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ORIGINAL ARTICLE

Evaluating root and canal configuration of mandibular first molars with cone beam computed tomography in a Turkish population

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Abstract *Background/purpose:* During root canal therapy, third roots of mandibular first molars (MFMs) provide an important route for bacterial leakage that can lead to root canal treatment failure and the need for additional surgical intervention. Therefore, the aim of this study was to investigate root and canal morphology of permanent MFMs in a Turkish population using cone beam computed tomography (CBCT).
Materials and methods: We collected 533 CBCT images of MFMs; 81 subjects had unilateral molars and 226 subjects had bilateral molars. The following observations were made: (1) root number; (2) number of canals per root; and (3) root canal configuration in each root using Vertucci's classification with additional modifications.
Results: The frequency of three-rooted MFMs was 2.4%. Of the 533 MFMs examined, two canals were present in 0.4%, three canals in 69.9%, four canals in 28.7% and five canals in 1.0%. The most common canal morphology in the mesial roots was Vertucci type IV (59.5%), followed by type II (32.8%). The distal roots showed predominantly Vertucci type I (74.7%), followed by types II (12.3%) and IV (9.7%).
Conclusion: Our results showed a low frequency (2.4%) of three-rooted MFMs in a Turkish population. This close to the average root number among people of European descent. Root and canal configurations of MFMs were consistent with previously reported data. CBCT may be recommended as an effective diagnostic modality for identifying root and canal configuration.

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Introduction

Successful root canal therapy consists of thorough biomechanical instrument and chemical debridement, followed by hermetic obturation of the root canal system. However, the complexity of the root canal anatomy presents clinical challenges and difficulties that often jeopardize the success of such therapy.[1,2]

The mandibular first molars (MFMs) have the most complex root and canal morphology of the mandibular dentition, and many studies have attempted to assess their anatomic characteristics. It is now generally accepted that the most common form of MFM has two roots and three canals. The most relevant variation related to the number of roots is the presence of a third distolingual root, and its incidence has been linked to specific ethnic groups. Additionally, the morphology and buccolingual width of the mesial root allow for intercanal communication and isthmuses (anastomosis).[1–4]

The methods used in analyzing the root canal morphology of MFM are plastic resin injection,[5] conventional radiographs,[6,7] digital and contrast medium-enhanced radiographic techniques,[8,9] canal staining and clearing,[10,11] scanning electron microscopy (SEM) evaluation,[12] microcomputed tomography[13] and cone beam computed tomography (CBCT).[4,14,15] One of these methods, CBCT, potentially offers dentistry a practical tool for noninvasive and three-dimensional reconstruction imaging for use in endodontic applications and morphologic analyses. From this reason, CBCT has been proposed as a tool to assist in identifying root canal systems.[16]

A review of the literature on root and canal morphology using the PubMed Database (National Library of Medicine) turned up several reports on the root canal morphology of MFM in the Turkish population.[17–20] However, there were no findings pertaining to the frequency of three-rooted MFM in these reports. Additionally, there were no reports on the root and canal morphology of MFM among Turkish people using CBCT. The purpose of this study was to determine the frequencies of root and canal morphologies of permanent MFMs using a sample of CBCT images obtained from a Turkish population.

Materials and methods

We designed a retrospective cohort study composed of tomographic images of 323 patients who came to the Oral Diagnosis and Radiology service at the Ataturk University Dentistry Faculty between March 2010 and April 2011. Patients had been scanned with CBCT (NewTom FP QR-DVT 9000, 110 kVp, 15 mA, 36 s scan time, 5.4 s typical X-ray emission time, 17 cm diameter and 13 cm height scan volume, Verona, Italy). We selected MFMs with fully formed apices and lacking root canal fillings, posts and crown restorations for inclusion in the study. Permanent mandibular second molars that had shifted mesially to the position of early lost first molars were identified by tooth morphology and tilting and were excluded. The final set of samples consisted of 533 CBCT images of MFMs, of which 81 subjects had unilateral molars and 226 subjects had bilateral molars [187 females and 120 males; aged between 12 and 69 years (mean age: 23.9 years)]. Age and gender were recorded for all patients.

On one of the axial views, the long axis of the tooth examined was traced, and the software generated lateral and frontal cross-sectional reconstructions perpendicular and parallel to the long axis of the tooth, respectively. The thickness of the image slices was 1 mm and the distance between slices was 1 mm for both lateral and frontal reconstructions. Images were reviewed on a digital imaging workstation. The images were examined by two investigators at the same time (one a research assistant endodontist and one an assistant professor of dentomaxillofacial radiology). To check for diagnostic reproducibility and the inter-reliability of the two investigators, 10% of the radiographs categorized by them were randomly examined each day for three consecutive days. Examination of results using the Wilcoxon matched pairs signed-rank test showed no statistically significant differences between the two observers, indicating diagnostic reproducibility. In addition, 10% of the remaining radiographs were selected at random and re-evaluated twice by the same examiners 6 weeks after the first evaluation. Intra-examiner reproducibility was found to be 96% and 92%, respectively.

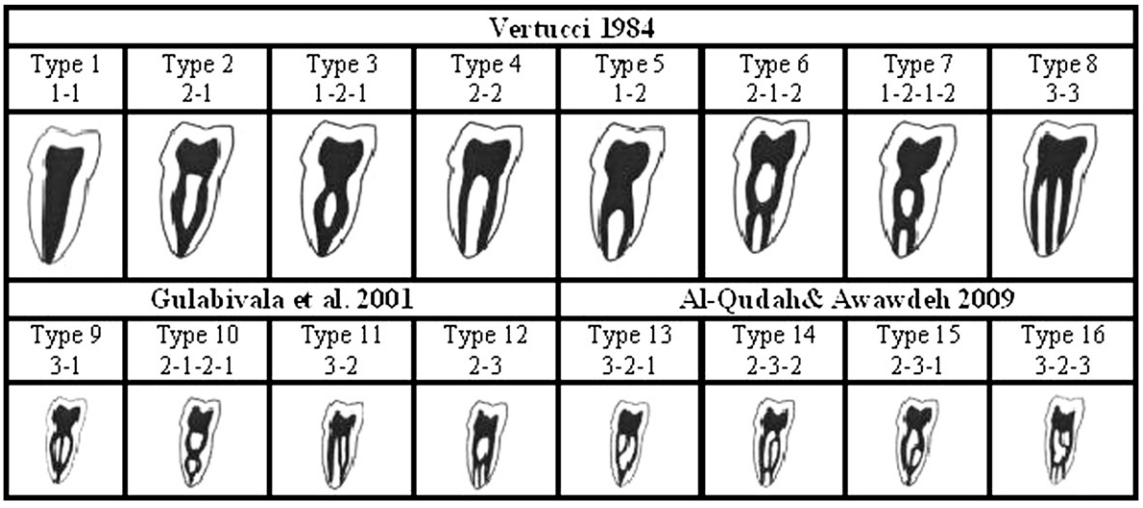

Figure 1 Systematic representation of types of canal systems classified by Vertucci and the additional modifications used.

Table 1 Classification of mandibular first molar by root number and morphology.

			Classification of root morphology				
			GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
			Three separate roots ($n = 13$)	Two separate roots ($n = 510$)	Two fused roots ($n = 10$)	Single conical root ($n = 0$)	Single C-shaped root ($n = 0$)
	Percentage		2.4	95.7	1.9	0.0	0.0
Laterality	Bilateral		2	178	3	0	0
	Unilateral	Left	4	78	2	0	0
		Right	5	86	2	0	0

Table 2 Characteristics of the studied samples of 307 Turkish individuals including numbers and percentages with two- and three-rooted mandibular first molars.

	Gender						P value
	Female		Male		Total		
	n	%	*n*	%	*n*	%	
Individuals with three roots	6	3.2	5	4.2	11	3.6	0.53
Individuals with two roots	181	96.8	115	95.8	296	96.4	

The following observations were made:

(1) root number and morphology: the identification of the teeth as MFMs was based on crown morphology according to accepted criteria[21];
(2) number of canals per root; and
(3) root canal configuration: canal configurations were categorized using Vertucci's classification.[22] Additional root canal configurations[11,23] were also taken into consideration (Fig. 1).

We calculated the gender ratio, bilateral, and unilateral appearance and the right-side and left-side occurrence of MFMs. The Pearson chi-squared test was used to determine gender differences in the distribution of three-rooted MFMs. A P value of <0.05 was considered statistically significant.

Results

Number and morphology of roots

The majority (97.6%) of the 534 MFMs had two roots, of which 95.7% were two separate roots. The incidence of two-rooted MFMs was higher in females (181/187, 96.8%) than in males (115/120, 95.8%). Thirteen patients (2.4%) had three roots. The incidence of an extra distolingual root of the MFMs was 3.2% (6/187 patients) for females and 4.2% (5/120) for males. The incidence of three-rooted MFMs did not differ between females and males ($P > 0.05$). Of the 11 patients with three-rooted MFMS, two (0.7%) had bilateral three-rooted MFMs and nine (2.9%) had unilateral three-rooted MFMs. Of the nine unilaterally occurring three-rooted teeth, four occurred on the left side and five occurred on the right side (Tables 1 and 2 and Fig. 2).

Number of root canals

The number of root canals in the MFMs is summarized in Table 2. Of the 533 MFMs examined, two canals were present in 0.4%, three canals in 69.9%, four canals in 28.7%, and five canals in 1.0% of cases. Root canal configuration of the mesial root revealed one canal in 0.4%, two canals in 97.3% and three canals in 2.3%. Root canal configuration of the distal root displayed one canal in 74.7% and two canals in 25.3% (Figs. 3A, B and 4).

Figure 2 (A) Unilateral (arrow) and (B) bilateral (arrows) three-rooted mandibular first molars.

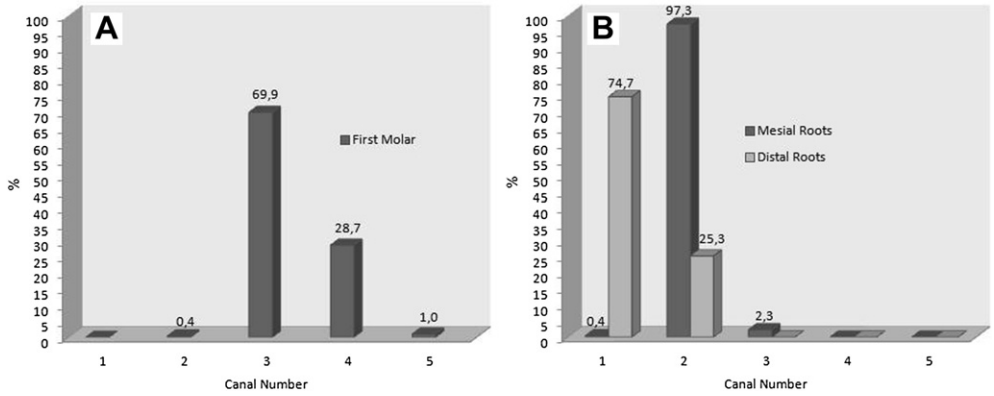

Figure 3 (A) Number and percentage of canals in mandibular first molars by roots. (B) Number and percentage of canals in mesial and distal roots of mandibular first molars.

Root canal configurations

Of the 520 two-rooted MFMs examined, the most common canal morphology in the mesial roots was Vertucci type IV (59.8%), followed by type II (32.5%). The distal roots were predominantly type I (73.5%), followed by types II (12.9%) and IV (10.2%). Of the 13 three-rooted MFMs, 92.3% of the mesial roots had type IV and II canal forms. All of the distobuccal and distolingual roots contained a type I canal. In total, of the 533 MFMs examined the proportional canal configurations appeared in descending order as follows in mesial roots: type IV 59.5%, type II 32.8%, type V 2.4%, type III 2.3% and type VIII 1.3% (Table 3 and Fig. 5). They were as follows in the distal roots: type I 74.7%, type II 12.3%, type IV 9.7%, type V 1.8% and type III 1.5% (Table 3 and Fig. 5).

Discussion

Of the techniques used to study root canal morphology, it has been reported that fine details of the root canal system can be visualized by staining and clearing.[10,11] Root canal information that is obtained before or during endodontic therapy, however, is more valuable for further dental management. In this study, we evaluated the internal anatomic variations of dental roots using CBCT. Conventional radiographs are two-dimensional, so they do not consistently reveal the actual number of canals present in teeth. Matherne et al[24] found that with digital radiography, endodontists failed to identify at least one root canal in 40% of teeth, despite taking parallax radiographs. Neelakantan et al[25] reported that CBCT was as accurate in identifying root canal systems as the modified canal staining and tooth clearing technique. The main advantages of CBCT images are that they are nondestructive and allow three-dimensional reconstruction and visualization of the external and internal anatomy of the teeth. Our study shows that the sum of roots and root canals can be visualized clearly in axial sections. The lateral and frontal CBCT scans obtained from axial sections could be a useful tool for the study of the anatomy of root canals without surgical intervention.

The predominance of two separate roots in Turkish MFMs identified in our study is similar to observations made by Gulabivala et al[11] and Al-Qudah and Awawdeh.[23] The presence of fused roots (1.9% in our study), however, has clinical implications for dental management. Fused roots may present with narrow root grooves that

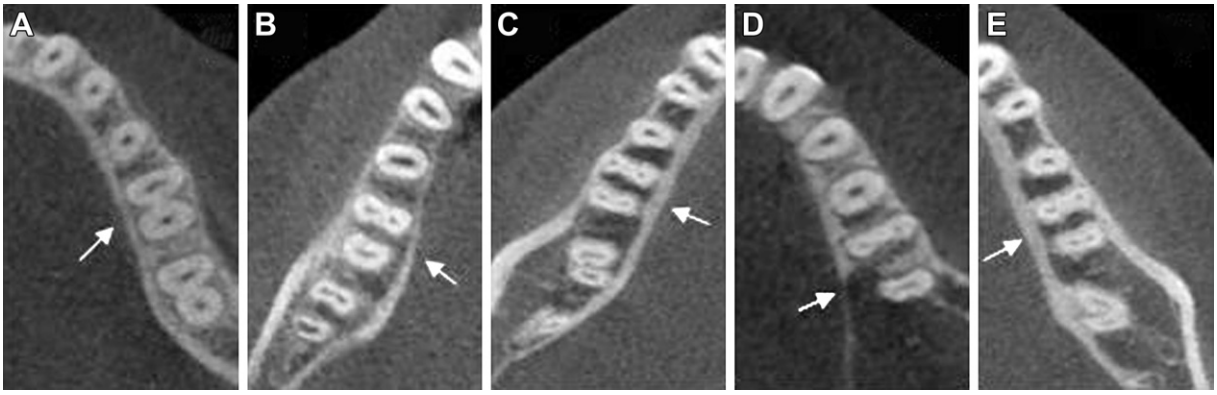

Figure 4 Cases of mandibular first molars with canal numbers in axial section; the white arrows indicate the examined tooth: (A) two-canal molar (one in mesial and one in distal); (B) three-canal molar (two in mesial and one in distal); (C) five-canal molar (three in mesial and two in distal); (D) four-canal molar (three in mesial and one in distal); and (E) four-canal molar (two in mesial and two in distal).

Table 3 Number of canal system types in two- and three-rooted mandibular first molars.

Number of roots		Types, *n* (%)								Additional types, *n* (%)								
		Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type VIII	Type IX	Type X	Type XI	Type XII	Type XIII	Type XIV	Type XV	Type XVI
		1–1	2–1	1–2–1	2–2	1–2	2–1–2	1–2–1–2	3–3	3–1	2–1–2–1	3–2	2–3	3–2–1	2–3–2	2–3–1	3–2–3
Three	M	—	6 (46.2)	1 (7.6)	6 (46.2)	—	—	—	—	—	—	—	—	—	—	—	—
	DB	13 (100.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	DL	13 (100.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Two	M	2 (0.4)	169 (32.5)	11 (2.1)	311 (59.8)	13 (2.5)	2 (0.4)	—	7 (1.3)	—	—	3 (0.6)	2 (0.4)	—	—	—	—
	D	382 (73.5)	67 (12.9)	8 (1.5)	53 (10.2)	10 (1.9)	—	—	—	—	—	—	—	—	—	—	—
Mesial roots (n = 533)		2 (0.4)	175 (32.8)	12 (2.3)	317 (59.5)	13 (2.4)	2 (0.4)	—	7 (1.3)	—	—	3 (0.6)	2 (0.4)	—	—	—	—
Distal roots (n = 546)		408 (74.7)	67 (12.3)	8 (1.5)	53 (9.7)	10 (1.8)	—	—	—	—	—	—	—	—	—	—	—

D = distal; DB = distobuccal; DL = distolingual; M = mesial.

predispose to localized periodontal disease, which may, in fact, be the first diagnostic indication of this anatomical variation.[26]

The presence of a third root in the MFMs has important clinical consequences in root canal treatment. The necessity of cleaning, shaping and obturating more than the usual two canals during root canal treatment of MFMs is self-evident. Classical triangular access preparation during root canal treatment should be extended towards the distolingual direction in a rectangular form to improve canal identification. Apart from the root canal procedure, a third root has been found to be a contributing factor to localized periodontal destruction. Additionally, teeth with three roots are more vulnerable and easily fractured in extraction even with an experienced dentist.[3,4,27] These findings suggest that to achieve long-term retention, more effort should be made to increase the success rate of dental treatment of three-rooted MFMs.

In this study, the frequency of three-rooted MFMs was 2.4% of all teeth examined. The occurrence of three-rooted MFMs in Caucasians varies from 1% to 4%.[5,23,28] This is lower than the figure reported for Burmese (10%),[11] Southern Chinese (15%)[29] and Baffin Eskimo (21.7%)[30] populations. Several studies have specifically analyzed the presence of a third root in Taiwan's population and determined the incidence of a third root to be higher than 20%.[1,4,15] In these regions, the three-rooted variation occurs in such a high percentage of individuals that it can be mentioned as a special characteristic of their dentition. The results of our study supported evidence from recent papers stating that difference in prevalence of three-rooted MFMs according to sex was statistically insignificant.[14,27] Some studies, however, have suggested sex-related differences in the incidence of three-rooted MFMs.[31,32]

Our results showed a higher rate of unilateral distribution of three-rooted MFMs than bilateral. This finding differs from that of previous studies.[15] Many studies have reported right-side predominance for three-rooted MFMs distributed unilaterally,[4,32] but there are also studies showing that three-rooted MFMs occur more frequently on the left side.[11,28] The ratio of left/right side in the present study was found to be quite similar (4/5). The diversity in the outcomes between studies might be explained by marked differences in sample sizes, case selection and methods used. Further investigation is necessary to clarify the issue.

Skidmore and Bjorndal[5] first drew attention to the prevalence of four canals in MFMs in more than a quarter (29%) of the teeth they examined. Reported variation in the occurrence of four-canal MFMs was between 26.0% and 57.7%.[1,23,33] Our results showed that a majority (69.9%) of MFMs had three canals and 28.7% had four. This result is not consistent with the findings of Sert et al,[19] who reported four canals in 46% of MFMs in the Turkish population.

In the mesial roots, our findings showed that the type IV configuration was most prevalent (59.5%) followed by type II (32.8%) canal configuration. The most prevalent canal configuration in the distal roots was type I (74.7%) followed by type II (12.3%) and type IV (9.7%). These results are in agreement with the findings of de Pablo et al,[1] who

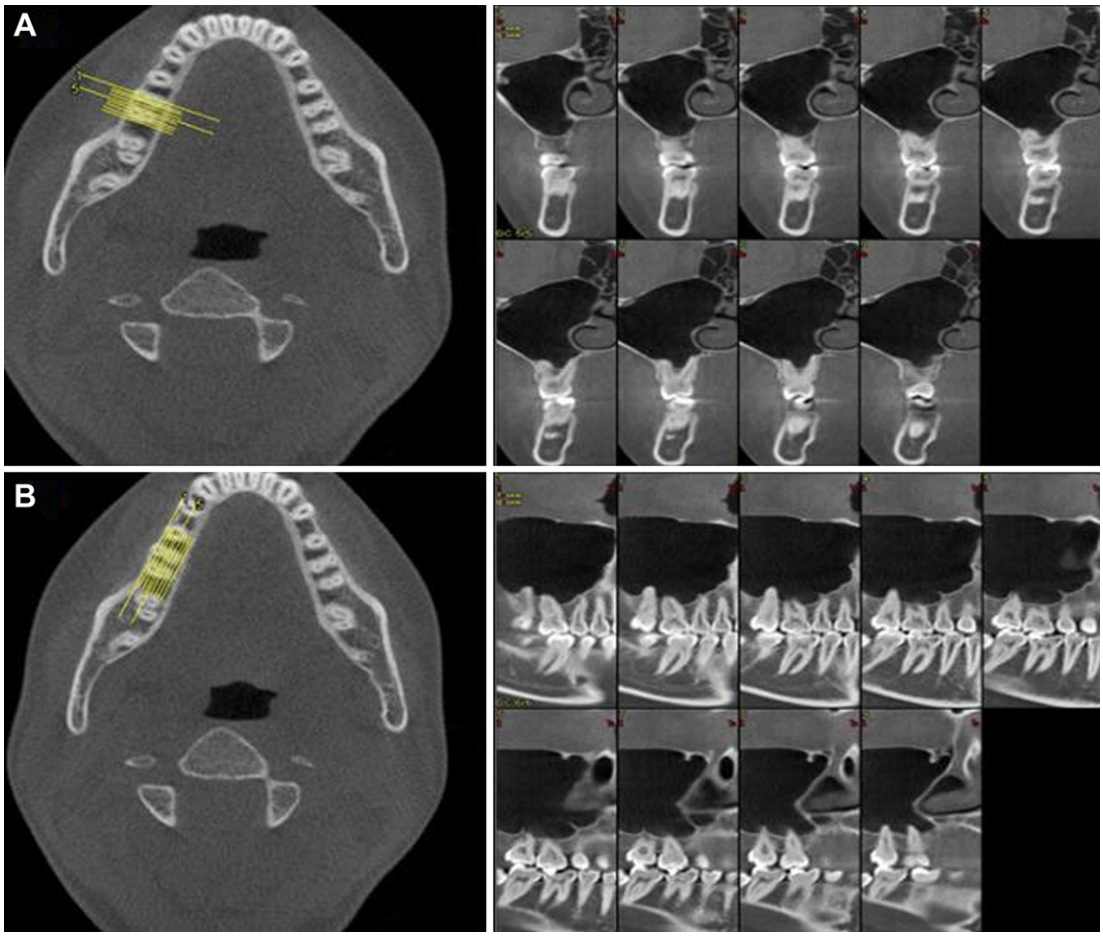

Figure 5 Cone beam computed tomography images demonstrate four-canal molar (two in mesial and two in distal) with two-rooted mandibular first molar: (A) cross-sagittal images; while the second section shows type IV (2—2) canal configuration in mesial root, seventh and eighth sections show type II (2—1) canal configuration in distal root; (B) coronal images of the same patient; second and third sections indicate mesio- and distobuccal canals, fifth and sixth sections indicate mesio- and distolingual canals.

reported a prevalence in mesial roots of 52.3% for type IV. The prevalence they recorded in distal roots was 35% for type II and 62.7% for type I, 14.5% for type II and 12.4% for type IV in their systematic review. In the Turkish population, Caliskan et al[17] found 37% of mesial roots with type II and 44% with type IV configuration, and 61% of distal roots had type 1 configuration. Sert et al[18,19] found type II configuration in 44% and type IV configuration in 43% of mesial roots. They also found type I configuration in 54% of distal roots. These differences may be related to study design (*in vivo* vs. *in vitro*) or to the technique used for canal identification (CBCT examination and clearing).

Accessory canals were extensive at various levels in the mesial and distal roots. They represent an important route for bacterial leakage that can lead to root canal treatment failure and the need for additional surgical intervention. Identification, preparation and filling of type I and IV canal systems are relatively straightforward because each of the canals is separate and distinct between the orifice and apex. Root canal treatment of types II, III, V, VI and VII, where two canals join into one small canal at a sharp angle, is more difficult. The obturation of simple tubular and tapered canals may be achieved satisfactorily with the right techniques, adequate dental skills, sufficient instruments and, most importantly, timely diagnosis.[11,23,34]

In a Turkish population, 28.7% had MFMs with four canals and 97.3% of the mesial roots had two canals. Types IV and II were the most common configurations of mesial roots. The incidence of three canals at the mesial root was found to be 2.3% of cases. In spite of the low frequency of a third root in mandibular molars (2.4%) among the Turkish population, the clinical consequences must be borne in mind in any treatment of these teeth. Additionally, clinicians should consider the potential value of CBCT when more information is needed for diagnosis or treatment planning beyond that obtained from conventional radiographs.

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