Root Canal Anatomy and Morphology of Mandibular First Molars in a Selected Iranian Population: An In Vitro Study

Nahid Mohammadzadeh Akhlaghi a, Zohreh Khalilak a, Mehdi Vatanpour a, Saman Mohammadi b, Sakineh Pirmoradi b, Mahta Fazlyab a, c*, Kamran Safavi d

a Department of Endodontic, Dental Branch, Islamic Azad University, Tehran, Iran; b Private Practice, Tehran, Iran; c Iranian Center for Endodontic Research, Research Institute of Dental Sciences, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran; d Department of Endodontic, University of Connecticut, Connecticut, USA

ARTICLE INFO

Article Type: Original Article

Received: 25 May 2016
Revised: 13 Sep 2016
Accepted: 29 Sep 2016
Doi: 10.22037/iej.2017.18

*Corresponding author: Mahta Fazlyab, Islamic Azad University, 10th Neyestan St, Pasdaran Ave. Tehran, Iran.
Tel:+98-21 22598224
E-mail: Dr.mfazlyab@gmail.com

Introduction: The aim of this study was to evaluate root canal anatomy of mandibular first molars (MFM) in a selected Iranian Population using clearing technique. Methods and Materials: A total of 150 extracted MFMs were cleared. The root canal morphology (including the root numbers and root length) and the anatomy of the root canal system (including is the number and type of canals based on Vertucci's classification, canal curvature according to Schneider's method and the presence of isthmus) was evaluated using the buccolingual and mesiodistal parallel x-rays and stereomicroscope. The data were analyzed using the chi-square test. Results: Two and three roots were present in 96.7% and 33% of the teeth, respectively (P=0.0001). All the teeth (100%) had two canals in the mesial root, while 61.3% of the samples had one distal root canal (P=0.006). The root canal configuration in the mesial canal included type IV (55.3%) and type II (41.3%) (P=0.0001). In doubled-canalled distal roots, 68.8% and 24.3% were type II and type IV, respectively (P=0.0001). Isthmii were observed in 44.6% of mesial and 27.3% of distal roots (P=0.0001). Conclusion: The notable prevalence of type IV configuration in both roots of mandibular first molars, presence of isthmus and root curvature, necessitates the careful negotiation and cleaning of all accessible canal spaces.

Keywords: Iranian Population; Mandibular First Molar; Root Canal Anatomy; Root Canal Morphology; Tooth Clearing

Introduction

Successful outcome of endodontic treatment largely depends on proper cleaning and shaping of the entire root canal system. Thorough understanding of the root canal morphology and configuration is mandatory [1]. Mandibular first molars are amongst the most commonly teeth requiring endodontic treatment due to their early emergence in the oral cavity and subsequent caries [2]. Like any other tooth, a clear and thorough knowledge of the root canal morphology and anatomy of mandibular first molars, will help the clinician with conducting a proper and standard treatment through enabling to foresee possible variations that potentially challenge the treatment outcome [3-6].

Mandibular first molars commonly have two roots and three root canals [2, 7]. However, due to genetic, ethnic and gender varieties, a wide range of anatomic and morphological variations can be encountered [7]. Commonly used methods to evaluate root canal morphology include root canal staining and tooth clearing [8-11], plastic injection [12], conventional and digital radiography [13, 14] and radiopaque gel infusion and radiography [15, 16]. Recently, cone-beam computed tomography (CBCT) and micro-CT images have been found to be useful in providing accurate three-dimensional anatomic details [17-19].

Numerous reports on root canal morphology of mandibular molars were from different countries and variable ethnicities [5-7, 10, 20-22]. These studies have evaluated the root and canal morphology of the mandibular first molars in Korean [23, 24],
Indian [25, 26], Chinese [27], German [28], Jordanian [29] and Sudanese [30] populations.

Iranian national surveys in this regard are not numerous. Baziar et al. [31], reported the management of a six-canaled mandibular first molar with three canals in the distal root using CBCT. In a case series, Aminsobhani et al. [32], reported the endodontic treatment of 27 mandibular first and second molars with the third mesial canal (middle mesial canal) that in all cases joined to mesiobuccal or mesiolingual canals. Ghoddusi et al. [33], reported a rare case of a mandibular first molar with six canals (two mesial and four distal canals in two distal roots). In the one and only study in this regard, Razmi et al. [2] evaluated the number of distal roots and canals in 310 mandibular first molars and their internal anatomy, using radiographies. They reported a 4.5% incidence of two distal roots (100% Vertucci’s type I). According to Vertucci’s classification 54.9% of the teeth with one distal root type I, 19% type II, 1.9% type III, 14.2% type IV, 4.2% type V, 1% type VI, 0.3% type VII and 0% type VIII [2]. However, the latter study just focused on the distal root of mandibular first molars. Shahi et al. [34] conducted a study on the anatomy and root morphology of mandibular first molars in an Iranian population using clearing and staining. They showed that 98.56% and 1.44% of the teeth were two-rooted and three-rooted, respectively. Also 65.56% of mandibular first molars had three canals, while 31.57% had four and 2.87% had two canals. Mesial roots with two canals were of type II (41.87%), type III (0.49%), type IV (53.69%) and type V (3.94%). Distal roots were type I (68.42%), type II (11.96%), type III (1.99%), type IV (17.22%) or type V (0.48%) based on Vertucci’s classification.

Due to the lack of a complete national morphological survey in this regard and the different results of the latter two national studies, the aim of this in vitro cross-sectional study was to evaluate the anatomy and morphology of mandibular first molars (including the number of roots and root canals, canal curvature and presence of isthmuses) in an Iranian population using clearing technique.

Materials and Methods

This study was conducted on a total number of 150 extracted mandibular first molars with mature apices, free of any crack, internal/external resorption and without root filling material. The teeth were collected from dental clinics and a selected Iranian population of variable age and gender during 2013 and 2014. The teeth were scrubbed under tap water for 30 min to remove adherent soft tissues and were then disinfected in 5.25% NaOCl for 1 h. The teeth were stored in sterile normal saline until the assessment time.

The teeth were coded and a data form was assigned to each sample. The number of the roots and root lengths (measured in millimeters from anatomic apex to cemento enamel junction) were assessed and recorded.

Then for each sample, access cavity preparation was done and the pulp chamber space was rinsed with 5.25% NaOCl solution for removal of the necrotic tissues. After locating the canal orifices and canal negotiation using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland), two parallel digital radiographies (Digora, Soredex, Orion Corporation Ltd., Helsinki, Finland) were taken in buccolingual and mesiodistal directions with a #15 K-file placed to the working length. The images were assessed in Autocad software (2015, Autodesk, San Rafael, Calif, USA) and determination of root canal curvature was done according to Schneider’s method [35].

The root canals were subsequently irrigated with 5.25% NaOCl solution and distilled water using a 30-gauge needle. After allowing the samples to dry for 24 h, the same syringe and needle was used for injection of Indian ink (Pelikan, Tehran, Iran). Then for complete distribution of the ink in entire root canal the teeth were stored in a vertical position by placing them in the head of high vacuum saliva ejector. Distribution of ink in the apical foramina indicated the end of the process.

Decalcification process was performed by immersion of teeth in 5% nitric acid for 3 days at room temperature. The solution was refreshed daily and the teeth were washed under running tap water for 10 min. The teeth were dehydrated by immersing subsequently in 80, 90 and 100% ethanol for 1 day. After drying with tissue paper, the samples were inserted in 50% methyl salicylate for 5 h to make them transparent.

The transparent samples were evaluated using a stereomicroscope (Nikon SMZ1500, Nikon Corporation, Tokyo, Japan) under 10× magnification. The number of root canals, the type of canals based on Vertucci’s classification and the isthmii at the distances of 2, 4 and 6 mm from the apex, were recorded for each tooth [1]. A single operator did all the procedure and microscopic evaluation was double-checked by a second observer. The data were analyzed by the chi-square test using SPSS software (Statistical Package for Social Science, SPSS, version 18.0, SPSS, Chicago, IL, USA). The level of significance was set at 0.05.

| Table 1. Distribution of the root canal number and configuration in 150 mandibular first molars |
|---------------------------------------------------------------|
| Number of canals (%) | Root canal configuration (Vertucci’s classification) (%) |
|----------------------|----------------------------------------------------------|
| Root |
| Mesial | 1 | 2 | 3 | Type I | Type II | Type III | Type IV | Type V | Type VI | Type VII | Type VIII |
| 0 | 100 | 0 |
| Distal | 61.3 | 38.7 | 0 | 61.3 | 26.6 | 2 | 9.4 | 0.65 | 0 | 0 | 0 |
Results

A total of 150 samples were ready for final evaluation. Among these, 145 teeth (96.7%) had two roots while 5 (3.3%) were three-rooted with a separate distolingual root ($P=0.0001$). In all double-rooted teeth the mesial root had two canals while the distal root had one canal in 61.3% and two canals in 38.7% of the samples ($P=0.006$). In three-rooted samples, the distobuccal and distolingual root had a single canal.

In mesial roots, the most frequent canal types were type IV (55.3%), type II (41.3%), type III (3.3%) and type V (0.7%) ($P=0.0001$). In distal roots with two canals, the frequent anatomoies were Vertucci’s type II (68.8%), type IV (24.3%), type III (5.18%) and type V (1.72%) ($P=0.0001$) (Table 1).

Isthmii were found in 44.6% of mesial roots and 27.3% of distal roots ($P=0.0001$). In 2, 4 and 6 mm levels from the apex of mesial roots, isthmii were found in 22.5%, 41.7% and 35.8% of the samples, respectively. In distal roots, isthmii were found in 34.3%, 36.5% and 29.2% of teeth in 2-, 4- and 6-mm distances from the apex, respectively.

The mean root canals curvatures for each of the canals and the mean root lengths are presented in Tables 2 and 3, respectively.

Discussion

This cross-sectional in vitro study evaluated the root canal anatomy and morphology of extracted mandibular first molars from a selected Iranian population. In this study the clearing technique was used as suggested by Singh and Pawar [8], Okumara and Tsurukichi [36] and Robertson et al. [37], to determine the root canal morphology, anatomy and presence of isthmii. Moreover, root lengths and curvatures were also determined by radiographic method. Apart from being inexpensive and easy to conduct, other important advantages of clearing technique include retaining the original form of the canal, enabling the assessment of canal form and isthmus and maintenance of the samples for long time [38].

Kim et al. [23], conducted a retrospective study on root and canal morphology of the mandibular first molars in a Korean population by analysis of a large number of CBCT images. Among the examined molars, 25.82, 73.51 and 0.67% had 3, 2 roots, and 1 root, respectively.

Table 2. The mean (SD) of canal curvature in mandibular first molars based on Schneider’s method

| Canal     | Buccolingual | Mesiodistal |
|-----------|--------------|-------------|
| Mesiobuccal | 13.8 (6.78) | 11.8 (5.4) |
| Mesiolingual | 9 (5.1) | 7.53 (4.39) |
| Distobuccal | 5 (4.01) | 5.3 (3.6) |
| Distolingual | 7.16 (4.95) | 2.7 (1.19) |
| Distal     | 21.5 (5.3) | 18.5 (8.4) |

In the mesial and distal roots, type IV and type I canal was the most frequent morphology. They reported a high prevalence of four-canaled molars with separate distolingual (DL) root and/or separate DL canals [23]. In another study on Korean population using CBCT, Kim and Yang [24] evaluated the incidence of separate DL root and a separate DL canal in the distal root. They reported a higher prevalence of two distal canals and two distal roots on the right side compared to the left side (26.6% and 19.0%, respectively). This evaluation showed significantly lower prevalence of one distal root with two distal canals [24]. Chourasia et al. [25], determined the number of roots, root canals, root canal configurations and frequency of isthmii and apical deltas in mandibular first molars in an Indian population, using clearing technique in vitro. They reported two mesial and distal roots and a separate DL root in 94.6 and 5.3% of the mandibular first molars. Moreover, 36% of the two-rooted molars had separate DL canals [25]. Garg et al. [26] also reported the prevalence of three-rooted mandibular first molars to be 5.97% in Indian population (6.88% for female and 4.89% for male patients). Ahmed et al. [30] stated that 59% of the mandibular first molars in Sudanese population had four canals with 3% having a third distolingual root. Also the most common canal configurations were Vertucci’s type IV (73%) and type II (14%) and the prevalence of isthmii was reported to be 65%. Al-Qudah and Awawdeh [29] conducted a similar study on Jordanian population and reported the majority of mandibular first molars to have three (48%) or four (46%) canals, whilst 4% had a third distolingual root. The most common configuration in the mesial root was type IV (53%) and in distal root was type I (54%). Schäfer et al. [28] stated that the overall incidence of three-rooted mandibular first molars in a selected German population was rare (1.35%). Moreover, all three-rooted molars occurred unilaterally (0.80% in left and 0.57% in right side). Zhang et al. [27] reported the majority of mandibular first molars (70%) had two separate roots and three roots were identified in 29% of first molars. Three canals were found in 56% of teeth and most distal roots had a simple type I configuration.

The present study showed that the majority of mandibular first molars of the Iranian population had two roots (96.7%) whereas three-rooted cases were less common (3.3%). All the mesial roots had two root canals and based on Vertucci’s classification, type II and IV were the most common types.

Table 3. The mean (SD) of root length in mandibular first molars

| Root   | Root length (mm) |
|--------|------------------|
| Mesial | 15.68 (2.88)     |
| Distal | 15.1 (3.5)       |
| Distolingual | 8 (1.6) |
Distal roots presented more variable canal types. The most common type was type I (61.3%) and the rest (38.7%) consisted of less frequent types including types II, III, IV and V.

There are variable methods for assessing the morphology of teeth and root canal system. Some studies showed the superiority of clearing technique over radiographic techniques which have limited value in studying the anatomy of the root canal system [39, 40]. Lu et al. [41] used cross-sectioning method which is complicated. A study by Neelakantan et al. [42] concluded that CBCT was as accurate as in vitro techniques such as canal staining and clearing technique, which necessitate tooth extraction. However, in a recent study by Lee et al. [43] it was stated that in micro-CT, the combination of two-dimensional projection with minimum intensity and three-dimensional volume rendering for reconstruction images, provide a more detailed canal morphology than the clearing technique. This state may be true, but the expenses and high beam dosage of tomography are not cost effective.

**Conclusion**

Based on the results of this study, mandibular first molars have complicated root canal system with widely found isthmii and anatomical variations, and therefore require more attention in access cavity preparation for negotiating all root canal orifices, and during cleaning, shaping and obturation.

**Acknowledgment**

The authors wish to thank the staff of ICER.

**Conflict of Interest:** ‘None declared’.

**References**

1. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endodontic Topics. 2005;10(1):3-29.
2. Razmi H, Shokouhinejad N, Hooshyar M. An In Vitro Study of the Number of Distal Roots and Canals in mandibular First Molars in Iranian Population. Iran Endod. 2008;2(4):126-30.
3. Nixdorf DR, Moana-Filho EJ, Law AS, McGuire LA, Hodges JS, John MT. Frequency of persistent tooth pain after root canal therapy: a systematic review and meta-analysis. J Endod. 2010;36(2):224-30.
4. de Pablo ÓV, Estevez R, Péix Sánchez M, Heilborn C, Cohenca N. Root Anatomy and Canal Configuration of the Permanent Mandibular First Molar: A Systematic Review. J Endod. 36(12):1919-31.
5. Song JS, Choi H-J, Jung I-Y, Jung H-S, Kim S-O. The Prevalence and Morphologic Classification of Distolingual Roots in the Mandibular Molars in a Korean Population. J Endod. 36(4):653-7.
6. Chandra SS, Chandra S, Shankar P, Indira R. Prevalence of radix entomolaris in mandibular permanent first molars: a study in a South Indian population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 112(3):e77-e82.
7. Skidmore AE, Bjorndal AM. Root canal morphology of the human mandibular first molar. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1971;32(5):778-84.
8. Singh S, Pawar M. Root canal morphology of South asian Indian mandibular premolar teeth. J Endod. 2014;40(9):1338-41.
9. Vertucci FJ. Root canal morphology of mandibular premolars. J Am Dent Assoc. 1978;97(1):47-50.
10. Alavi AM, Opasanon A, Ng YL, Gulabivala K. Root and canal morphology of Thai maxillary molars. Int Endod J. 2002;35(5):478-85.
11. Awawdeh L, Abdullah H, Al-Quada A. Root Form and Canal Morphology of Jordanian Maxillary First Premolars. J Endod. 34(8):956-61.
12. Barker BC, Parsons KC, Williams PR, Mills PR. Anatomy of root canals. IV deciduous teeth. Aust Dent J. 1975;20(2):101-6.
13. Pineda F, Kuttler Y. Mesiodistal and buccolingual roentgenographic investigation of 7,275 root canals. Oral Surg Oral Med Oral Pathol. 1972;33(1):101-10.
14. Weine FS, Hayami S, Hata G, Toda T. Canal configuration of the mesiobuccal root of the maxillary first molar of a Japanese sub-population. Int Endod J. 1999;32(2):79-87.
15. Fan B, Gao Y, Fan W, Gutmann JL. Identification of a C-shaped canal system in mandibular second molars-part II: the effect of bone image superimposition and intraradicular contrast medium on radiograph interpretation. J Endod. 2008;34(2):160-5.
16. Patel S, Davood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: part 1. Conventional and alternative radiographic systems. Int Endod J. 2009;42(6):447-62.
17. Sberna M, Rizzo G, Zacchi E, Cappare P, Rubinacci A. A preliminary study of the use of peripheral quantitative computed tomography for investigating root canal anatomy. Int Endod J. 2009;42(1):66-75.
18. Szabo BT, Pataky L, Mikusi R, Fejerdy P, Dobo-Nagy C. Comparative evaluation of cone-beam CT equipment with micro-CT in the visualization of root canal system. Ann Ist Super Sanita. 2012;48(1):49-52.
19. Mao T, Neelakantan P. Three-dimensional imaging modalities in endodontics. Imaging science in dentistry. 2014;44(3):177-83.
20. Gulabivala K, Aung TH, Alavi A, Ng YL. Root and canal morphology of Burmese mandibular molars. Int Endod J. 2001;34(5):359-70.
21. Pattanshetti N, Gaidhane M, Al Kandari AM. Root and canal morphology of the mesiobuccal and distal roots of permanent first molars in a Kuwait population – a clinical study. Int Endod J. 2008;41(9):755-62.
22. Wasti F, Shearer AC, Wilson NHF. Root canal systems of the mandibular and maxillary first permanent molar teeth of South Asian Pakistanis. Int Endod J. 2001;34(4):263-6.
23. Kim SY, Kim BS, Woo J, Kim Y. Morphology of mandibular first molars analyzed by cone-beam computed tomography in a Korean population: variations in the number of roots and canals. J Endod. 2013;39(12):1516-21.
24. Kim SY, Yang SE. Cone-beam computed tomography study of incidence of distolingual root and distance from distolingual canal to buccal cortical bone of mandibular first molars in a Korean population. J Endod. 2012;38(3):301-4.
25. Chourasia HR, Meshram GK, Warhadpande M, Dakshindas D. Root canal morphology of mandibular first permanent molars in an Indian population. Int J Dent. 2012;2012:745152.
26. Garg AK, Tewari RK, Kumar A, Hashmi SH, Agrawal N, Mishra SK. Prevalence of three-rooted mandibular permanent first molars among the Indian population. J Endod. 2010;36(8):1302-6.
27. Zhang R, Wang H, Tian YY, Yu X, Hu T, Dummer PM. Use of cone-beam computed tomography to evaluate root and canal morphology of mandibular molars in Chinese individuals. Int J Endod. 2011;44(11):990-9.
28. Schafer E, Breuer D, Janzen S. The prevalence of three-rooted mandibular permanent first molars in a German population. J Endod. 2009;35(2):202-5.
29. Al-Qudah AA, Awawdeh LA. Root and canal morphology of mandibular first and second molar teeth in a Jordanian population. Int J Endod. 2009;42(9):775-84.
30. Ahmed HA, Abu-bakr NH, Yahia NA, Ibrahim YE. Root and canal morphology of permanent mandibular molars in a Sudanese population. Int J Endod. 2007;40(10):766-71.
31. Baziar H, Daneshvar F, Mohammadi A, Jafarzadeh H. Endodontic management of a mandibular first molar with four canals in a distal root by using cone-beam computed tomography: a case report. J Oral Maxillofac Res. 2014;5(1):e5.
32. Aminsohbandi M, Bolhari B, Shokouhinejad N, Ghorbanzadeh A, Ghabraei S, Rahmani MB. Mandibular first and second molars with three mesial canals: a case series. Iran Endod J. 2010;5(1):36-9.
33. Ghanadzadeh A, Naghavi N, Zarei M, Rohani E. Mandibular first molar with four distal canals. J Endod. 2007;33(12):1481-3.
34. Shahi S, Yavari HR, Rahimi S, Torkamani R. Root canal morphology of human mandibular first permanent molars in an Iranian population. J Dent Res Dent Clin Dent Prospectives. 2008;2(1):20-3.
35. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971;32(2):271-5.
36. Okumura T. Anatomy of root canals: Tokyo Dental College; 1927.
37. Robertson D, Leeb II, McKee M, Brewer E. A clearing technique for the study of root canal systems. J Endod. 1980;6(1):421-4.
38. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain contrast medium-enhanced digital radiography in studying root canal morphology. J Endod. 2010;36(9):1547-51.
39. Omer OE, Al Shalabi RM, Jennings M, Glennon J, Claffey NM. A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. Int J Endod. 2004;37(5):291-6.
40. Wu D, Wu Y, Guo W, Sameer S. Accuracy of direct digital radiography in the study of the root canal type. 2014.
41. Lu T-Y, Yang S-F, Pai S-F. Complicated Root Canal Morphology of Mandibular First Premolar in a Chinese Population Using the Cross Section Method. J Endod.32(10):933-6.
42. Neelakantan P, Subbarao C, Subbarao CV. Comparative evaluation of modified canal staining and clearing technique, cone-beam computed tomography, peripheral quantitative computed tomography, spiral computed tomography, and plain contrast medium-enhanced digital radiography in studying root canal morphology. J Endod. 2010;36(9):1547-51.
43. Lee K-W, Kim Y, Perinpanayagam H, Lee J-K, Yoo Y-J, Lim S-M, Chang SW, Ha B-H, Zhu Q, Kum K-Y. Comparison of Alternative Image Reformatting Techniques in Micro–Computed Tomography and Tooth Clearing for Detailed Canal Morphology. J Endod. 2014;40(3):417-22.

Please cite this paper as: Mohammadzadeh Akhlaghi N, Khalilak Z, Vatanpour M, Mohammadi S, Pirmoradi S, Fazlyab M, Safavi K. Root Canal Anatomy and Morphology of Mandibular First Molars in a Selected Iranian Population: An In Vitro Study. Iran Endod J. 2017;12(1):87-91. Doi: 10.22037/iej.2017.18.