Original Article

Evaluation of the association between the number and configuration of root canals of mandibular molars in an Iranian subpopulation: A cone-beam computed tomography study

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Abstract

Introduction: This study aimed to evaluate the association between the number and configuration of root canals of mandibular first and second molars in an Iranian subpopulation residing in Qazvin city using cone-beam computed tomography (CBCT) scans.

Materials and Methods: In this descriptive analytical study, 500 CBCT scans of patients taken for purposes other than this study were retrieved from a radiology clinic in Qazvin city, Iran. The number of roots and canals and the morphology of the root canals of 129 mandibular first and 198 mandibular second molars were studied on CBCT scans. The data were analyzed using the Monte Carlo test.

Results: Most of the first (96.1%) and second (81.8%) molars had two roots. The frequency of three-rooted mandibular first molars was 3.9%. The mesial and distal roots of the mandibular first molars were mainly Vertucci's Type II (62.1%) and Type I (57.4%), respectively. In the second molars, Vertucci's Type II (61.9%) and Type I (92.3%) had the highest frequency in the mesial and distal roots, respectively. A significant association was noted between the presence of three canals and Vertucci's Type II configuration and between the presence of four canals and Vertucci's Type IV in the mesial root of the mandibular first and second molars ($P < 0.05$).

Conclusion: There is a significant association between the number of canals and configuration of the mesial root canal of the mandibular first and second molars.

Keywords: Anatomy, cone-beam computed tomography, mandibular molars, morphology, root canal

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INTRODUCTION

Endodontic treatment of the teeth is performed to restore function and esthetics and includes thorough cleaning, disinfection, and shaping of the root canals followed by three-dimensional filling of the root canal space.[1] Thus, comprehensive knowledge about the anatomy and morphology of the root canals is imperative for a successful endodontic treatment.

Mandibular molars have a high prevalence of dental caries and are subjected to endodontic treatment more frequently than other teeth.[2] The anatomy and morphology of the mandibular molar root canals are highly variable. These variations are attributed to genetics and racial factors. Clinicians must be well aware of these variations and their frequency in different populations.[3]

Mandibular first and second molars often have two roots and three or four canals.[4] The root canals may merge and share a common apical foramen. In such cases, preparation of the entire length of all canals would create an hourglass preparation form and lead to void formation when filling the apical region below the constriction. Moreover, fracture of instrument, particularly rotary files, may occur.[5]

An isthmus is present in a root with two canals. The type of root canal configuration may be associated with the presence of isthmus and its type at any level of the root.[6,7] As we know, two-dimensional radiographic images do not reveal all the anatomical details.[8] In daily practice, identification of the number of canals with a common or separate apical foramen is often challenging. Furthermore, in clinical practice, it seems that the mesial root canals of the mandibular molars with four canals more commonly have separate foramina in comparison with the mandibular molars with three canals. Numerous studies have focused on the prevalence and morphologic characteristics of mandibular molar root canal systems,[9-12] but none of them evaluates the association between the number and configuration of root canals of mandibular molars. However, to the best of our knowledge, no previous studies have evaluated the association between the number and configuration of root canals of mandibular molars. Therefore, this study was conducted to evaluate the association between the number and configuration of root canals of mandibular first and second molars using cone-beam computed tomography (CBCT).

MATERIALS AND METHODS

This study approved by the Ethical Committee of Qazvin University of Medical Sciences with ethical number of IR.QUMS.REC.1394.615. This descriptive analytical study was conducted on CBCT scans of the mandible retrieved from the archives of a radiology clinic in Qazvin city, Iran. The CBCT scans had been taken for purposes other than this study. The sample size was calculated to be 119 for each type of the tooth ($\alpha = 0.05$, $z = 1.96$, $d = 0.09$).

The inclusion criteria were CBCT scans of the mandible visualizing permanent mandibular first and second molars with completely formed apices without apical radiolucency and no internal or external root resorption. Teeth with extensive coronal restoration or prosthetic crown and endodontically treated teeth were excluded from the study. Third molar teeth with a mesial shift that had replaced second molars were detected radiographically and excluded from the study. Poor-quality CBCT scans were excluded as well. The collected sample size included 327 molar teeth (129 first molars and 198 second molars) which were selected among total 500 CBCT scans. The mean age of the patients was 37 years.

Tomographic sections with a 0.2-mm slice thickness were obtained using ProMax 3D CBCT unit (Planmeca Oy, Helsinki, Finland) in the axial, coronal, and sagittal planes and were saved and viewed using Planmeca Romexis ® viewer 3.8.3 (Planmeca Oy, Helsinki, Finland); the contrast and brightness were adjusted for better visualization. The CBCT scans had been taken with the following exposure settings: 84 kVp, 10 mA, and 12 s.

All of the CBCT images were evaluated by three viewers (two endodontists and one oral and maxillofacial radiologist). To ensure reproducibility and intraobserver reliability, 10% of the CBCT images were randomly chosen and evaluated again on 3 consecutive days, and also, each observer assessed the CBCT image separately and entered the data in a checklist. Wilcoxon test showed no significant difference between the results of the three observers, indicating acceptable reproducibility and reliability. Any disagreements were resolved by discussion.

The number of roots and root canals was determined on axial sections, and cross-sectional views were used to determine the root canal configuration [Figures 1-3]. The root canal configuration was evaluated according to the Vertucci's classification,[13] Al-Qudah and Awawdeh,[14] and Gulabivala *et al*.[15]

The data were analyzed using SPSS version 20 (SPSS Inc., IL, USA). The Monte Carlo test was applied to assess the correlation between different parameters at $P < 0.05$ level of significance.

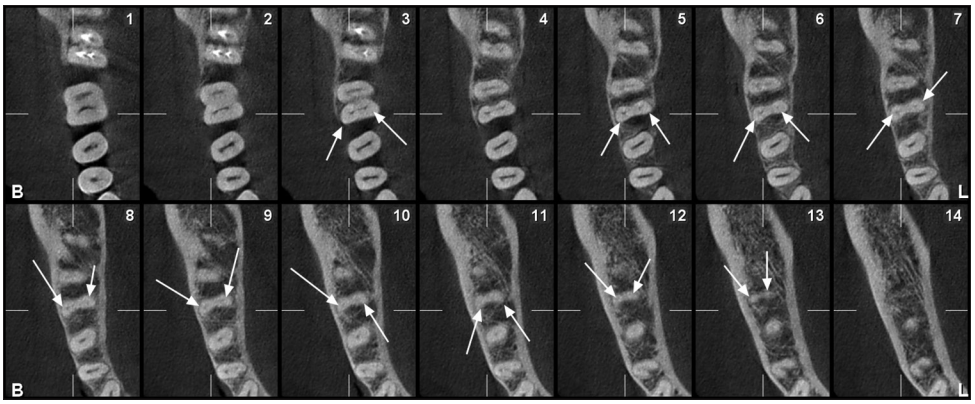

Figure 1: Axial cone-beam computed tomography sections of the mandibular first molar. Arrows denote the canals of the mesial root

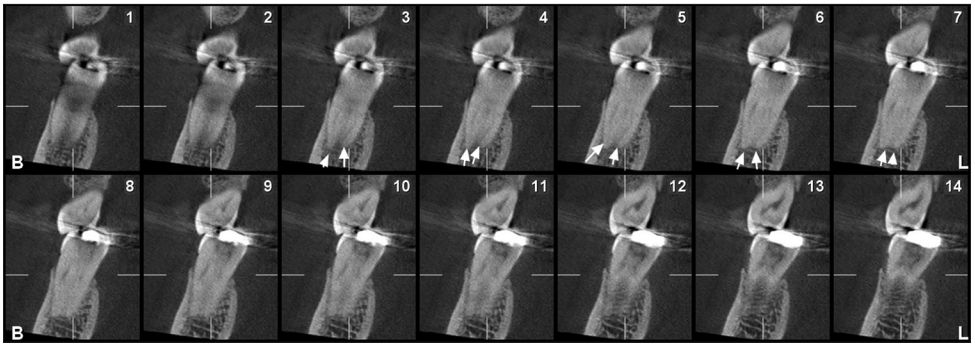

Figure 2: Cross-sectional cone-beam computed tomography sections of the mandibular first molar. Arrows denote the apical foramens of the mesial root

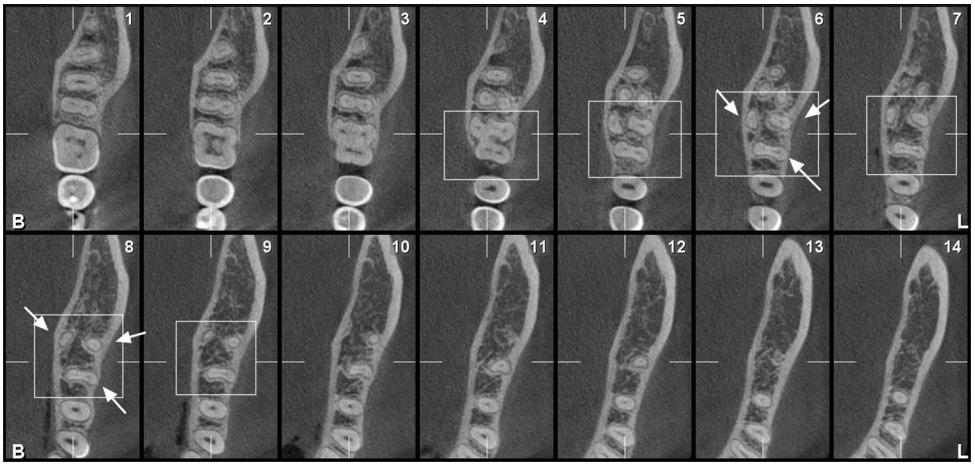

Figure 3: Axial cone-beam computed tomography sections of the first mandibular molar. Arrows denote three roots

RESULTS

First molars

Of the 129 first molars, 49.6% (n = 64) were on the right side and 50.4% (n = 65) were on the left side. In addition, 61.2% (n = 79) of the teeth belonged to female patients and 38.8% (n = 50) belonged to male patients.

Most of the first molars (96.1%, n = 124) had two roots. The frequency of first molars with three roots was 3.9% (n = 5). The number of canals of the first molars ranged from 2 to 5. The presence of three canals had the highest frequency (72.0%, n = 93), followed by four canals (24.8%, n = 32).

The mesial root had two canals in 95.3% of the first molars. The distal root had one canal in 75.2% and two canals in 24.8%. The most frequent canal configuration of the mesial root was Vertucci's Type II (62.1%), followed by Type IV (29.5%). Type I (57.4%), Type II (18.6%) and

Type III (17.8%) had the highest frequency in the distal root. The root canal configuration of the distolingual root was Vertucci's Type I in all teeth.

Second molars

Of the 198 second molars, 46% ($n = 91$) were on the right side and 54% ($n = 107$) were on the left side. In addition, 56.6% ($n = 112$) of the teeth belonged to female patients and 43.4% ($n = 86$) belonged to male patients. Of the 198 second molars, 162 (81.8%) had two roots, 30 (15.2%) had one root, and 6 (3%) had three roots. All distolingual root canals of the second molars also had Vertucci's Type I configuration. Of 30 single-rooted second molars, 21 (70%) had a C-shaped configuration and nine (30%) had one single conical root. The frequency of C-shaped second molars was 10.6%.

Table 1 shows the canal configuration and number of canals in the mesial root of the first and second molars with two roots. The Monte Carlo test showed a significant association between the number of canals and canal configuration in the mesial root ($P = 0.006$). Of the three-canal molars (two mesial canals and one distal canal), 74.2% and 20.3% were Type II and Type IV, respectively.

Table 1: Relationship of canal configuration (Vertucci's classification) of mesial root and number of canals in mandibular first and second molars

Tooth Canals type (mesial root)	Number of canals in first and second molar (%)	
	3	4
Type II	161 (74.2)	17 (47.2)
Type III	7 (3.2)	0
Type IV	44 (20.3)	19 (52.8)
Type V	2 (0.9)	0
Type VI	3 (1.4)	0
Total	217 (100)	36 (100)

In four-canal teeth (two mesial and two distal canals), 52.8% and 47.2% were Type IV and Type II, respectively. The same relationship was observed in both the first and second molars.

Table 2 shows the relationship between gender and canal configuration in the mesial root. The most common morphology in mandibular first and second molars was Type II in mesial roots and Type I in distal roots in male and female patients. The correlation of gender and canal configuration in the mesial and distal roots was not significant ($P > 0.05$).

Table 3 shows the relationship of the canal configuration of the mesial and distal roots and the quadrant of the tooth (right/left) in the jaw. In both sides, Vertucci's Type II was the most prevalent configuration of mesial root canals, followed by Type IV. No significant correlation was noted between the root canal configuration and right/left quadrant of the mandible ($P > 0.05$).

Bilateral molars

Of the 129 first molars, 32 were bilateral, of which 68.75% had the same number of roots and canals and 31.25% had the same number of roots and canals and the same root canal configuration. Of the 198 second molars, 50 were also bilateral; in 76% of these molars, the number of roots and canals was the same, and in 52%, the number of roots and canals as well as the canal configuration of roots was the same. In bilateral first and second molars, a significant association was noted only in terms of the similarity in the number of roots and canals ($P < 0.05$).

Adjacent molars

In this study, first and second molars were adjacent in 88 cases; in 54% of them, the number of roots and canals

Table 2: Relationship of canal configuration of mesial and distal roots of the mandibular first and second molars with gender

Tooth type	Mesial canal type	Gender		Distal canal type	Gender	
		Male	Female		Male	Female
First molar	Type II	30 (60)	50 (63.3)	Type I	24 (48)	50 (63.3)
	Type III	3 (6)	2 (2.5)	Type II	13 (26)	11 (13.9)
	Type IV	15 (30)	23 (29.1)	Type III	8 (16)	15 (19)
	Type V	0	1 (1.3)	Type IV	1 (2)	2 (2.5)
	Type VI	0	1 (1.3)	Type V	3 (6)	1 (1.3)
	Type (2-1-2-1)	0	1 (1.3)	Type VI	1 (2)	0
	Type XII (3-2)	1 (2)	0			
	Type XXII (3-2-1)	1(2)	1(1.3)			
Second molar	Type I	5 (6.8)	5 (5.3)	Type I	68 (93.2)	87 (91.6)
	Type II	44 (60.3)	60 (63.2)	Type II	3 (4.1)	4 (4.2)
	Type III	9 (12.3)	12 (12.6)	Type III	2 (4.7)	4 (4.2)
	Type IV	14 (19.2)	12 (12.6)			
	Type V	0	1 (1.1)			
	Type VI	0	2 (2.1)			
	Type XXI (2-3-2)	0	1 (1.1)			
	Type XII (3-2)	0	1 (1.1)			
	Type XXII (3-2-1)	1 (1.4)	1 (1.1)			

Table 3: Relationship of canal configuration of mesial and distal roots and right/left quadrant of the mandible

Tooth type	Mesial canal type	Quadrant of the mandible		Distal canal type	Quadrant of the mandible	
		Right	Left		Right	Left
First molar	Type II	37 (57.8)	43 (66.2)	Type I	33 (51.6)	41 (63)
	Type III	5 (7.8)	0	Type II	13 (20.3)	11 (16.9)
	Type IV	18 (28.1)	20 (30.8)	Type III	11 (17.2)	12 (18.5)
	Type V	1 (1.6)	0	Type IV	3 (4.7)	0
	Type VI	1 (1.6)	0	Type V	3 (4.7)	1 (1.5)
	Type X (2-1-2-1)	0	1 (1.5)	Type VI	1 (1.6)	0
	Type XII (3-2)	1 (1.6)	0			
	Type XXII (3-2-1)	1 (1.6)	1 (1.5)			
Second molar	Type I	6 (7.9)	4 (4.3)	Type I	68 (89.5)	87 (94.6)
	Type II	42 (55.3)	62 (67.4)	Type II	3 (3.9)	4 (4.3)
	Type III	10 (13.2)	11 (12)	Type III	5 (6.6)	1 (1.1)
	Type IV	13 (17.1)	13 (14.1)			
	Type V	1 (1.3)	0			
	Type VI	2 (2.6)	0			
	Type XXI (2-3-2)	1 (1.3)	0			
	Type XII (3-2)	0	1 (1.1)			
	Type XXII (3-2-1)	1 (1.3)	1 (1.1)			

was the same, and in 25%, the number of roots and canals as well as the canal configuration was the same. In adjacent molars, no significant association was noted in terms of the number of roots or canals or root canal morphology ($P > 0.05$).

DISCUSSION

Several techniques are commonly used to study the anatomy of the root canals. The staining and clearing technique can reveal the finest details in root canal anatomy.[14,15] However; this *in vitro* technique can only be performed on the extracted teeth. While in the clinical setting, information obtained before or during endodontic therapy is highly valuable.

CBCT is superior to the other available methods for assessment of the root canal anatomy.[16] The main advantage of CBCT for evaluation of the root canal anatomy is its nondestructive nature (i.e. it does not require tooth sectioning). Furthermore, it enables the three-dimensional reconstruction of images to visualize the internal and external anatomy of the teeth.[17] It seems that the axial sections are suitable to determine the number of roots and canals. Moreover, cross-sectional views are suitable to study the root canal anatomy. In the current study, the number of mandibular molar canals and their morphology were evaluated on CBCT scans taken for other purposes.

Most of the first and second molars had two roots in this study, which was similar to the results of other studies.[1,3,4,9,10] The mesial and distal roots of the mandibular first and second molars were mainly Vertucci's Type II and Type I, respectively. Moreover, a significant association was noted between the presence of three canals in teeth (two canals in mesial root and one canal in distal root) and Vertucci's Type II configuration in the mesial root of the mandibular first and second molars. In this study, the results showed that most of the first molars had three canals (72.1%), and a smaller percentage had four canals (24.8%), which were in line with the previous findings in the Jordanian, Iranian, and Turkish populations.[15,18,19]

In terms of the mesial root canal morphology of the first molars, Vertucci's Type II (62.1%) and Type IV (29.5%) had the highest frequency. Vertucci's Type IV followed by Type II was the most common configuration of the mesial root of mandibular first molars in most previous studies.[1,15,18-21] The results of this study were in agreement with those of studies on the Caucasian, Korean, Kuwaiti, Iranian, and Spanish populations,[4,20,22,23] which reported Vertucci's Type II to be the most common configuration of the mesial root. In some previous studies, Vertucci's Type I, Type II, and Type IV were the most commonly found configurations of the distal root of mandibular first molars.[15,19,23] The same findings were obtained in this study.

The frequency of three-rooted first molars was 3.9%, which was close to the value reported in the other studies.[3,4,15,19,24] Overall, the frequency of three-rooted first molars is <5% in Caucasians and Indian-Europeans,[1] which is in line with the findings of the current study.

In the current study, most of the second molar teeth had three (76.6%) or two (16.7%) canals. The mesial and distal roots of the second molars in most cases were Vertucci's Type II (61.9%) and Type I (92.3%), respectively. Gulabivala *et al*.[14] and Kim *et al*.[25] reported Vertucci's Type IV to be the most common configuration of the mesial root of

second molars. In contrast, Gulabivala *et al*.[26] and Janani *et al*.[27] in their studies on mandibular second molars in the Burmese and Iranian subpopulations reported Type II to be the most commonly found configuration, which was in accordance with the results of the present study. According to most previous studies, Vertucci's Type I is the most commonly found configuration of the distal root of second molars.[14,15,23,25-28] This finding was also confirmed in the present study.

The frequency of C-shaped second molars was found to be 10%. Naseri *et al*.[28] in their review article reported the frequency of C-shaped molars to be 3% to 13.8% in Iran. The frequency of C-shaped second molars in this study (10.6%) was similar to that reported in the Sudanese, Saudi Arabian, Thai, Jordanian, and Turkish populations.[3,10,14,15,29] Frequency rates higher than 10% and as high as 39% to 44.5% have been reported in the Chinese and Korean populations.[30,31] The results of the aforementioned studies and the present findings indicate the high frequency of C-shaped molars in Asia, particularly in East Asia.

In the current study, no significant association was noted between the canal morphology and the patients' gender or the right/left quadrant of the mandible, which was similar to the findings of other studies.[9,20,32]

The present study revealed a significant association between bilateral molars in terms of their similarity in the number of roots and canals, which was in agreement with the findings of Plotino's study.[33] Tu *et al*.[34] reported the frequency of bilateral first molars with three roots to be 53.65%.

In the current study, no significant association was noted in terms of similarity in the number of roots/canals or canal configuration between the adjacent molars. A search of the literature yielded no similar study that could be used for comparison. Variations in the reported values in different studies are attributed to the racial and ethnic differences among the study populations, the sample size, and the assessment technique. High variability exists across studies in terms of race, sample size, and the methods used to assess the root canal configuration. Evidence shows significant correlations between race and anatomical variations, such as the frequency of third roots or C-shaped canals.[16,18] It appears that the root canal configuration is also influenced by race, but this relationship has yet to be statistically documented.

Previous studies showed the correlation between complicated root canal configurations of permanent mandibular first premolar and central incisors with distolingual roots in the mandibular first molar.[35,36] The frequency of the middle mesial canals have also showed a higher incidence in mandibular molars with two separate distal canals.[11] It seems that there is a relationship between the number of canals and root canal configurations.

The present findings revealed a significant association between the number of canals and mesial root configuration, indicating that Vertucci's Type II had a significantly higher frequency in the mesial root of the first and second molars with three canals (two mesial and one distal canal) compared with four canals (two mesial and two distal canals). Furthermore, Vertucci's Type IV had a significantly higher frequency in the mesial root of four-canal molars compared with three-canal molars. No similar study was found in the literature for the purpose of this comparison.

Evaluation of the associations between the number and configuration of root canals, bilateral and adjacent first and second molars in terms of the number of roots/canals, and canal configuration was a strength of this study since no previous study has evaluated these parameters. The selection of patients from a single center in Qazvin city may be considered as a limitation of this study. Future multicenter studies with larger sample size are required to obtain more reliable results regarding the anatomical variations of the mandibular molars in the population of Qazvin city. Another limitation of this study was that most of the patients had received dental treatment, such as extraction or root canal treatment, especially bilateral assessment was difficult.

Clinicians should raise awareness of the positive correlation between the number of root canals and mesial root canal configuration in mandibular molars.

Adequate knowledge about the variations in root canal configurations often results in more detailed assessment of the canal configuration in the clinical setting, which may lead to a modified canal preparation and can help prevent procedural errors.

CONCLUSION

Within the limitations of this study, the results revealed a significant association between the number of root canals and mesial root canal configuration in mandibular molars in an Iranian subpopulation.

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Conflicts of interest

There are no conflicts of interest.

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