number of main and additional roots.
2. Number of canals per root at the cementoenamel junction (CEJ) Level.
3. Root canal configuration: Root canal configurations were classified using Vertucci's (11) classification as the primary reference. Additional root canal configurations were assessed using supplementary types documented by Sert and Bayirli (12). These classifications are based on the number of canals originating from the pulp chamber, uniting, and diverging over their course before exiting from the root apex.
4. Root canal cross-sectional shape: The shape of each root canal was examined in its coronal, middle, and apical thirds. Canals were categorized as round if the ratio of buccolingual (BL) to mesiodistal (MD) diameter was less than 1.3. If the BL to MD ratio fell between 1.3 and 4, the canals were deemed oval-shaped. Canals with a ratio greater than 4 were classified as flat-shaped.
5. Presence of C-shaped canal: If the canal shape resembled an uninterrupted C it was classified as a C-shaped canal. Canals with a semicolon shape, due to a discontinued C outline, were also considered C-shaped canals (4).
6. Presence of lateral canals.
7. Presence of apical Delta: An apical delta refers to multiple accessory canals (more than two) at or near the root apex (13).
8. Distance between the anatomic and radiologic apices: The measurement was calculated by counting the number of axial slices with a thickness of 0.075 mm between the anatomical and radiological apices.

Results

The majority of teeth (97.9%) had three separate roots, while the prevalence of teeth with two and four roots was 1.5% and 0.6%, respectively. The prevalence of teeth with two, three, four, and five canals was 0.3%, 47.9%, 50.3%, and 1.5%, respectively. All distobuccal (DB) and palatal (P) roots presented with a single canal. In contrast, the main mesiobuccal roots (MB) exhibited variabilities, containing one (47.3%), two (50.6%), or three (2.1%) canals.

Table 1 illustrates the root canal configurations in three-rooted maxillary first molars. The MB root canal displayed a wide range of canal configurations. The most common was type I (33.1%), followed by type II (29.0%), type III (9.8%), and type IV (8.2%). P and DB roots predominantly exhibited a type I canal configuration (99.4% and 96.5%, respectively). Overall, 298 MB roots conformed to Vertucci's classification (11) and modified configuration types (12), as depicted in Figure 1. Interestingly, 26 MB roots exhibited 13 non-classifiable configuration types not accounted for in Vertucci's classification or modified types, as shown in Figure 2.

Table 1. Root canal configuration of three-rooted maxillary first molar teeth (Vertucci's classification and modified configuration types)

Three-rooted teeth N (%)	Canal Type	Palatal N (%)	Distobuccal N (%)	Mesiobuccal N (%)
317 (97.9%)	Type I (1-1)	315 (99.4)	306 (96.5)	105 (33.1)
	Type II (2-1)		5 (1.6)	92 (29.0)
	Type III (1-2-1)		5 (1.6)	31 (9.8)
	Type IV (2-2)			26 (8.2)
	Type V (1-2)		1 (0.3)	17 (5.4)
	Type VI (2-1-2)	2 (0.6)		10 (3.2)
	Type VII (1-2-1-2)			6 (1.9)
	Type X (1-2-3-2)			2 (0.6)
	Type XII (2-3-1)			2 (0.6)
	Additional canals			26 (8.2%)

These included types like 2–1–2–1, 2–1–2–1–2, 2–1–2–3, 2–3, 3–2, 2–3–2–1–2, 2–1–3–2, 3–2–1, 2–3–2, 3–1, 3–2–3, and 3–2–1–2. Notably, four configurations (2–1–3–2, 3–2–3, 2–3–2, and 3–2–1–2) were reported for the first time in maxillary first molar MB roots.

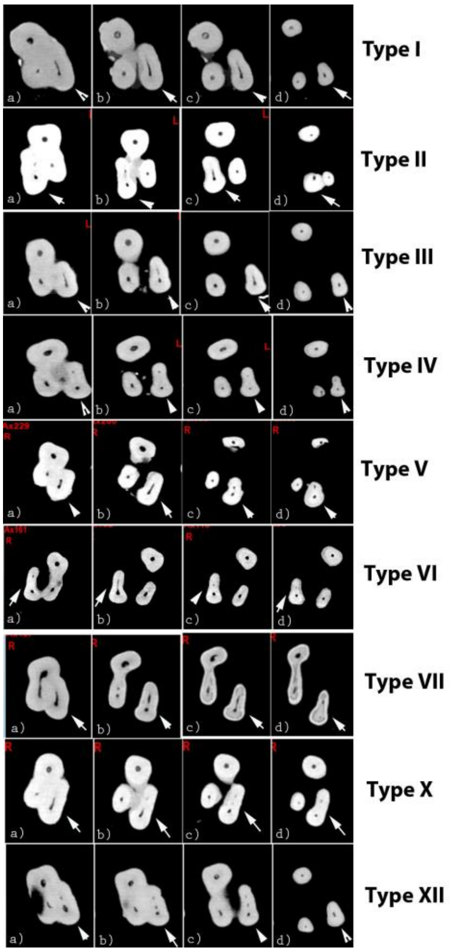

Figure 1. CBCT scans in the axial plane of the cervical (a and b), middle (c), and apical (d) thirds of the roots demonstrated variations in canal morphology. Arrows indicate mesiobuccal roots of maxillary first molars.

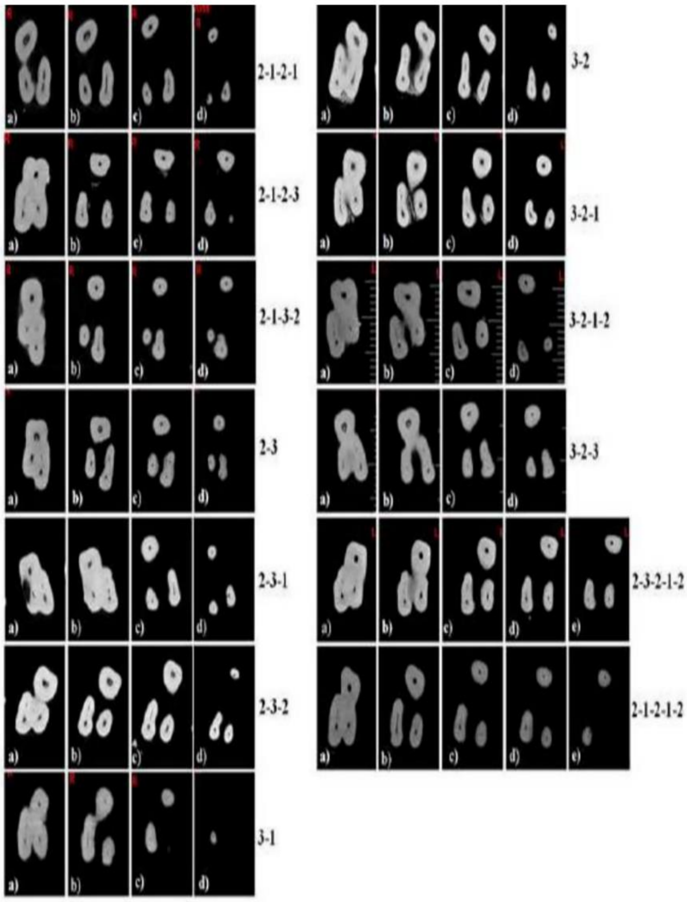

Figure 2. CBCT scans in the axial plane of the cervical (a and b), middle (c), and apical (d and e) thirds of the roots illustrated additional classes of canal configurations, not accounted for in Vertucci's classification or modified types.

Table 2 presents the cross-sectional shapes of the root canals. MB, MB2, and DB canals frequently displayed oval shapes, while palatal canals were predominantly round. C-shaped and flat-shaped canals were mostly observed in the coronal and middle thirds but were rarely seen in the apical third. In the coronal and middle thirds, root canal shapes were mostly oval, transitioning to a round shape in the apical third. Apical deltas were most commonly found in MB and palatal canals (Table 2). Lateral canals were identified in MB, DB, and palatal roots at rates of 8.6%, 0.6%, and 1.5%, respectively.

Table 3 provides information on the distance between the apical foramen and the anatomical apex. The MB2 canal exhibited the greatest distance between the apical foramen and the anatomical apex, measuring an average of 1.67 mm.

Discussion

Understanding the anatomy of roots and canals is vital for a successful endodontic treatment. Many studies have emphasized the quality and clinical relevance of CBCT imaging in assessing root canal morphology before endodontic treatment (6). CBCT scanning provides a noninvasive method for direct in vivo assessment. For this study, high-resolution CBCT imaging was chosen over micro-CT due to its cost-effectiveness and quicker scanning times, which enable us to analyze a larger sample.

The maxillary first molars typically possess three distinct roots. In this study, all maxillary first molars had three roots, with a 2.1% exception. These findings align with previous research involving Turkish, Brazilian, Chinese, Indian, and Korean populations (12, 14-17). A recent meta-analysis reported a 0.047% prevalence of four-rooted maxillary first molars, with the highest prevalence found in the Greek-Turkish population at 0.804% (17). This value almost aligns with the 0.6% prevalence rate of four-rooted first molars found in the present study.

Morphological variations of maxillary molars have been the subject of various studies. The Vertucci classification (11) is the most commonly applied classification system for root canal configuration. In this study, additional root canal configurations were considered, consistent with the findings of Sert et al. (18). MB canals were predominantly type I (33.1%), followed by type II (29.0%) and type III (9.8%). The majority of palatal and DB root canals were type I. The results of this study are in line with previous studies (10-12, 18- 20). It is worth mentioning that in the Vertucci classification, type I refers to a single canal extending from the pulp chamber to the apex of the tooth. Type II means that two separate canals leave the pulp chamber but merge into one canal before reaching the apex. Type III implies a condition where one canal leaves the pulp chamber, divides into two within the root, and then merges to exit as one canal. In contrast to the findings of this study, Thai and Japanese populations showed a predominance of type IV canal configuration, in which two distinct canals extend from the pulp chamber to the apex, without merging (21, 22). Thomas et al. (23) noted that the mesiodistal and buccolingual deposition of dentin causes significant variations in MB canals of maxillary molars.

The complex morphology of maxillary first molar root canals often stems from the presence of the MB2 canal. In this research, 50.6% of maxillary first molars exhibited an MB2 canal, which is higher than the reported rates of

Table 2. The frequency (N) and percentage (%) of different shapes of root canals in the coronal, middle, and apical sections

	Coronal				Middle				Apical				
	C-shaped	Oval	Round	Flat	C-shaped	Oval	Round	Flat	C-shaped	Oval	Round	Flat	Apical delta
MB	31 (9.6)	152 (46.9)	39 (12.0)	102 (31.5)	3 (0.9)	119 (36.7)	67 (20.7)	135 (41.7)	5 (1.5)	117 (36.1)	98 (30.2)	3 (0.9)	101 (31.2)
MB2	0 (0)	101 (61.6)	32 (19.5)	31 (18.9)	0 (0)	57 (53.3)	26 (24.3)	24 (22.4)	0 (0)	43 (48.9)	31 (35.2)	0 (0)	14 (15.9)
DB	16 (4.9)	167 (51.5)	117 (36.1)	24 (7.4)	0 (0)	137 (42.3)	179 (55.2)	8 (2.5)	0 (0)	98 (30.2)	206 (63.6)	0 (0)	20 (6.2)
P	10 (3.1)	106 (32.7)	208 (64.2)	0 (0)	8 (2.5)	105 (32.4)	211 (65.1)	0 (0)	0 (0)	96 (29.6)	176 (54.3)	3 (0.9)	49 (15.1)

MB:Mesiobuccal, MB2: Second mesiobuccal, DB: Distobuccal and P: Palatal

Table 3. Descriptive statistics of the distance between radiographic and anatomic apices in maxillary first molars

	Minimum	Maximum	Mean ± standard deviation
MB (Mesiobuccal)	0.15	3.675	0.77 ± 1.7
MB2 (Second mesiobuccal)	0.3	4.42	1.67 ± 2.12
DB (Distobuccal)	0.15	2.32	0.69 ± 1.08
P (Palatal)	0.225	2.32	0.91 ± 1.05

Erkan et al. (24), Silva et al. (25), and Plotino et al. (3) (43.5%, 42.63%, and 38.5%, respectively). However, our findings were lower than the reported rates of some other studies (26-29). Anirudhan et al. (26) and Cleghorn et al. (27) reported a prevalence rate of 64.76% and 60.5%, respectively, for the MB2 canal. These differences may partly be attributed to ethnic differences, various sample sizes, and different methodologies.

Complex anatomical structures, like oval, flat, and C-shaped canals, complicate root canal treatments. Round root canals enable better instrumentation and obturation control. In this study, the MB and MB2 canals in the maxillary first molars were generally oval-shaped and showed a greater frequency of round shapes in the apical third. Contrarily, Cowherd et al. (30) observed that the canal's apical portion was often not round. Data on the root canal shape across different sections remains relatively sparse, underscoring the need for more CBCT-based studies in diverse populations**.**

C-shaped canals in maxillary first molars were mainly identified in the coronal third, with rates between 3.1% and 9.6%. Other studies reported much lower incidence rates (5, 15). The higher prevalence of C-shaped canals in our study might be because we examined the presence of C-shaped canals in three different regions of the root canals which could increase the chance of detection.

The number of apical deltas and inter canal communications holds importance in surgical endodontics during the process of root-end resection and root-end cavity preparation. Variations, such as lateral canal and apical delta, in the MB roots of the first maxillary molars, have been more frequently observed than other roots (14). We found 28 (8.6%), 2 (0.6%), and 5 (1.5%) lateral canals in MB, DB, and palatal canals, respectively. Furthermore, the apical delta was found in 101 (31.2%), 20 (6.2%), and 49 (15.1%) of the MB, DB, and palatal root canals, respectively. A higher prevalence of apical deltas in MB canals than in the DB or P roots has also been reported in a previous study (31).

The obtained results in this study are consistent with the findings of Sariyilmaz et al. (8) who observed that the canal frequently exits short of the anatomic apex of a root. The current study revealed over 70% of maxillary first molars had canals that were 0-1 mm short of the anatomic apex. The average distance is nearly 0.77, 1.67, 0.69, and 0.91 mm in MB, MB2, DB, and palatal roots, respectively. Similarly, Wolf et al. (32) reported that the mean distances between the physiological foramina and anatomical root apex of the roots for MB, DB, and palatal canals were 0.82 mm, 0.81 mm, and 1.02 mm, respectively. CBCT imaging has been reported to be an accurate and valuable adjunct in determining actual working length in endodontic treatments (33).

This study had some limitations. The sample's age and gender demographics were unknown, whereas root canal morphology can change over time. The study's exclusive reliance on a single dental school sample may not capture the full spectrum of anatomical variations. To enhance understanding, further research involving diverse samples from various Turkish regions is crucial.

Conclusion

In conclusion, this CBCT study revealed that the Turkish population's first molars were mostly 3-rooted and had three (47.9%) or four (50.3%) canals. The MB roots of maxillary molars showed greater variations in canal morphology compared to other roots. While the C-shaped canal configuration in the maxillary first molar is rare, it was mostly seen in the MB canal and the coronal section. These anatomical differences may be related to ethnic variations, and they should be taken into account when performing surgical or nonsurgical root canal treatments on maxillary first molars.

Conflicts of Interest

The authors declare no conflict of interest related to this study.

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