

Original Article

Radicular anatomy of permanent mandibular second molars in an Iranian population: A preliminary study

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ABSTRACT

Background: Root morphology is of utmost importance to endodontic sciences. Since there are a few studies on the morphology of mandibular second molars' roots, and some anatomical variables are not evaluated before, the aim of this study was to investigate thoroughly radicular anatomy of this tooth.

Materials and Methods: This *ex vivo* study was performed on 150 intact mandibular second molars. After access cavity preparation and ensuring canal patency, Indian ink was injected into root canals from the orifices. The teeth became transparent using methyl salicylate storage. Then, they were inspected by an endodontist under a $\times 10$ stereomicroscope regarding numerous root morphological variables. Data were analyzed using chi-square test and analysis of variance ($\alpha = 0.05$).

Results: About 86.7% of teeth had two roots and 13.3% were single-rooted ($P = 0.0001$), of which, 50% were C-shaped (6.7% of all teeth, $P = 0.0001$). 86.7% of mesial roots were double canalled, whereas 75.3% of distal roots were single canalled ($P = 0.0001$). 71.45% and 95.3% of the mesial and distal roots had one apical foramen, respectively ($P = 0.0001$). Apical foramens were mostly central followed by lingual in most cases. Distances between apical foramen and apical constriction ranged between 0.27 and 0.40 mm ($P = 0.0545$). Distances between apical foramen and root apices ranged between 0.30 and 0.47 mm ($P = 0.0001$). Vertucci classifications of mesial canals were Type II in 62.6% and Type IV in 37.4%. 86.2% of single-canal distal roots were Type I. 66.7% of double-canal distal roots were Type II and 33.3% were Type IV ($P = 0.0001$). The mean root lengths from cervical to apex of mesial, distal, and single roots were 14.02 ± 0.85 (95% confidence interval [CI] = 13.87–14.17), 13.35 ± 0.91 (95% CI = 13.19–13.50), and 14.25 ± 0.72 mm (95% CI = 13.91–14.58), respectively. The extents of canal curvatures varied between 20° and 31° buccolingually ($P = 0.0000$), and between 19° and 27° mesiodistally ($P = 0.0000$).

Conclusion: There was a considerable rate of eccentric apical foramen in mandibular second molars.

Key Words: Anatomy, apical, constriction, apical foramen mandibular, second, molar, root, curvature

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INTRODUCTION

A successful endodontic treatment depends on the knowledge of internal anatomy of root canals.^[1,2] Conventional radiographs are two-dimensional and mask many anatomic properties.^[2,3] This is clinically important because apical foramina as the landmark of root canal therapy are not symmetrical in all teeth.^[2,4-6] Physiologic or pathologic factors such as tooth adaptation to the function and external resorption may influence apical anatomy.^[2,4-6] In many cases, the apical foramen stands buccally or lingually to the root apex, which can be superimposed on the root structure and lead to erroneous working length determinations^[7] and causes treatment failure.^[1] Moreover, it is difficult to detect the apical constriction and apical foramen in radiographic examination, which is important because root apex is usually used as a radiographic reference for estimating the working length.^[8]

Although there is a close relationship between apical foramen and root apex, they frequently do not coincide.^[2,9] Some authors reported that foramen openings never coincided with the long axis of the root.^[2,10] The mandibular second molar has a high variation of associations between apical foramina and root apices and needs assessment.^[11] Moreover, there is no study on the extent of root curvatures or the position of apical foramina of the mandibular second molars worldwide. Therefore and due to the clinical importance of this issue, this study was conducted to determine certain parameters not assessed before (i.e., the positions of major apical foramen in relation with the root apex), as well as other morphological variables evaluated worldwide but not in Iran (such the distances between apical foramina, apical constrictions, and root apices), plus some variables evaluated in a city from central Iran (i.e., the number and types of root canals, in two Iranian populations).

MATERIALS AND METHODS

In this *ex vivo* study, mandibular second molar teeth were collected from clinics of Tehran and Marand (Azarbayjan). The specimens were stored in normal saline at room temperature until the examination date. Afterwards, they were stored for 1 h in 5.25% sodium hypochlorite for

disinfection. Then, teeth with external resorption, open apex, root fractures, or cracks were excluded. The remaining teeth were radiographically investigated (buccolingually) and ones with any canal manipulations, root obturation, or internal resorption were excluded.

The remaining teeth were manually cleansed from calculus and periodontal tissues. Afterwards, access cavity was prepared, and canal orifices were detected. The teeth were stored in 5.25% sodium hypochlorite for 1 h to dissolve debris and pulpal tissues. They were then rinsed for 10 min with tap water. K-files #8 and 10 were inserted into canals to ensure canal pathway openness. Teeth with obstructed canals were excluded. This procedure was repeated until reaching the predetermined sample size of 150 teeth. When the file was placed in the canal, digital parallel periapical radiographs were taken from buccal and mesial aspects. The extent of root curvature was measured using the AutoCad program (version 2010, AutoDesk, San Rafael, California, USA) according to Schneider method.^[12]

Under $\times 2.5$ magnification, the location of foramen (centric or eccentric) and its exit (in buccal, lingual, mesial, or distal) were recorded using a #10 K-file passing through the apex. The distance between the exit and the root apex was measured in mm.

Using a high-speed suction placed closed to the apical area of the tooth, vacuum condition was provided during the ink injection into root canals from the orifices. The teeth were stored in 5% nitric acid at room temperature for 3 days to become demineralized. The nitric acid solution was changed every day. They were inspected for any distortion due to acid storage. Distorted specimens were excluded and replaced by new teeth. The teeth were then rinsed under flowing tap water for 3 h. The teeth were dehydrated by storing in 100% ethanol for 24 h.

Dehydrated teeth were stored in methyl salicylate to become transparent. Afterwards, $\times 10$ micrographs were taken from the apices, using a stereomicroscope [Figure 1]. The number of canals, the distribution of mesiobuccal (MB), mesiolingual, distobuccal (DB), distolingual, and C-shaped canals, canal types (according to the Vertucci classification),^[13,14] the length of roots (from the cemento-enamel junction to apex), the distance between apical constriction and apical

foramen, the distance between apical foramen and root apex, and the extent of canal curvature according to Schneider method^[12] were evaluated and recorded. If there was one canal in the mesial root, it was recorded as MB; if there was one canal in the distal root, it was recorded as DB.

Descriptive statistics were calculated together with 95% confidence intervals (CIs). Data were analyzed using chi-square and analysis of variance (ANOVA) of SPSS version 20.0 (IBM, Armonk, New York, USA).

RESULTS

Of the 150 evaluated teeth, 86.7% had two roots and 13.3% were single-rooted ($P = 0.0001$). None of the single-rooted teeth were single canalled. Fifty percentage of the single-rooted teeth (which all were double-canalled), had C-shaped canals with one apical foramen (6.7% of all teeth, $P = 0.0001$) and the remainder 50% had non-C-shaped canals and one apical foramen (no double-foramen existed). In the 130 double-rooted teeth (130 mesial and 130 distal roots), 87% of mesial roots (=113 mesial roots) were double canalled, while only 24.7% of 130 distal

roots were double canalled ($P = 0.0001$). Among 130 double-rooted teeth, 71.45% and 95.3% of the mesial and distal roots respectively had one apical foramen ($P = 0.0001$). Among the 130 mesial roots of the 130 double-rooted teeth, 28.5% had two canals and two apical foramina, 58.5% had two canals and one foramen, and 12.7% had one canal and one foramen. The 95% CIs for the numbers of apices per root were 1.25–1.40 apices in each mesial root and 1.01–1.08 apices in each distal root. The locations of apical foramen showed that distributions of apical foramen locations were significant for all canals [$P < 0.05$, Table 1]. The difference between different roots in terms of “apical foramen to foramen constriction distances” was marginally significant according to ANOVA [$P = 0.0545$, Table 2]; the difference between roots in terms of “apical foramen-to-root apex distances” was significant [ANOVA $P = 0.0000$, Table 2].

Regarding the Vertucci classification, 62.6% of mesial canals were Type II and 37.4% were Type IV. Of the single-canal distal canals, 86.2% were Type I. Of the double-canal distal canals, 66.7% were Type II and 33.3% were Type IV ($P = 0.0001$).

The mean root length of the mesial root was 14.02 ± 0.85 mm (95% CI = 13.87–14.17) while the mean length of distal root was 13.35 ± 0.91 mm (95% CI = 13.19–13.50). Root length of single-root molars was 14.25 ± 0.72 mm (95% CI = 13.91–14.58).

The extents of canal curvatures (in degrees) varied between 20° and 31° buccolingually, which was statistically significant according to ANOVA [$P = 0.0000$, Table 3]. It varied between 19° and 27° mesiodistally, which was statistically significant [$P = 0.0000$, Table 3].

DISCUSSION

In this study, 6.7% of specimens had C-shaped roots, which was similar to the results from an American population.^[15] However, it differed considerably

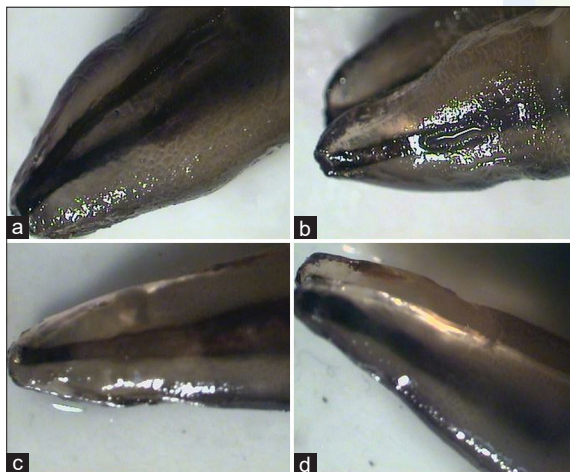


Figure 1: A tooth with Type II in mesial (a) and Type I in distal (b) roots. A tooth with Type I in mesial (c) and distal (d) roots.

Table 1: Distribution of apical foramen locations

Root type	Central (%)	Buccal (%)	Lingual (%)	Mesial (%)	Distal (%)	Total (%)
MB [†]	92 (61.33)	17 (11.33)	26 (17.33)	8 (5.33)	7 (4.67)	150 (100)
ML [§]	79 (60.77)	15 (11.54)	17 (13.08)	10 (7.69)	9 (6.92)	130 (100)
DB [*]	96 (64.00)	6 (4.00)	30 (20.00)	10 (6.67)	8 (5.33)	150 (100)
DL [§]	11 (61.11)	0 (0.00)	3 (16.67)	1 (5.56)	3 (16.67)	18 (100)
C-shaped	7 (70.00)	1 (10.00)	0 (0.00)	1 (10.00)	1 (10.00)	10 (100)

Distributions of apical foramen locations were significant for all canals ($P < 0.05$). [†]Mesiobuccal; [§]Mesiolingual; ^{*}Distobuccal; [§]Distolingual

Table 2: Mean distances between apical foramen with apical constriction or apex (mm)

Root type	Apical foramen to apical constriction					Apical foramen to root apex				
	Mean	SD	Minimum	Maximum	95% CI	Mean	SD	Minimum	Maximum	95% CI
MB [†]	0.37	0.14	0.1	0.91	0.35 0.39	0.33	0.13	0.1	0.73	0.31 0.35
ML [§]	0.34	0.16	0.1	0.91	0.31 0.37	0.30	0.20	0.1	1.45	0.27 0.33
DB [*]	0.38	0.16	0.1	1.10	0.35 0.41	0.38	0.16	0.1	0.91	0.35 0.41
DL [§]	0.40	0.25	0.1	0.91	0.28 0.52	0.47	0.31	0.1	1.18	0.33 0.61
C-shaped	0.27	0.08	0.18	0.45	0.22 0.32	0.30	0.15	0.18	0.55	0.21 0.39

[†]Mesiobuccal; [§]Mesiolingual; ^{*}Distobuccal; [§]Distolingual. CI: Confidence interval; SD: Standard deviation

Table 3: Mean canal curvatures (°) of second molar roots

Root type	Buccolingual direction					Mesiodistal direction				
	Mean	SD	Minimum	Maximum	95% CI	Mean	SD	Minimum	Maximum	95% CI
MB [†]	31.03	15.72	2	76	28.51 33.55	26.61	15.65	2	80	24.11 29.11
ML [§]	31.65	15.56	4	74	28.98 34.32	25.29	12.97	3	61	23.06 27.52
DB [*]	20.04	15.83	2	83	17.51 22.57	19.02	13.48	2	72	16.86 21.18
DL [§]	27.50	14.33	4	53	20.88 34.12	20.56	8.95	4	43	16.43 24.69

[†]Mesiobuccal; [§]Mesiolingual; ^{*}Distobuccal; [§]Distolingual. CI: Confidence interval; SD: Standard deviation

from the results of other studies from China showing 31.5–39% prevalence of C-shaped canals,^[16,17] in Lebanon reporting 19.1% prevalence,^[18] in Korea reporting 44.5% prevalence,^[19] and in Saudi Arabia showing 10.6%.^[20] It seems that ethnicity might be an affecting factor, potentially being greater in Asians, especially the Far East.^[3]

In a study using stereomicroscopy,^[9] the average distance between main apex and anatomic apex was estimated as 0.82 mm in posterior teeth, and it was shown that about 1/3 of roots had central apices, contrasting our results. Arora and Tewari^[21] measured the distance between apical foramen and apical constriction of mesial and distal roots of mandibular second molars of Indians as 0.78 mm and 0.8 mm, respectively. Cheung *et al.*^[22] estimated the distance between the apex and apical foramen of C-shaped roots as 0.89 mm and 0.79 mm in mesial and distal roots, which contrasted the results of this study, being much smaller. Various studies on the location of apical foramen and its distance to root apex have been conducted by different methods such as light microscopy (anatomical studies),^[6] stereomicroscopy,^[11] radiography,^[23] scanning electron microscopy,^[2] tactile sensation,^[23] digital roentgenography,^[24] electronic apex locators,^[23,25] and cone-beam computed tomography (CBCT).^[1,16,19] Using light microscopy, Martos *et al.*^[2] observed that in mandibular molars of Brazilians, more than 3/4 of roots had central apices. Sayão Maia *et al.*^[26] observed central apices as the most common in mandibular second molars. There is a considerable controversy

over the locations of apices, with a deviation of the main foramen ranging from 34% to 92.4%.^[2,4-7,9,27,28] Perhaps ethnic differences and methodological variations (such as the sizes of the assessed segments) might contribute to the controversy.^[2,10] Unlike another study finding the buccal deviation as the second most common variation,^[2] in this study lingual deviation of apical foramen was considerable; this is crucial clinically, as it may cause erroneous canal measurements and over-instrumentation.^[2,29] The clinical determination of such issues is based on the operator's tactile sensitivity and the subjective interpretation of the radiographic image as well as auxiliary methods such as precision electronic apex locators, operating microscopes, and CBCT.^[1,2] No previous studies had evaluated root curvatures to compare our results with.

This study was limited by some factors. It was rather difficult to locate the apical constriction in micrographs, since the colored tooth would cloud the vision. Therefore, our results pertaining to the distances between the apical foramen and the apical constriction should be verified in studies adopting more accurate methodologies. Moreover, it was better to collect a larger sample based on a pilot study. Still, the size of this study was large, considering the long list of variables involved. For instance, a recent study on an Iranian population from the Isfahan city evaluated only Vertucci classes in roots of 100 dyed second molars.^[28] The inclusion of two different cities with different ethnical populations can improve the generalizability.

CONCLUSION

The central position followed by the lingual and then buccal positions were the common types of the apical foramen in this Iranian population. However, eccentric positions were quite frequent, appearing in about 40% of cases. The distances between anatomic and root apices were 0.32 mm and 0.42 mm in mesial and distal roots, respectively. These findings undermine the value of conventional techniques and warrant using auxiliary devices like apex locators in determining the working length.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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