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# Root canal anatomy and morphology evaluation of mandibular molars according to gender by cone-beam computed tomography in Iranian population

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**Abstract**
**Introduction:** This study aimed to evaluate anatomy and morphology of mandibular permanent molars using cone-beam computed tomography (CBCT) in a selected Iranian population.
**Methods and Materials:** CBCT images of 638 first and second mandibular molars (322 of males and 316 of females) were included in this *in vitro* study. Number of roots and root canals, Vertucci's configuration of each root, radix paramolaris (RP), radix entomolaris (RE), and C-shaped canals were determined in both genders. Data were analyzed by Pearson-Chi square test using SPSS (V.22) software (P = 0.05).
**Results:** The most common configuration of distal roots were type I for both genders. Among 266 first molars, 97.3% teeth had two roots, 0.75% had RP and 1.87% had RE. All RP and RE were type I. C-shaped canals were found in 1.12% teeth and all were in male population, significantly at the left side (P=0.045). Among 372 second molars, 94.08% had two roots, 0.53% had RP and 0.26% had RE. The prevalent canal configuration of mesial roots was type III (52.96%) with significant difference between right (P=0.006) and left (P=0.049). C-shaped canals were found in 5.64% of second molars and more specifically detected in male group. Significant difference was observed between two genders in the right (P=0.024) and the left (P=0.009).
**Conclusion:** Vertucci's type III and type II were the most prevalent configurations in mesial roots while for distal roots the predominant configuration was type I. RE, RP, and C-shaped channels were not common in mandibular molars between Iranian population and their prevalence were higher among male population.

**Keywords:** Anatomy, cone-beam computed tomography, c-shaped canals, gender, mandibular molar, morphology

## Introduction
A successful endodontic treatment depends on effective cleaning and shaping of the root canal system [1]. To achieve this goal and to prevent undesirable failures of root canal treatment, prior knowledge of root canal anatomy and morphology for conservative and meticulous process of mechanical instrumentation and chemical debridement is required [2, 3].
Toure *et al.* [4] reported mandibular molars as the most frequently extracted teeth between endodontically treated teeth due to failure of root canal treatment (19.3%). The anatomical and morphological characteristics of mandibular molar root canal systems varies greatly among different individuals of either similar or different races. Proper knowledge of these variations in different populations is highly important to locate root canals and manage instrumentation during root canal therapy of mandibular molars [5]. Usually mandibular molars have two separate roots of mesial and distal with two canals in mesial and one or two canals in distal root in the majority of them [3].Configuration of C-shaped roots first introduced by Cooke and Cox [6] in 1979, may be found in case of lingual or buccal fusion of mesial and distal roots. This variation is mostly seen in mandibular second molars [7].
Globally, several studies evaluated various characteristics of mandibular molar teeth anatomy and morphology from ethnicities of different countries including Turkish, Indian, Chines, Korean, and Sudanese populations [2, 8-12].

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Iranian national studies in regard to some anatomic and morphologic features of mandibular molars in selected populations have been done in previous years [3, 13, 14]; Ghoddusi *et al*. [15] reported a rare case of six-canaled (2 mesial, 4 distal canals) mandibular first molar. A six-canaled mandibular first molar with three canals in distal root was reported by Baziar *et al*. [16]. Aminsobhani *et al*. [17] reported a case series of 27 mandibular molars with middle mesial canal. Root canal anatomy of 310 mandibular first molars were studied by Razmi *et al*. [14]. Akhlaghi *et al*. [3] evaluated root canal anatomy of 150 mandibular first molars using clearing technique. Madani *et al*. [5] assessed root canal morphology of mandibular first and second molars, and the thinnest area around root canals using cone-beam computed tomography (CBCT) in northern Iranian people.

Several methods have been used to study root canal systems including staining and tooth clearing, plastic injection, radiopaque gel infusion, radiography. CBCT and micro-CT images introduced as accurate and conservative methods, recently [3].

Due to different results of previous studies, this study was carried out to evaluate three dimensional CBCT images of the root canal anatomy and morphology of 638 fully erupted permanent mandibular first and second molars in a selected` Iranian population.

## Method and Materials

This study recruited CBCT images of 242 Iranian patients referred to a maxillofacial radiology center in Tehran, Iran between 2019-2020. The images were taken for diagnostic and therapeutic purposes including implantation surgery and surgical removal of third molar. All CBCT images were performed with exposure conditions of 6.59 mA, 90 KVp, and exposure time of 3.6 seconds.

Inclusion criteria were; high quality CBCT images of mandibular permanent teeth with complete root formation and without any sign of periapical lesion, resorption or calcification. Excluding criteria were the teeth with root canal therapy, filling, post-core or crown restoration. Also, CBCT images of non-Iranian or syndromic patients were excluded. Out of 242 CBCT images, 638 permanent mandibular first and second molars of patients (322 males and 316 females) were enrolled in this study.

CBCT images were transferred from external hard (1Tb, my passport- Ultra, model: WDBGPU0010BBY-EESN, Thailand) to PC with windows, then images started up in NEW TOM software (copyright 2001-2005, Verona/Italy). Teeth were classified by gender, mandible side (right and left), number of roots and root canals, presence and type of C-shaped canals, root canal morphology (based on Vertucci's classification), radix paramolaris (RP) and radix entomolaris (RE) in three Sagittal, Coronal and Axial plans separately with 1mm slice of thickness for more precise evaluation.

**Statistical Analysis:** Descriptive analysis of collected data according to gender were calculated. Sample size was detected to be at least 314 teeth in each group using Mini Tab software assuming d=0.03. Data were analyzed by Pearson-Chi square test using SPSS (V.22) software.

## Results

A total of 638 teeth (322 of males and 316 of females) were evaluated. All the variables analyzed for the mandibular first and second molars are detailed in Table 1 and 2.

Among 266 mandibular first molars, 259 (97.3%) teeth had two separate roots (mesial and distal). RP and RE was observed in two (0.75%) and five (1.87%), respectively with all type I of Vertucci configuration.

Out of 132 mandibular first right molars, most of them (97.7%) had two roots, 114 (86.3%) had three canals, only one (0.7%) had RP and two (1.5%) had RE roots. The most frequent Vertucci's type of mesial roots was type II and III (40.9% each). Type I was the most prevalent type in distal roots (88.6%) (P=0.035) with significant difference between two genders (P=0.035). About 52 (39.3%) showed two root deviations, 41 (31%) had one deviation while no deviation found in 38 (28.8%) teeth (P =0.609). Only 1 tooth (1%) had C-shape canal with type I (P=0.301).

Among 134 first molars at the left side, two (3.4%) teeth had symmetric C-shaped canals in male population while no C-shaped canals observed in females. There was significant difference between male and female groups (P=0.045).

Out of 134 mandibular first left molars, most of them (97%) had two roots, one root's deviation (43.2%), and three root canals (84.3%). RP, RE, and C-shaped canals were found in 0.7%, 2.2%, and 1.5%, respectively. The most frequent Vertucci canal type for mesial roots were type III (41%), followed by type II (40.3%), type IV (16.4%) and type I (2.2%) (P =0.576). Predominant canal type in distal roots was type I (88%) (P=0.203).

Among 372 mandibular second molars, 350 (94.08%) had two separate roots, 19 (5.10%) had one roots. Also, two (0.53%) teeth had RP and one (0.26%) had RE roots. The most canal configuration of mesial roots was type III (52.96%), followed by type II (30.10%) while type I (6.45%) was only seen in male population. Only one mesial root (0.94%) showed type V canal. There was statistically significant difference in terms to Vertucci canal configuration of mesial roots between right (P=0.006) and left (P=0.049) mandibular second molars. Type I (94.08%) was the predominant configuration in distal roots in both male and female groups. C-shaped canals were found in 21 (5.64%) of second molars and more specifically were detected in male group. Significant difference was observed between two genders in the right (P=0.024) and the left (P=0.009) mandibular molars.

From 180 mandibular second right molars, Vertucci's type in mesial roots were type III (48.8%), followed by type II (31.6%), type I (7.7%), type IV (5%) and type V (0.5%). The other 11 teeth were single-rooted with 5.5% type I (P=0.006) and 0.5% type II (P=0.512). Type I was the most common Vertucci's type in distal roots (93.3%) (P=0.572). Most of the teeth had at least one root deviation (38.8%) (P=0.656) and three canals (87.2%) (P=0.024).

Out of 192 mandibular second left molars, 4.1% were single-rooted, and 94.8% had two roots, 0.5% had RP and 0.5% RE roots (P=0.325). Vertucci's type in mesial roots were type III (56.7%), followed by type II (28.6%), type I and 4 (5.2% for each) respectively (P=0.049). The remained eight teeth were single-rooted (3.6%: type1 and 0.5%: type 8) (P=0.536). Type I was the most common Vertucci's type in distal roots (P=0.544). Most of the teeth had one root deviation (47.3%) (P=0.435), and three canals (91.1%) (P=0.078). C-shape canals found in 6.2% teeth; all were type I (P=0.009).

**Table 1:** Variables analyzed for the mandibular first molars

| | Mandibular First Molar | | | |
|---|---|---|---|---|
| | Right (n=132) | | Left (n=134) | |
| | Male (n=64) | Female (n=68) | Male (n=58) | Female (n=76) |
| **Root Number** | | | | |
| One root | - | - | - | - |
| Two roots | 62 (96.8%) | 67 (98.5%) | 56 (96.5%) | 74 (97.3%) |
| RP [∈] | 1 (1.4%) | - | 1 (1.7%) | - |
| RE [¥] | 1 (1.4%) | 1 (1.5%) | 1 (1.7%) | 2 (2.6%) |
| **P Value** | 0.699 | | 0.987 | |
| **Mesial Configuration** | | | | |
| I | 1 (1.5%) | - | 2 (3.4%) | 1 (1.3%) |
| II | 26 (40.6%) | 28 (41.1%) | 24 (41.3%) | 30 (39.4%) |
| III | 29 (45.3%) | 25 (36.7%) | 25 (43.1%) | 30 (39.4%) |
| IV | 8 (12.5%) | 15 (22%) | 7 (12%) | 15 (19.7%) |
| **P Value** | 0.336 | | 0.576 | |
| **Distal Configuration** | | | | |
| I | 61 (95.3%) | 56 (82.3%) | 53 (91.3%) | 66 (85.5%) |
| II | - | 5 (7.3%) | - | 4 (5.2%) |
| III | 3 (4.6%) | 7 (10.2%) | 5 (8.6%) | 7 (9.2%) |
| **P Value** | 0.035* | | 0.203 | |
| **RP [∈] (Vertucci)** | | | | |
| Type I | 1(1.4%) | - | 1 (1.3%) | - |
| **P Value** | 0.301 | | 0.251 | |
| **RE [¥] (Vertucci)** | | | | |
| Type I | 1(1.4%) | 1 (1.5%) | 1 (1.3%) | 2 (3.4%) |
| **P Value** | 0.966 | | 0.725 | |
| **Number of Canals** | | | | |
| 1 | - | - | - | - |
| 2 | - | - | 1 (1.7%) | 1 (1.3%) |
| 3 | 60 (93.7%) | 54 (79.4%) | 52 (89.6%) | 61 (80.2%) |
| 4 | 4 (6.2%) | 14 (20.55) | 5 (8.6%) | 14 (18.4%) |
| **P value** | 0.016* | | 0.271 | |
| **Number of C-Shaped Canals** | | | | |
| 1 | 1 (1.5%) | - | 2 (3.4%) | - |
| **P Value** | 0.301 | | 0.045* | |

*P<0.05, Pearson-Chi square test, as appropriate.
RP [∈]: Radix Paramolaris, RE [¥]: Radix Entomolaris

**Table 2:** Variables analyzed for the mandibular second molars

| | Mandibular Second Molar | | | |
|---|---|---|---|---|
| | Right (n=180) | | Left (n=192) | |
| | Male (n=94) | Female (n=86) | Male (n=106) | Female (n=86) |
| **Root Number** | | | | |
| One root | 6 (6.3%) | 5 (5.8%) | 4 (3.7%) | 4 (4.6%) |
| Two roots | 87 (92.5%) | 81 (94.1%) | 100 (94.3%) | 82 (95.3%) |
| RP [∈] | 1 (1.1%) | - | 1 (0.9%) | 0 |
| RE [¥] | - | - | 1 (0.9%) | 0 |
| **P Value** | 0.896 | | 0.325 | |
| **Mesial configuration** | | | | |
| 0 | 6 | 5 | 4 | 4 |
| Type I | 14 (14.8%) | - | 10 (9.4%) | 0 |
| Type II | 24 (25.5%) | 33 (38.3%) | 28 (26.4%) | 27 (31.3%) |
| TypeIII | 45 (47.8%) | 43 (50%) | 60 (56.6%) | 49 (56.9%) |
| Type IV | 5 (5.3%) | 4 (4.6%) | 4 (3.7%) | 6 (6.9%) |
| Type 5 | - | 1 (1.2%) | - | - |
| **P Value** | 0.006* | | 0.049* | |
| **Distal Configuration** | | | | |
| 0 | | | 4 | 4 |
| Type I | 6 | 5 | 101 (95.2%) | 81 (94.1) |
| Type II | 88 (93.6%) | 80 (93%) | 0 | 1 (1.2%) |
| Type III | 0 | 1 (1.2%) | 1 (0.94%) | - |
| **P Value** | 0.572 | | 0.544 | |
| **RP [∈] (Vertucci)** | | | | |
| Type I | 1 (1.1%) | - | 1 (0.94%) | - |
| P Value | 0.337 | | 0.366 | |
| **RE [¥] (Vertucci)** | | | | |
| Type I | - | - | 1 (0.94%) | - |

| P Value | - | | 0.366 | |
|---|---|---|---|---|
| **Number of Canals** | | | | |
| 1 | 6 (6,3%) | 4 (4.6%) | 4 (3.7%) | 3 (3.4%) |
| 2 | 11 (11.7%) | 1 (1.2%) | 8 (7.5%) | - |
| 3 | 77 (81.9%) | 80 (92%) | 93 (87.7%) | 82 (95.3%) |
| 4 | - | 1 (1.2%) | 1 (0.94%) | 1 (1.2%) |
| **P value** | 0.024* | | 0.078* | |
| **Number of C-shaped Canals** | | | | |
| 1 | 8 (8.5%) | 1 (1.2%) | 11 (10.3%) | 1 (1.1%) |
| **P value** | 0.024* | | 0.009* | |

*$P< 0.05$, Pearson-Chi square test, as appropriate.

RP [€]: Radix Paramolaris, RE [¥]: Radix Entomolaris

## Discussion
In this study, we provided a detailed report on the root canal anatomy and morphology of 638 mandibular first and second permanent molars in a selected Iranian population by using CBCT images. CBCT provides a non-destructive three-dimensional assessment of external and internal characteristics of roots and canals [2]. Most of the samples were two-rooted (95.4%). Vertucci type III (47.9%) and type II (34.4%) were the most prevalent type in mesial roots, totally. Most of the teeth had three canals (two canals in mesial root and one in distal root) (87.6%).

In the current study, 97.3% of first molars and 94.3% of second molars had two separate roots of mesial and distal which were similar to the Madani et al. [5] evaluation for first molars (96.7%) but more for second molars (81.6%). The more teeth evaluated in our study (638) might be considered in comparison with Madani et al. evaluation (301 teeth). The proportion of two-rooted first molars were greater than that reported in a Korean (66.9%), Chines (74.9%), and Brazilian (87%) population [18-20].

Martins et al. [21] reported a high prevalence of three-rooted morphology in the mandibular first molars of Asian populations. However, three roots were observed in 2.6% of first and 0.8% of second mandibular molars, respectively which was reported 1.9% and 0.6% in Madani et al. [5] evaluation of Iranian population. Three-rooted first molars of our study was more than 1.44% of teeth reported by Shahi et al. [13] evaluation on Iranian people. Three-rooted second molar prevalence of this study was low when compared to Indian population (7.53%), but similar to Chinese (1.27%). The prevalence of additional RE (2.2%) and RP (1.5%) roots in the present study was low among the Iranian population.

Most of the molar teeth in the current study had three canals which was similar to other studies including Brazilian and Iranian and Turkish population [2, 3, 22].

The most canal configurations of our study were Type III (47.9%) and Type II (34.4%) in mesial roots which was in contrast to some previous studies; Madani et al. [5] reported type IV (4.57%-42.9%) and type II (31.5%-28%) as the most prevalent canal type in 301 molar teeth of selected Iranian population. Pawar et al. [9] showed type IV and type II were the most common canal type in Indian people. Shahi et al. [13] also stated that type IV and then type II were more common in first molars of a selected Iranian evaluation. Chourasia et al. [11] used hematoxylin dye to evaluate morphology of mandibular first molars using microscope. Most of the samples were two-rooted (94.6%), but type 4 of Vertucci's classification in mesial roots. The differences of Vertucci's classification in mesial roots of different studies may be due to racial differences or the method of study.

The predominant canal configuration in distal roots was type I which in consistent with the previous studies in Iranian and Indian population [3, 5, 9, 13].

No incidence of type VI, VII, and VIII Vertucci canal type was observed either in mesial or distal roots in our evaluation which was the same as the Shahi et al. [13] study on Iranian population. However, Madani et al. [5] found only one mesial root with type VI in mandibular second molars.

The presence of C-shaped canals was 3.76% which was more than Chilian (1.9%), but less than that of Belgian (8.9%), Saudi (9.1%), Sudanese (10%), Chines (29%), and Mayan (35%) (10, 23-26). In Madani et al. [5], evaluation of 301 mandibular molars, 9.3% showed C-shaped canals that was greater when compared to our results. The differences of C-shaped canals incidence among the different races are claimed to be strongly related to ethnicity [10, 25, 27].

A significantly higher prevalence of C-shaped canals in females has been reported in previous studies of Saudi, Turkish, Chilian, Iranian population [2, 5, 23, 25]. However, in our study, male population had more C-shaped canals in comparison to female population. Evaluations of dental anatomy and morphology usually include a characterization according to gender due to correlation between root development and the X chromosome [28].

Previous CBCT studies reported more common C-shaped canals in mandibular second molars than that of first molars [2, 5, 25, 29] which is similar to the results of the current study. C-shaped root canals are usually reported in mandibular second molars that is more common in Asian population compared to other ethnic groups [5, 30].

## Conclusion
Additional roots of RE, RP, and C-shaped channels were not very common among mandibular molars in the Iranian people and their prevalence is higher in male than female population. Overall, a great anatomical and morphological variations were observed between the selected specimens, therefore, more attention should be considered to decrease endodontic failures in this population.

## Highlight
1. The most canal configurations of our study were Type III and Type II in mesial roots while Type I was more prevalent in distal roots.
2. RE, RP, and C-shaped channels were not very common among mandibular molars in the Iranian population.
3. Prevalence of RE, RP, and C-shaped canals is higher in male than female population
4. Additional RP and RE roots showed only the first type of Vertucci.

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