Original Article

Evaluation of the Internal Anatomy of Maxillary First Molars in an Iranian Population Using Cone-Beam Computed Tomography

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Abstract

Background and Aim: The heightened incidence of endodontic failure in maxillary first molars (MFMs) has been attributed to their morphological complexities notably evident in the mesiobuccal (MB) root canals. Given the absence of data on the internal anatomy of MFMs among the Iranian population, this research aimed to evaluate the root canal system (RCS) morphology of MFMs utilizing cone beam computed tomography (CBCT).

Materials and Methods: In this descriptive retrospective study, internal anatomy of 314 MFMs was evaluated on CBCT scans taken from patients attending a dentomaxillofacial radiology clinic. CBCT scans of MFMs were retrieved and interpreted by observers for their internal anatomy. Fisher's Exact test, Chi- Square test, independent-samples t-test and one-way ANOVA were used to analyze data using SPSS 26 software.

Results: Of a total of 314 MFMs evaluated, 97.5% [95% CI: (95.7%, 99.2%)] had three roots and 67.2% [95% CI: (62.0%, 72.3%)] had four root canals; the difference in number of canals was not significant between males and females (P=0.130). In 68.4% of cases, MFMs on both sides exhibited morphological similarity. Accessory canals were more commonly encountered in individuals between 40 to 60 years of age in all roots except for MB root; whereas in MB root, accessory canals were more commonly seen in 20-40 year olds. Vertucci's types II, I and III were the most common canal types in evaluated MB roots. Vertucci's type I was the most common type in distobuccal (DB) and palatal (P) root canals.

Conclusion: More than half of the MB roots of MFMs had two root canals. CBCT scans could give valuable anatomical information prior to endodontic treatments. Some anatomical features varied according to the patient's gender and age.

Key Words: Internal anatomy; Root canal system; Maxillary first molar; Anatomical variations; Cone beam computed tomography

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Introduction

Maxillary first molars (MFMs) commonly represent the largest teeth within the oral cavity. Investigating the root morphology and internal anatomy of MFMs has been the focus of extensive research owing to their elevated incidence of endodontic failure. This can primarily be linked to the intricate nature of their root canal system (RCS), such as the existence of a second (and occasionally a third) mesiobuccal (MB) root canal, which often remains undetected. (1) While MFMs typically represent three or four root canals, diverse anatomical patterns have been documented in the literature.(2) The internal anatomy of the root canal system (RCS) is determined by the genetic makeup unique to each individual. Therefore, examining the root canal morphology across various populations holds significance not just in therapeutic contexts but also in anthropological investigations. (3 -5)

Several methods are used for morphological evaluation of root canals such as clearing technique, sectioning, injection of contrast material (in-vitro), introducing a file into the root canal or filling the RCS and taking conventional radiographs, digital radiography, computed tomography (CT) and use of a dental microscope during access cavity preparation (in-vivo) (1),(3),(4). However, these techniques have their own limitations. Intraoral periapical radiography is the most commonly used diagnostic tool for evaluation of internal morphology of RCS in the clinical setting. However, it is not highly reliable since it has some limitations. For example, it provides two-dimensional information of 3D structures and there is a risk of overlap of the roots or superimposition of adjacent anatomical structures such as the maxillary sinus on the roots (5),(6). Wolcott et al, in 2002 evaluated the presence of second MB canals in primary endodontic treatment and retreatment of 3,578 teeth. The incidence of second MB canal in primary endodontic treatment was 59% while this rate was reported to be 67% after retreatment. They showed that a significant difference existed in incidence of second MB canal in primary endodontic treatment and retreatment and emphasized that failure in finding and treating the second MB canal decreases the long-term prognosis of endodontically treated tooth (7).

The main advantage of CBCT is that it provides several projections in different planes by rotational scanning and yields volumetric data. Smaller size and lower cost of CBCT compared to CT, high-speed scanning, sub-millimeter resolution, low patient radiation dose and low image artifact are among the main advantages of CBCT.(8) This imaging modality has the potential to detect and diagnose endodontic diseases and periapical radiolucencies and allows thorough evaluation of anatomical structures in endodontic surgeries. It also enhances the detection of horizontal and vertical root fractures and enables thorough evaluation of RCS and monitoring of treatment outcome (8). Ezoddini Ardakani et al (9), in an in vitro study in 2014 evaluated the anatomy of MB root canal of permanent MFMs using CBCT and reported the presence of second MB canal in 60% of the teeth; second MB canal was observed in coronal third in 55.55%, in middle third in 33.33% and in apical third in 11.11% of the cases. Guo et al in 2014 assessed the number of roots and shape of root canals of permanent first molars in a North American population by evaluating 317 CBCT scans of MFMs bilaterally (10). Incidence of second MB canal was significantly variable among different age groups. Vertucci's type IV was the most common type in second MB canal. Also, significant differences were noted in terms of canal type according to Vertucci's classification among different ethnic groups. Lin YH et al in (11) 2017 evaluated the anatomy of MB root canal of 196 MFMs and 212 maxillary second molars using 3D CBCT scans of 114 Taiwanese patients. The prevalence of two MB canals was 56% in MFMs and 7.7% in maxillary second molars. Based on a review study by Cleghorn et al(12) in 2006 incidence of second canal was 56.8% in MB root, 1.7% in distobuccal (DB) root and less than 1% in palatal (P) root. Missing or incomplete treatment of accessory canals can result in failure of endodontic treatment. (12) This is due to the primary objective of root

canal therapy, which is the mechanical and chemical debridement of the root canal system (RCS) and the subsequent efficient shaping for an efficient obturation. (13)Hence, successful endodontic treatment necessitates a comprehensive understanding of the 3D morphology of the RCS. (14)

Dental anatomy can be affected by several developmental abnormalities and diseases. Lhpoh, Y et al reported that in patients with clefts, numerous abnormalities can be encountered in the shape, number, and size of the teeth, especially in the areas adjacent to the defect. (15)

To the best of the authors' knowledge, no study has been conducted on the root canal morphology and internal anatomy of the MFMs in representative Iranian population. In addition, the relationship between anatomical variables such as isthmus, root fusion, extra root or canal in cleft patients has not been elucidated.

This study aimed to evaluate various aspects including the number of roots, examination of furcation areas, determination of isthmus presence or absence along with its location, the morphology of individual canals, and their classification based on Vertucci's system. Additionally, the influence of age, gender, and cleft conditions on these parameters was assessed.

Materials and Methods

This descriptive retrospective study involved the evaluation of 1,100 CBCT scans obtained from patients with bilateral presence of MFMs imaged in a private dentomaxillofacial radiology clinic in Tehran. Teeth with sound MB, DB and P roots were evaluated. Teeth with open apices, calcification of the RCS, history of root canal therapy, presence of post and core restoration and periapical lesions were excluded from the study. Considering the inclusion and exclusion criteria, a total of 314 CBCT scans were included in the investigation. The CBCT scans belonged to 143 males (45.5%) and 171 females (54.5%). A total of 159 left (50.6%) and 155 right (49.4%) MFMs were retrospectively evaluated. The mean age of patients was 37.98±15.35 years (ranging from 9 to 80 years).

All CBCT scans had been taken by NewTom 5G (QR Srl, Verona, Italy) system with the exposure settings of 110 kVp, 19mA, 8x8 cm field of view, 1mm slice thickness and 0.15 voxel size and evaluated in 0.5mm sections in axial, sagittal and coronal planes. Number of roots, number of canals in each root and shape of root canals according to the Vertucci's classification, furcation area(s) in the root, presence/absence of isthmus and its location as well as presence or absence of fusion(s) were evaluated and recorded. In this study, isthmus was defined as a narrow communication between two or more canals in one root. (16) In addition, the presence of isthmus was confirmed only if this communication was visible on at least four or five consecutive axial CBCT sections. When two or more roots in one tooth were merged such that their canals were also related, or if the number of roots was less than three and evidence of merging the canals was noticed, the tooth was reported as a case of fusion. The effect of age and gender on the above-mentioned factors was also evaluated. (17) The CBCT scans were interpreted by three observers, a dentist, an endodontist and a maxillofacial radiologist using NNT Viewer version 3.00 software (QR Srl, Verona, Italy). To avoid diverging interpretations, CBCT scans were also re-evaluated by observers to reach consensus between observers.

Statistical Analysis

Descriptive statistics, encompassing mean values and standard deviations, were presented for quantitative data, whereas qualitative data were summarized using frequency and percentage calculations. Inferential statistical analyses, including Fisher's Exact test, Chi-Square test, independent-samples t-test, and one-way ANOVA, were conducted to examine the data and assess correlations. A significance level of 0.05 was chosen for type-one error, and SPSS 26 software served as the tool for all analyses.

Results

In this study, diagnostic CBCT scans of 1,100 patients with the age range of 9 to 80 years (mean=37.98±15.35yrs) taken in a private oral and maxillofacial radiology clinic were retrospectively evaluated. Patients were divided into <20(17%), 20-40(37%), 40-60(39%) and 60-80(7%) year-old age groups. Of all, 143 (45.5%) CBCT scans belonged to male and 171 (54.5%) to female patients. The CBCT scans had 0.2 mm (0.3%), 0.3 mm (32.8%) and 0.4 mm (66.9%) axial thickness. After applying the inclusion and exclusion criteria, 219 CBCT scans visualizing 314 MFMs were evaluated.

In this study, uni- and bi-lateral presence of the maxillary first molar was seen in 124(56.6%) and 95(43.3%) patients, respectively. The right and left MFMs were morphologically identical in 68.4% of the patients.

The results can be categorized into two main parts including external root morphology and internal root canal anatomy.

External root morphology

General Root Morphology

The frequency of MFM roots in male and female patients are given in table 1. Base on Fisher's Exact test this association is not statistically significant.

Morphological data in patients with cleft palate and Root fusion

In the statistical population of this study, 11 patients (4 females and 7 males) had a cleft palate, out of which only 2 patients (males) showed root fusion. Root fusion was noted in 6% of the patients. Fusion was more commonly seen in female patients and this difference was statistically significant (P=0.030). Due to the lack of frequency in patients with cleft palate, statistical analysis to determine relationship between cleft and root fusion was not possible. The relationship between fusion and cleft is demonstrated in tables 1 and 2.

Internal root canal anatomy

Results of internal root canal anatomy in terms of number, location, morphology, presence of bifurcation and/or isthmus, etc are represented as follows.

Number, location and morphology of the canals

Frequency of MFMs with more than 3 canals was 82.5% and 71.35% in male and female subjects, respectively. Also, MFMs with less than 3 root canals were reported in 1 patient. No significant difference was noted between males and females in terms of number of canals (P=0.130) (See table 1).

Only one patient within the age range of 40-60 exhibited teeth with dual root canals (See table 2). Teeth with three root canals were more commonly seen in 40-60 year-old patients, but those with four canals were mostly seen in 20-40 year-old patients. In all age groups 4 canals are the most frequent finding.

Root canal morphology according to the Vertucci's classification:

In the MB root, Vertucci's types II (58.6%) and V (0.6%)configurations were the most and least frequently encountered feature, respectively. In DB root, type I (90.4%) was the most (n=284) and types V and II (1.9%) were the least frequent configurations encountered. In P root, type I was the most common type seen (96.8%) and type III was seen in the remaining 10 teeth (3.2%). (See tables 3 and 4)

No significant correlation was found between root canal morphology and gender or age (P>0.05) except for palatal and agegroup (p=0.002). In general, prevalence of uncommon types was 9.5% in DB, 4.4% in MB and 3.2% in P roots.

Canal bifurcation and its distance to the apex

In all examined root canals, 29.3% [95% CI (24.3%, 34.3%)] of all canals exhibited isthmi within their pathways from coronal to apical portion. Prevalence of isthmus was more significantly found in males (p=0.044). The mean bifurcation-to-apex distance was 10.62mm in MB, 10.55mm in DB and 11.25±1.72mm in P canals. The bifurcation distance from the apex of all roots had a normal and symmetrical distribution but was different in terms of gender. Isthmus was located farther in male subjects compared with females with respect to the MB, DB and P root apices, but such effect was considered minimal in MB and P but moderate in DB roots according to Cohen's test.

The distance between the bifurcation area and the apex of both the mesiobuccal (MB) and distobuccal (DB) roots showed a significant

Table1. Parameters evaluated in males and females

Variable		Gender		P value
		Female(n=171)	**Male(n=143)**	
Number of roots	2	2(1.2%)	1(0.7%)	0.538*
	3	165(96.5%)	141(98.6%)	
	4	4(2.3%)	1(0.7%)	
Number of canals	1	0(0%)	0(0%)	0.130*
	2	1(0.6%)	0(0%)	
	3	48(28.1%)	25(17.5%)	
	4	107(62.6%)	104(72.7%)	
	5	14(8.2%)	13(9.1%)	
	6	1(0.6%)	1(0.7%)	
Prevalence of isthmus 95% CI for prevalence		42(25.0%) (18%, 31%)	50(35.0%) (27%, 43%)	0.044$
Distance from the root canal bifurcation area to the apex (in millimeters)	Mesiobuccal	10.28±1.82	11.02±1.69	<0.001#
	Distobuccal	10.13±1.79	11.06±1.70	<0.001#
	Palatal	10.88±1.72	11.69±1.61	<0.001#
Distance from isthmus to apex (in millimeters)	Mesiobuccal	8.12±1.99	9.07±1.86	0.020#
	Distobuccal	8.13±2.13	9.29±1.86	0.006#
	Palatal	8.9±2.00	9.74±1.86	0.040#
Cleft/fusion	Fusion of mesiobuccal with palatal	2(1.2%)	0(0.0%)	0.030*
	Fusion of mesiobuccal with distobuccal	5(2.9%)	0(0.0%)	
	Fusion of distobuccal with palatal	9(5.3%)	3(2.1%)	
	Cleft	4(2.3%)	7(4.9%)	0.220$
	Cleft with fusion of mesi-obuccal and distobuccal	0(0%)	1(0.6%)	NA
	Cleft with fusion of palatal and distobuccal	0(0%)	1(0.6%)	NA

* Based on Fisher's Exact test, $: Based on chi- square test, #: Based on Independent Samples t-test

correlation with age. Specifically, the shortest distance was observed in individuals under 20 years old, while the longest distance was found in patients aged 60-80 years (See table 3).

Isthmi and their location

Isthmus was noted in 92 (29.3%) patients involving 50 (35.0%) [95% CI (27.0%, 43.0%)] males and 42 (25.0%) [95% CI (18.0%, 31.0%)] females. The detailed statistics about isthmi are given in tables 1 and 2.

The mean location of isthmus was at 8.64±1.97 mm from the apex in MB, 8.76±2.06 mm from the apex in DB and at 9.37±1.95 mm from the apex in P roots. An association was noted between the location of isthmus and gender such that in all roots, isthmus in females was closer to the apex compared to males ($p<0.05$ for all variables) (Table 1).

Table 2. Parameters evaluated in different age groups

Number of canals	Age group				P value
	<20 (n=53)	20-40(n=115)	40-60(n=122)	60-80(n=24)	
1	0(0%)	0(0%)	0(0%)	0(0%)	
2	0(0%)	0(0%)	1(0.8%)	0(0%)	
3	21(39.6%)	18(15.7%)	28(23.0%)	6(25.0%)	
4	31(58.5%)	88(76.5%)	79(64.8%)	13(54.2%)	0.010*
5	1(1.9%)	9(7.8%)	13(10.7%)	4(16.7%)	
6	0(0%)	0(0%)	1(0.۳%)	1(4.2%)	
Number of roots					
2	1(1.9%)	1(0.9%)	1(0.8%)	0(0%)	
3	52(98.1%)	111(96.5%)	119(9۷.5%)	24(100%)	0.868*
4	0(0%)	3(2.6%)	2(1.6%)	0(0%)	
Prevalence of isthmus	9(17.0%)	43(37.4%)	33(27.0%)	7(29.2%)	0.050$
95% CI for prevalence	(7%, 27%)	(28%, 46%)	(19%, 35%)	(10%, 49%)	
Distance from isthmus to apex (in millimeters)					
Mesiobuccal	8.89±2.45	8.45±1.69	8.77±2.33	8.67±1.17	0.860#
Distobuccal	9.90±2.31	8.50±1.68	8.72±2.52	9.10±1.06	0.300#
Palatal	10.48±2.12	9.11±1.75	9.45±2.18	9.13±1.69)	0.280#
Distance from the root canal bifurcation area to the apex (in millimeters)					
Mesiobuccal	9.81±1.61	10.71±1.63	10.75±1.89	11.35±1.94	0.600#
Distobuccal	10.03±1.54	10.64±1.65	10.56±1.97	11.25±2.03	0.510#
Palatal	10.81±1.66	11.46±1.63	11.16±1.77	11.64±1.79	0.220#
Cleft/fusion					
Fusion of mesiobuccal with palatal	0(0%)	1(0.9%)	1(0.8%)	0(0%)	
Fusion of mesiobuccal with distobuccal	0(0%)	1(0.9%)	4(3.3%)	0(0%)	0.138*
Fusion of distobuccal with palatal	4(7.5%)	2(1.7%)	3(2.5%)	3(12.5%)	
Cleft	10(18.9%)	1(0.9%)	0(0%)	0(0%)	<0.001*
Cleft with fusion of mesiobuccal and distobuccal	1(1.9%)	0(0%)	0(0%)	0(0%)	NA
Cleft with fusion of distobuccal and palatal	1(1.9%)	0(0%)	0(0%)	0(0%)	NA

* Based on Fisher's Exact test, $: Based on chi- square test, #: Based on one-way ANOVA

Table 3. Morphology of root canals according to the Vertucci's classification in male and female subjects

Canal	Canal configuration type	Gender		P-value
		Male (n=143)	Female (n=171)	
Mesiobuccal	I	31(21.7%)	52(30.4%)	0.075*
	II	85(59.4%)	99(57.9%)	
	III	19(13.3%)	14(8.2%)	
	IV	3(2.1%)	0(0%)	
	V	0(0%)	2(1.2%)	
	VI	5(3.5%)	4(2.3%)	
	VII	0(0%)	0(0%)	
	VIII	0(0%)	0(0%)	
Distobuccal	I	130(90.9%)	154(90.1%)	0.533*
	II	1(0.7%)	2(1.2%)	
	III	12(8.4%)	12(7.0%)	
	IV	0(0%)	0(0%)	
	V	0(0%)	3(1.8%)	
	VI	0(0%)	0(0%)	
	VII	0(0%)	0(0%)	
	VIII	0(0%)	0(0%)	
Palatal	I	137(95.8%)	167(97.7%)	0.521*
	II	0(0%)	0(0%)	
	III	6(4.2%)	4(2.3%)	
	IV	0(0%)	0(0%)	
	V	0(0%)	0(0%)	
	VI	0(0%)	0(0%)	
	VII	0(0%)	0(0%)	

* Based on Fisher's Exact test

Table 4. Morphology of root canals according to the Vertucci's classification in different age groups

Canal	Canal configuration type	Age group				P-value
		60-80(n=24)	40-60(n=122)	20-40(n=115)	<20 (n=53)	
Mesiobuccal	I	21(39.6%)	21(18.3%)	34(27.9%)	7(29.2%)	0.088*
	II	26(49.1%)	77(67.0%)	70(57.4%)	11(45.8%)	
	III	3(5.7%)	9(7.8%)	15(12.3%)	6(25.0%)	
	IV	1(1.9%)	1(0.9%)	1(0.8%)	0(0%)	
	V	0(0%)	1(0.9%)	1(0.8%)	0(0%)	
	VI	2(3.8%)	6(5.2%)	1(0.8%)	0(0%)	
	VII	0(0%)	0(0%)	0(0%)	0(0%)	
	VIII	0(0%)	0(0%)	0(0%)	0(0%)	
Distobuccal	I	52(98.1%)	105(91.3%)	107(87.7%)	20(83.3%)	0.259*
	II	1(1.9%)	0(0%)	2(1.6%)	0(0%)	
	III	0(0%)	9(7.8%)	11(9.0%)	4(16.7%)	
	IV	0(0%)	0(0%)	0(0%)	0(0%)	
	V	0(0%)	1(0.9%)	2(1.6%)	0(0%)	
	VI	0(0%)	0(0%)	0(0%)	0(0%)	
	VII	0(0%)	0(0%)	0(0%)	0(0%)	
	VIII	0(0%)	0(0%)	0(0%)	0(0%)	
Palatal	I	53(100%)	114(99.1%)	117(95.9%)	20(83.3%)	0.002*
	II	0(0%)	0(0%)	0(0%)	0(0%)	
	III	0(0%)	1(0.9%)	5(4.1%)	4(16.7%)	
	IV	0(0%)	0(0%)	0(0%)	0(0%)	

* Based on Fisher's Exact test

Discussion

Untreated canals during root canal treatment procedures is among the most common causes of endodontic failure. (3),(4) MFMs are reported to have a wide range of morphological variations. Hence, a comprehensive understanding of the root and root canal morphology is imperative for clinicians before undertaking endodontic procedures on these teeth. (10) The objective of this study was to evaluate the root canal system (RCS) morphology of MFMs within an Iranian population utilizing CBCT imaging. Furthermore, the study sought to assess the impact of age and gender on the anatomical variations present. Currently, CBCT is an efficient imaging modality due to low effective radiation dose, short exposure time (2-5 seconds), lower cost compared to conventional CT and high accuracy in providing 3D images. It enables thorough evaluation of internal and external anatomy of teeth and other structures with high accuracy. (3),(4) Several studies have shown that CBCT is superior to other imaging techniques such as digital radiography using charge-coupled devices or photostimulable phosphor plates and clinical sectioning (standard method) for evaluation of internal anatomy of teeth. (10)

In this retrospective study, anatomy of 314 MFMs were evaluated using CBCT scans. The results showed that the majority of patients evaluated had MFMs with three roots 165 (96.5%) and four root canals 107(62.6%). High prevalence of second MB canal in Iran was noteworthy and was not significantly different between males and females. The findings of the current study on an Iranian population were in agreement with the findings of previous studies on Indian (1), (3), (10) and a subgroup of Chinese population (5). Zhang et al. (5) conducted research on a Chinese population, examining 299 maxillary first and 210 second molars. Their findings indicated that all first molars had three roots, with the majority (52%) displaying four canals. (5) Nevertheless, Shalab et al., in their investigation of an Irish population, presented contrasting findings, indicating that the majority of MFMs (78%) exhibited four roots.(18)

In the current study, morphologically identical teeth were found in 68.4 % of cases in left and right sides. This finding was supported by the study done by Tzeng LT et al who found out that symmetry in root canals morphology in bilateral maxillary first and second molars were 87.36% and 79.85%, respectively .(19) Furthermore, the present findings indicated the presence of accessory canals across all roots, with a higher prevalence noted in the mesiobuccal (MB) root. This observation aligns with the outcomes reported in studies conducted by Neelakantan et al. (3) within an Indian population and Jing Guo et al. (10) across five distinct racial groups in North America. Nevertheless, findings from Zhang et al. (5) in their investigation of a Chinese population, as well as the study by Hartwell et al. (20), indicated that all fourth canals in MFMs were exclusively located within the MB root. The current study revealed that the presence of a second MB canal or other accessory canals exhibited no association with gender or the tooth's positional aspect (right or left quadrant). This finding corresponds with the outcomes of a prior study conducted on MFMs within a Korean population. (1) In the present investigation involving an Iranian population, the prevalence of accessory canals in all roots, excluding the mesiobuccal (MB) root, was notably elevated among individuals aged 40-60. Conversely, within the MB root, a higher incidence of accessory canals was observed in the 20-40 age group. This trend resonates with findings from studies conducted on Chinese and Korean populations. (1),(5) Zhang et al (5) evaluated CBCT scans of 775 MFMs in a Chinese population and found that the prevalence of second MB canal was 52.24%; 71.11% of cases had second MB canals in their MFMs bilaterally and the highest prevalence of second MB canal was in the age group of 20-30 years. A previous study on a Korean population showed that age affected the incidence of second MB canals in molar teeth to some extent. Maxillary first and second molars had the highest incidence of

second MB canals in 30-40 and 10-20 year-old age groups, respectively. Their findings regarding MFMs were in line with our results to some extent (1). However, Thomas et al,(21) and Neaverth et al (22) reported higher incidence of second MB canal in 40-60 year olds. Neaverth et al,(22) in their in vivo study on 228 MFMs during endodontic treatment found that the prevalence of second MB canal was 77.2%; out of which, 61.8% had two foramina. They also concluded that age group of 20-40 years had the highest incidence of second MB canals. This controversy in the results may be attributed to differences in races and ethnic groups, methodology of studies and sample size. On the other hand, an inverse correlation was noted between age and incidence of second MB canal in first and second maxillary molars in a Korean population (1). By an increase in age, teeth are further subjected to external stimuli such as dental caries, trauma and root canal calcifications due to restorative treatments. Thus, the odds of finding the second MB canal decrease (22). It may be stated that higher incidence of second MB canals in our Iranian population in 20-40 year old age group was due to the above-mentioned reason. This underscores the significance of identifying the presence of a second MB canal, particularly within this age group. This holds particular relevance for patients demonstrating a second MB canal in one of their MFMs, as they are likely to exhibit a similar anatomical feature in the corresponding tooth on the opposite side. (10).

Within the present population, the MB root of MFMs predominantly exhibited Vertucci's canal configurations in the following order of prevalence; type II was the most commonly observed, followed by type I and type III. However, this result was in contrast to those of Gue et al,(10) in a North American population. They reported that type IV (41.9%), type I (28.3%) and type II (26.3%) were the most common MB root canal types irrespective of gender and race. Another study on an Indian population demonstrated that the most common canal types in MB roots were types I, IV and III, which was not in accordance with our findings (3). Also, in a Korean population, type III was the most common type of MB root (1). In a study on a Chinese population, the most common canal types in MB roots were types II (69%), V (16%) and II (14%) (5). In the current study, the most common canal type in DB root was type I followed by type III. In P roots, only types I and III were reported and type I was more common. These results were in agreement with the findings of a previous study on five races in North America. Similarly, they reported only types I and III in DB roots and type I was significantly more common than type III. However, only type I was reported in P roots in their study (10). On the contrary, studies on Indian and Chinese populations only reported type I for DB and P roots (3),(5).

The location of bifurcation in type III P roots in our Iranian population was mainly in the apical half of the root while the bifurcation site was more commonly located in the coronal half in other roots. To the best of our knowledge, this parameter has not been evaluated in any previous study. Root canal shape has been previously evaluated in Turkish, North American, Korean, Japanese, Burmese, Thai, Indian and Chinese populations and it has been concluded that variability in presence of second MB canal is probably related to race. (12) Neelakantan et al (4) evaluated maxillary first and second molar root shapes in an Indian population. They inspected 220 extracted MFMs using CBCT and reported that type I (51.8%) and type IV (38.6%) were the most common types in buccal roots of three-rooted molars. In general, in all racial and ethnic groups, types I, II and IV were the most common types in MB roots of MFMs with three roots; these findings were similar to those of Guo, J et al (10) On a North American population. Nevertheless, the results were only consistent in relation to types I and II with the findings of the present study. Guo et al (10) evaluated five common racial groups namely African-American, Asian, Spanish, white Hispanic and other races residing in the United States and found no significant difference in presence of second MB canal among different races, although significant differences were noted in canal shape and type among different races. This

highlights the importance of a thorough search to find out the canal shape when treating patients of different races. Thus, a correct understanding of the morphology of RCS is a prerequisite for success of endodontic treatment .(12) Use of CBCT is valuable for better understanding of root canal morphology. Considering the existing controversies in our findings and those of previous studies on other races, further studies with larger sample size are required on first molars and other teeth in Iranian populations.

Conclusion

It can finally be concluded that in this subgroup of Iranian population, MFMs represent two canals in more than half of the MB roots. Patient's age and gender are deemed as important factors in some anatomical features.

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Conflict of interest

The authors have unequivocally declared the absence of any conflicts of interest associated with this article.

References

1. Lee J, Kim K, Lee J. Mesiobuccal root canal anatomy of Korean maxillary first and second molars by cone-beam computed tomography. 2011;111(6):785–91.
2. Filho FB, Zaitter S, Haragushiku GA, Campos EA De, Abuabara A, Correr GM. Analysis of the Internal Anatomy of Maxillary First Molars by Using Different Methods. J Endod [Internet]. 2009;35(3):337–42. Available from: http://dx.doi.org/10.1016/j.joen.2008.11.022.
3. Neelakantan P, Subbarao C, Ahuja R. Cone-Beam Computed Tomography Study of Root and Canal Morphology of Maxillary First and Second Molars in an Indian. J Endod [Internet]. 2010;36(10):1622–7. Available from: http://dx.doi.org/10.1016/j.joen.2010.07.006.
4. Mds PN, Bds CS, Mds CVS. Comparative Evaluation of Modified Canal Staining and Clearing Technique , Cone-Beam Computed Tomography , Peripheral Quantitative Computed Tomography , Spiral Computed Tomography , and Plain and Contrast Medium – enhanced Digital Radiography in Studying Root Canal Morphology. J Endod [Internet]. 2010;36(9):1547–51. Available from: http://dx.doi.org/10.1016/j.joen.2010.05.008.
5. Zhang R, Yang H, Yu X, Wang H, Hu T, Dummer PMH. Use of CBCT to identify the morphology of maxillary permanent molar teeth in a Chinese subpopulation. 2011;162–9.
6. Ioannidis K, Lambrianidis T. Endodontic Management and Cone-beam Computed Tomography Evaluation of Seven Maxillary and Mandibular Molars with Single Roots and Single Canals in a Patient. J Endod [Internet]. 2011;37(1):103–9. Available from: http://dx.doi.org/10.1016/j.joen.2010.09.001.
7. Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S. Clinical Investigation of Second Mesiobuccal Canals in Endodontically Treated and Retreated Maxillary Molars. 2002;18–20.
8. Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. 2007;(April):818–30.
9. Ezoddini Ardakani F, Mirhosseini F, Karrabi M, Mokhtari N, Moeini M, Besharati S. Analysis of anatomy of mesio-buccal root canal in maxillary first permanent molars using CBCT technique. SSU_Journals. 2014 Jun 15;22(2): 1010-9.
10. Guo J, Vahidnia A, Sedghizadeh P, Enciso R. Evaluation of Root and Canal Morphology of Maxillary Permanent First Molars in a North American Population by Cone-beam Computed Tomography. J Endod [Internet]. 2014; 40 (5):635–9. Available from: http://dx.doi.org/10.1016/j.joen.2014.02.002.
11. Lin Y, Lin H, Chen C, Chen M. ScienceDirect Evaluation of the root and canal systems of maxillary molars in Taiwanese patients: A cone beam computed tomography study. Biomed J [Internet]. 2017;1–7. Available from: http://dx.doi.org/10.1016/j.bj.2017.05.003.

12. Cleghorn BM, Christie WH, Frcd C. Root and Root Canal Morphology of the Human Permanent Maxillary First Molar: A Literature Review. 2006;32(9):813–21.
13. Khedmat S, Assadian H, Saravani AA. Root Canal Morphology of the Mandibular First Premolars in an Iranian Population Using Cross-sections and Radiography. J Endod [Internet]. 2010;36(2):214–7. Available from: http://dx.doi.org/10.1016/j.joen.2009.10.002.
14. Assadian H, Dabbaghi A, Gooran M, Eftekhar B, Sharifi S, Shams N. for the Evaluation of Mandibular Incisor Root Canals. 2016; 11(2): 106–10.
15. Lhpoh Y, Gaia BF, Xr K, Lhpoh O. Cleft lip and palate: recommendations for dental anesthetic procedure based on anatomic evidences. 2010; 68:122–7.
16. Teixeira FB, Sano CL, Gomes BPFA, Zaia AA, Ferraz CCR. A preliminary in vitro study of the incidence and position of the root canal isthmus in maxillary and mandibular first molars. 2003;(Pineda 1973):276–80.
17. Ross IF, Evanchik PA. Root fusion in molars: incidence and sex linkage. Journal of periodontology. 1981 Nov;52(11):663-7.
18. Al Shalabi RM, Omer OE, Glennon J, Jennings M, Claffey NM. Root canal anatomy of maxillary first and second permanent molars. International endodontic journal. 2000 Sep 1;33(5): 405-14.
19. Tzeng L, Chang M, Chang S. ScienceDirect Analysis of root canal system of maxillary first and second molars and their correlations by cone beam computed tomography. J Formos Med Assoc [Internet]. 2019; (xxxx): 0–5. Available from: https://doi.org/10.1016/j.jfma.2019.09.012.
20. Hartwell G, Appelstein CM, Lyons WW, Guzek ME. The incidence of four canals in maxillary first molars. J Am Dent Assoc [Internet]. 2007;138(10):1344–6. Available from:http://dx.doi.org/10.14219/jada.archive.2007.0050.
21. Rp T, Aj M, Bryant R. Root canal morphology of maxillary permanent first molar teeth at various ages. 1993;26(5):8300257.
22. Neaverth EJ, Kotler LM, Kaltenbach RF. Clinical Investigation (In Vivo) of Endodontically Treated Maxillary First Molars. 1987;13(10):506–12.