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# Anatomy of Permanent Mandibular First Molars in a Selected Iranian Population Using Cone-beam Computed Tomography

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**ABSTRACT**

**Introduction:** Knowledge of radicular anatomy has a crucial impact on endodontic practices. Since some anatomic features such as modifications of Vertucci are not evaluated adequately, this study was conducted. **Methods and Materials:** In this *in vivo* study, cone-beam computed tomography (CBCT) images of 312 intact bilateral first molars from 156 patients (79 males and 77 females with an average age of 35.58±11.17 years) were investigated by a trained dentist in terms of number of roots, number of canals in each root and in each tooth, and shapes of canals according to Vertucci's classification and its modifications. Groups were compared using the *Chi*-square test. The level of significance was set at 0.05. **Results:** Of all teeth, 5.2% had 3 roots. Mesial roots had mostly 2 canals while distal roots had a similar frequency of 1 and 2 canals. Of all teeth, 39.7% had 3 canals, 45.2% had 4 canals, 13.8% had 5 canals, and 1.3% had 6 canals. There were no significant differences between males and females, in terms of number of roots ($P$=0.137), number of canals in mesial ($P$=0.453) or distal roots ($P$=0.328), and total number of canals ($P$=0.138). The most frequent Vertucci classes in mesial and distal roots were IV followed by II and I, respectively. There were no significant differences between males and females in terms of Vertucci classes of mesial ($P$=0.211) or distal ($P$=0.205) roots. **Conclusion:** In this population, there were 3 to 6 canals per tooth (mostly 4 and 3 canals). Males and female's might be similar regarding the number of roots, or number of canals in each root, number of canals in each tooth, or the predominant canal shape in each root.

**Keywords:** Anatomy; Cone-beam Computed Tomography; Endodontics; Root Anatomy

## Introduction

Proper knowledge of the internal anatomy of root canals is crucial for a successful endodontic treatment which relies on appropriate cleaning and shaping [1, 2]. Since mandibular first molars emerge very early in the mouth and have complex surfaces, they are one of the teeth most requiring root canal therapy; and therefore the knowledge of their root canal anatomy is important [2, 3]. These teeth usually have three canals within two roots although they can change due to ethnicity or normal variations [4-7].

Since ethnic background can affect root anatomy of mandibular first molars, it is important to document properties of these teeth in various populations. However, studies on Iranians are few and controversial [2, 3, 8-11]. Many aspects of anatomic features are not usually covered by them (such as modifications of Vertucci classification which is not covered in many studies worldwide). Many of older studies have used conventional or 2D radiography techniques that can be less accurate than 3D radiography techniques [12]. Nevertheless, recent studies have mainly used cone-beam computed tomography (CBCT) due to its numerous advantages [8-11].

This study evaluated number and shape of roots and canals of permanent mandibular first molars using CBCT images of an Iranian sample population.

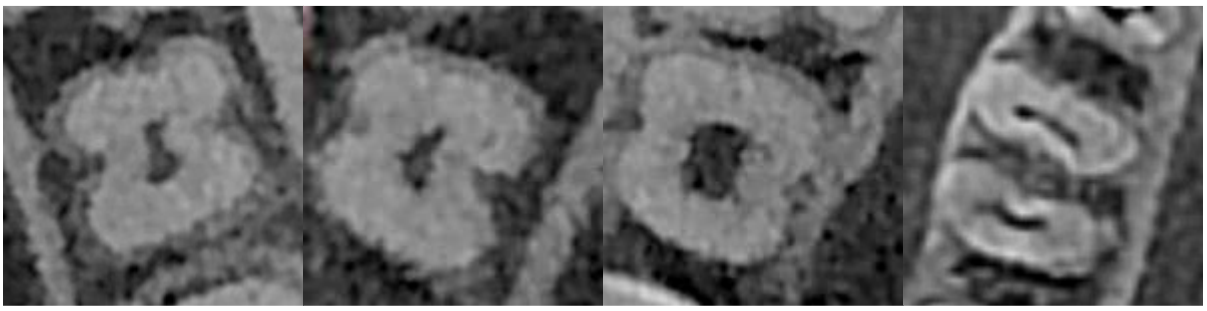

*Figure 1.* Examples of transverse CBCT sections

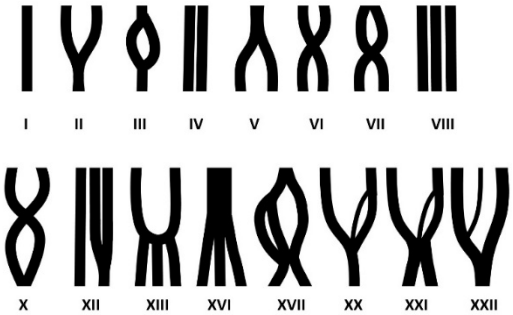


*Figure 2.* Schematic diagrams representing canals within a root [black columns drawn together from top (coronal) to bottom (apical)], arranged as all Vertucci classes (top row) and as certain Vertucci modifications that were observed in this sample of mandibular first molars (bottom row)

## Materials and Methods

This *in vivo* study was performed on CBCT images of patients aged 20 to 60 years who had attended two centers in Tehran. All CBCTs had been retrospectively taken solely for clinical purposes. No x-ray was emitted to patients for this study, and study ethics were approved by the research committee of Azad University of Medical Sciences, Dental branch, Tehran, Iran (#14859). All CBCTs had been taken with the same unit (NewTom, GiANO, Verona, Italy); with similar field of view (8×5 cm), focal size (0.3 mm), current (12 mA), peak kilovoltage (85 kVp), and time (0.4 sec). Inclusion criteria were availability of both mandibular first molarsand in each patient, full patient information was obtained. Exclusion criteria were resorption, previous endodontic treatment, open apex, agenesis, fractures, or pathologies. A total of 312 images of first molars from 156 patients were included.

All measurements were done by the same dentist trained by a maxillofacial radiologist, using NTT Viewer software program (NTT Software Corporation, Yokohama, Japan). CBCT images were examined in coronal, sagittal, and mainly axial dimensions (Figure 1). Evaluated parameters were number of roots, number of canals in each root and in each tooth, and shapes of canals according to the Vertucci classification [13] and its modifications [14-17]. Vertucci classes can be summarized based on the number of canals from coronal to apical portions of the root: type I (coronal canals: 1, apical canals:1 [1-1]), type II (2-1), type III (1-2-1), type IV (2-2), type V (1-2), type VI (2-1-2), type VII (1-2-1-2), type VIII (3-3), type IX (3-1), type X (3-1-2-1), type XI (4-2), type XII (3-2), type XIII (2-3), type XIV (4-4), type XV (5-4), type XVI (1-3), type XVII (1-2-3-2), type XVIII (1-2-3), type XIV (3-1-2), type XX (2-3-1), type XXI (2-3-2), type XXII (3-2-1), and type XXIII (3-2-3). Schematic diagrams of Vertucci classes and certain modifications observed are presented in Figure 2.

Descriptive statistics were calculated. Groups were compared using the *chi*-square of Statistical Package for Social Science (SPSS, version 24.0, SPSS, Chicago, IL, USA). The level of significance was predetermined as 0.05.

## Results

The observer was calibrated through repeating the diagnosis of cases (especially more difficult cases) under the supervision of a dental anatomist and an endodontist. Of 156 enrolled patients, 79 were males and 77 were females. Patients' average age was 35.58±11.17 years. Of patients, 101 (64.7%) were aged between 20 and 39 years old, while 55 (35.3%) were between 40 and 60 years old.

### *Number of roots and canals*

Table 1 summarizes the number of canals. Among 312 assessed teeth, 16 (5.2%) bilateral teeth in 8 patients had 3 roots; in all these cases, the third root was distolingual. All other teeth had 2 roots. Mesial roots had mostly 2 canals and in few cases 3 canals (Table 1). Distal roots showed a rather similar distribution of 1 and 2 canals, in addition to very few 3 canals (Table 1). All distolingual roots contained only 1 canal. Overall, number of canals ranged between 3 and 6. Of 312 teeth, 39.7% had 3 canals, 45.2% had 4 canals, 13.8% had 5 canals, and 1.3% had 6 canals. All 6-canaled teeth were 3-rooted. There were no significant differences between males

and females, in terms of number of roots ($P$=0.137), number of canals in mesial ($P$=0.453) or distal roots ($P$=0.328), and total number of canals ($P$=0.138).

***Vertucci classifications***

Tables 3 and 4 present Vertucci classes and Vertucci modifications. In mesial roots, the most common classes were type IV followed by II. In distal roots, the most common class was type I (Tables 2 and 3, Figure 2). The *Chi*-square did not show significant differences between males and females in terms of Vertucci classes in the mesial root ($P$=0.211) or distal root ($P$=0.205).

## Discussion

The findings of the present study showed that only 5.2% of first molars had three roots. Our results were similar to other Iranian studies reporting prevalence of third roots ranging between zero and 3.9% [2, 8-11]. Also our findings were consistent with studies on Jordan [14], India [18], Turkey [19, 20] and Sudan [21]. However, they were not in line with results from South Korea [22] and Burma [7]. It seems that presence of distolingual roots might depend on ethnicity, and results in Asians indicate a rather high prevalence of the third root (Table 4) [4-7, 22, 23].

In this study, prevalence of three and four canals in each tooth were rather similar. This finding was comparable to results of Kim *et al.* [22], Zhang *et al.* [23], Al-Qudah and Awadeh [14] who reported similar prevalence of three and four canals, but was in contrast to observations of Demirbuga *et al* .[20], Chourasia *et al.* [18], Ballullaya *et al.* [6], Nur [19] and Masoudi [9] who reported a considerably greater prevalence of 3-canaled roots compared to 4-canaled roots. Three-canaled roots can be problematic in endodontic treatments. This research showed prevalence of 3-canaled roots about 13% in mesial roots and 3.5% in distal roots; this was consistent with findings of Al-Qudah and Awawdeh [14], De Pablo *et al.* [5] regarding mesial roots and Ahmed *et al.* [21] regarding distal root. However, our result was not in line with other reports, which might be due to differences in ethnicity or methodologies. In this study, most of mesial roots had 2 canals but about 13% of them had 3 canals. This was similar to other studies stating that 2-canaled roots are much more prevalent (summarized in Table 5). In distal roots, similar prevalence of one or two canals were observed in this study (with very few cases of three canals). Such a high frequency of two canals in this root was similar to studies of Ahmed *et al.* [21], Arjmand *et al.* [10], and Al-Qudah and Awadeh [14]. All distolingual roots were single-rooted as what was reported by Akhlaghi *et al.* [2].

***Table 1.*** Distribution (%) of canal number in roots of mandibular first molars across mesial, distal, and distolingual roots

| | Canal number | | |
|---|---|---|---|
| **Root** | **1** | **2** | **3** |
| **Mesial** | - | 271 (86.9%) | 41 (13.1%) |
| **Distal** | 136 (43.6%) | 165 (52.9%) | 11 (3.5%) |
| **Distolingual** | 16 (100%) | - | - |

***Table 2.*** Distribution of canal types according to Vertucci classes (I to VIII) in mesial and distal roots of mandibular first molars

| | | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| **Mesial root** | **N** | – | 66 | 20 | 125 | 13 | 27 | 10 | – |
| | **%** | – | 21.1 | 6.4 | 40.0 | 4.1 | 8.6 | 3.2 | – |
| **Distal root** | **N** | 136 | 15 | 55 | – | 47 | – | 31 | – |
| | **%** | 43.6 | 4.8 | 17.6 | – | 15.0 | – | 9.9 | – |

***Table 3.*** Distribution of canal types according to Vertucci modifications (IX to XXIII) in mesial and distal roots of mandibular first molars. Modification with all-empty cells are removed from the table

| | | X | XII | XIII | XVI | XVII | XX | XXI | XXII |
|---|---|---|---|---|---|---|---|---|---|
| **Mesial root** | **N** | 10 | 9 | 4 | – | 7 | 13 | 8 | – |
| | **%** | 3.2 | 2.9 | 1.3 | – | 2.2 | 4.2 | 2.5 | – |
| **Distal root** | **N** | 17 | – | 3 | 4 | – | – | – | 4 |
| | **%** | 5.4 | – | 0.9 | 1.3 | – | – | – | 1.3 |

***Table 4.*** Summary of reports on number of roots

| Author /Country | Method | Sample size | Number of roots | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| Kim *et al.* /South Korea [22] | CBCT (*in vivo*) | 1952 | 0.67% | 73% | 25% |
| Abella *et al.* [4] | review of literature of 45 articles | 19056 | - | - | 14% (Range 0* to 29%) |
| Zhang *et al.*/China [23] | CBCT (*in vivo*) | 232 | 0.4% | 70% | 29% |
| DePablo *et al.*/Spain [5] | review of literature of 41 articles | 18787 | | | 13% (Range 0 to 32%) |
| Demirbuga *et al.*/Turkey [20] | CBCT (*in vitro*) | 1748 | 0.85% | 95.8% | 2% |
| Chourasia *et al.*/India [18] | *in vitro* (clearing technique) | 150 | | 94.6% | 5.3% |
| Garg *et al.*/India [24] | *in vitro* (periapical radiography) | 1054 | | | 6% |
| Al-Qudah, Awawdeh/Jordan [14] | *in vitro* (clearing technique) | 330 | | 96% | 4% |
| Ahmed *et al.*/Sudan [21] | *in vitro* (clearing technique) | 100 | | 94% | 3% |
| Mirzaie *et al.*/Iran [11] | CBCT (*in vivo*) | 66 | | 100% | |
| Ballullaya *et al.* [6] | review of literature of 97 articles | | | | Range: 3-35% |
| Gulabivala *et al.*/Myanmar [7] | *in vitro* (clearing technique) | 139 | | 90% | 10% |
| Nur *et al.*/Turkey [19] | CBCT (*in vivo*) | 966 | 0.3% | 99.2% | 0.5% |
| Zafar *et al.*/Saudi Arabia [25] | CBCT (*in vitro*) | 100 | | 100% | |
| Arjmand *et al.*/Iran [10] | CBCT (*in vivo*) | 121 | | 97.5% | 2.5% |
| Masoudi *et al.*/Iran [9] | CBCT (*in vivo*) | 129 | | 96.1% | 3.9% |
| Akhlaghi *et al.*/Iran [2] | *in vitro* (clearing technique) | 150 | | 69.7% | 3.3% |

**In studies from Iran, Uganda, Pakistan, Turkey, Kuwait and Spain, no three-root teeth had been observed*

***Table 5.*** Summary of reports on number of canals

| Author /Country | Method | Sample size | Number of canals | | |
|---|---|---|---|---|---|
| | | | Overall | Mesial root | Distal root |
| **Kim *et al.* /South Korea [22]** | **CBCT (*in vivo*)** | 1952 | 48.6% three, 49.2% four | - | - |
| **Zhang *et al.* /China [23]** | **CBCT (*in vivo*)** | 232 | 53% three-, 43% four- | 95% two-canal | |
| **De Pablo *et al.* /Spain [5]** | **review of literature of 41 articles** | 18787 | 61% three-, 35.7% four- | 94.4% two, 2.3% three | 63%: single-canal |
| **Demirbuga *et al.* /Turkey [20]** | ***in vitro* (CBCT)** | 1748 | 79.9% three-, 15.4 %% four- | - | - |
| **Chourasia *et al.* /India [18]** | ***in vitro* (clearing technique)** | 150 | 64% three, 36% four | | |
| **Al-Qudah, Awawdeh/Jordan [14]** | ***in vitro* (clearing technique)** | 330 | 49% three-, 46% four- | 93% two-, 6% three- | 54% single 45% two s |
| **Ahmed *et al.* /Sudan [21]** | ***in vitro* (clearing technique)** | 100 | | 86% two | 59% two-, 38% single, 3% three- |
| **Mirzaie *et al.* /Iran [11]** | **CBCT (*in vivo*)** | 66 | 63% three-, 37% four- | | |
| **Ballullaya *et al.* [6]** | **review of literature of 97 articles** | | 35% four- | Three canals: Range 0.95 to 15% | |
| **Nur *et al.* /Turkey [19]** | **CBCT (*in vivo*)** | 966 | 63% three-, 37% four- | 96.8% two , 0.2% three, 3% single | |
| **De Pablo *et al.* /Spain [5]** | **CBCT (*in vitro*)** | 53 | 41.5% three, 29.4% four, 28.3% five | 96.8% two , 0.2% three, 3% single | |
| **Zafar *et al.* /Saudi Arabia [25]** | **CBCT (*in vitro*)** | 100 | | 95.5% two | 20% double, 80% single |
| **Arjmand *et al.* /Iran [10]** | **CBCT (*in vivo*)** | 121 | | 92.5% two | 58.6% single, 37.2% double |
| **Masoudi *et al.* /Iran [9]** | **CBCT (*in vivo*)** | 129 | 72.1% three, 24.8% four, 1.6% five | | 74.7% single |
| **Akhlaghi *et al.*/Iran [2]** | ***in vitro* (clearing technique)** | 150 | | 100% two | 61.3% single, 38.7% double |

***Table 6.*** Summary of reports on Vertucci types and modifications (all reported values in percent)

| Author /Country | Method | Size | Mesial root | Distal root | Vertucci modifications |
|---|---|---|---|---|---|
| **Kim *et al.* /South Korea [22]** | **CBCT (*in vivo*)** | 1952 | IV 71<br>II 20 | I 66<br>II 19<br>IV 12 | 0.35% |
| **Zhang *et al.* /China [23]** | **CBCT (*in vivo*)** | 232 | IV 81<br>V 15 | - | - |
| **De Pablo *et al.* /Spain [5]** | **review of literature of 41 articles** | 18781 | IV 52.3<br>II 35 | I 63<br>II 14<br>IV 12.4 | |
| **Demirbuga *et al.* /Turkey [20]** | **CBCT (*in vitro*)** | 1748 | IV 68<br>II 30 | I 82<br>II 6<br>IV 5.6 | |
| **Chourasia *et al.* /India [18]** | ***in vitro* (clearing technique)** | 150 | IV 54<br>II 36.6 | I 65.3<br>II 20.6<br>IV 9.3 | |
| **Al-Qudah, Awawdeh/Jordan [14]** | ***in vitro* (clearing technique)** | 330 | IV 53<br>II 36 | I 54<br>II 17<br>V 11<br>IV 9 | Mesial root: 5.7%<br>Distal root: 1.7% |
| **Ahmed *et al.* /Sudan [21]** | ***in vitro* (clearing technique)** | 100 | IV 73<br>II 14 | I 38<br>II 28<br>V 22 | |
| **Gulabivala *et al.* /Myanmar [7]** | ***in vitro* (clearing technique)** | 139 | IV 38.1<br>II 28.8<br>V 6.5 | I 92.9 | Mesial: 12.9%<br>Distal: 10% |
| **Faraz *et al.* [26]** | ***in vitro* (clearing technique)** | 123 | IV 70.7<br>II 26.8 | I 65.8<br>II 14.6<br>V 19.5 | |
| **Nur *et al.* /Turkey [19]** | **CBCT (*in vivo*)** | 966 | IV 92<br>II 5 | I 60<br>II 12<br>IV 20<br>V 7 | |
| **Zafar *et al.* /Saudi Arabia [25]** | **CBCT (*in vitro*)** | 100 | II 30<br>IV 27.5<br>III 20<br>V 12.5 | I 58.6<br>II 20.3<br>III 16.9 | |
| **Arjmand *et al.* /Iran [10]** | **CBCT (*in vivo*)** | 121 | IV 65.3<br>II 27.2 | I 47.2<br>III 18.9 | |
| **Masoudi *et al.* /Iran [9]** | **CBCT (*in vivo*)** | 129 | II 62.1<br>IV 29.5 | I 74.7<br>III 18.6<br>II 17.8 | |
| **Akhlaghi *et al.* /Iran [2]** | ***in vitro* (clearing technique)** | 150 | IV 55.3<br>II 41.3<br>VIII 2.7 | I 61.2<br>II 26.6<br>IV 9.4 | |

The most common types of canal which were found in mesial roots of this study were Vertucci classes IV (40%), II (21.1%) and VI (8.1%), while about 16% of cases were Vertucci modifications. Higher prevalence of type IV followed by type II was seen in most other studies [2, 8] except those reported by Zafar *et al.* [24] and Masoudi *et al.* [9] (Table 7). In distal roots, most common Vertucci types were I (43.6%), III (17.6%), and V (15%); about 9% of cases were Vertucci modifications (Table 6). This was consistent with studies of Zafar *et al.* (37), Arjamand *et al.* [10], and Masoudi *et al.* [9]. Although Vertucci classes can simplify reports, they are not sufficient to cover all complexities of root canal structures which were observed in this study and few others that have evaluated Vertucci modifications [7, 14]. Sometimes, real canals are much more irregular to be easily categorized into one of Vertucci classes or modifications. Differences might be attributed to ethnicity.

## Conclusion

In this population, there were 3 to 6 canals per tooth (mostly 4 and 3 canals). Males and females might be similar regarding number of roots, or number of canals in each root, or number of canals in each tooth. The most frequent Vertucci classes in mesial and distal roots were IV (followed by II) and I, respectively without a significant sex dimorphism.

Conflict of Interest: 'None declared'.

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