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Assessment of the relationship of the distance between mandibular first and second molars with the inferior alveolar canal and cortical bone plate in an Egyptian subpopulation: a CBCT study

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Abstract: The aim of the current cone beam computed tomography (CBCT) study was to evaluate the proximity of mandibular first and second molar roots to the inferior alveolar canal (IAC) and mandibular cortex in an Egyptian subpopulation. Scans of 120 patients (480 molars, 960 roots) were obtained from the College of Dentistry database at the Suez Canal University, Egypt. Buccal and lingual bone plates and root thickness were measured at the specified resected root end 3 mm from the radiographic apex, and so was the proximity of the root apices to the IAC. Measurements of the right and left mandibular first and second molars were recorded for each root. Three examiners performed the measurements separately. ANOVA was used to compare the different roots. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA was significant. The significance level was set at $p \leq 0.05$. The findings displayed a closer proximity of the mandibular second molar apices to the IAC, as compared to the mandibular first molars. The mesial roots were at a shorter distance than the distal ones. Moreover, the mandibular second molars revealed the thickest total bone width including the root. So, it is beneficial for endodontists to be aware of the relation of the mandibular first and second molars to the surrounding cortical bone plates and the IAC before starting either nonsurgical or surgical endodontic treatment.

Keywords: Cone-Beam Computed Tomography; Mandibular Canal.

Introduction

The inferior alveolar nerve (IAN), which is located in the inferior alveolar canal (IAC), has been demonstrated to be in close relation with the apices of mandibular molars.[1-3] The IAN could be damaged in dental practice such as when administrating local anesthetics,[4] preparing and placing an implant,[5,6] third molar impaction, and other surgical maneuvers [7,8] in nonsurgical and surgical endodontic therapy.[9-13] As a result of sensory nerve injury, anesthesia, paresthesia, dysesthesia, or even pain might be the consequences.[5,8] The IAN could be injured mechanically during root canal treatment because of overinstrumentation into the

IAC.[9] Furthermore, the neurotoxic effect of extrusion of intracanal medicaments, irrigants, or obturation materials may add to the injury of the IAC.[9,10,11,12,13,14] It was noticed that dental mishaps are the etiology of 63% of the cases with neuropathy.[15]

Before an endodontic surgery, it is wise that the endodontist should be conversant with the anatomy of the area of concern, as well as with root anatomy and its measurements. Radiographic examination is of paramount importance in diagnosis and treatment planning to evaluate the prognosis, especially, the approximation of the IAC to the apices of mandibular molars and cortical bone plates. In such cases, depending on a two-dimensional image obtained from conventional periapical radiographs is not reliable.[16] Cone beam computed tomography (CBCT) is an accurate and non-invasive method to evaluate the relation of apices of posterior teeth with the IAC and cortical bone plates.[17]

To our knowledge, none of the published studies conducted in Egypt investigated the relation of apices of mandibular first and second molars with the IAC and surrounding cortical bone plates. Thus, the aim of the current CBCT study was to evaluate the distances of the IAC and mandibular cortex to the root apices of mandibular first and second molars in an Egyptian subpopulation.

Methodology

The present study was initiated after approval by the Research Ethics Committee of the Faculty of Dentistry, Suez Canal University, Ismailia, Egypt (Registration No. 329/2021). The CBCT scans (n = 120 patients) were taken from January 2018 to June 2019 and collected from the Department of Oral Radiology.

The scans were selected from the archive taken for diagnostic purposes deemed irrelevant to the present study. The scans were obtained by the oral radiologist who participated in the present study. The inclusion criteria were: a) Patients who had mandibular first and second molars on both sides and b) patient age ranging between 18 to 25 years. Exclusion criteria were: a) more than one mandibular posterior or anterior tooth lost on each side, except for third molar, b) severe periodontitis, c) external or internal root resorption of any mandibular tooth in the examined area, d) existence of a lesion in the examined area, e) past history of an orthodontic treatment, f) skeletal or dental malocclusions, g) unusual root anatomy, and h) former root canal treatment in the examined area. Four hundred and eighty molars met the inclusion criteria (240 for mandibular first molars and 240 for mandibular second molars). A total of 960 roots were examined for the current study.

All CBCT images were acquired using a SCANORA 3DX scanner (Scanora 3DX, Soredex, Finland). The field of view was fixed at 240 x 165 mm for all images using the standard resolution mode. The operating parameters were 90 kVp and 10 mA and the scanning time was about 6 seconds. The isotropic voxel size was 0.5 mm using a silicon flat panel detector. The acquired data were converted to the DICOM format and then exported to the On Demand 3D application software (On Demand Cybermed. Co., Seoul, Korea) for image analysis and measurements that were used to evaluate the mandibular molars and nearby anatomy. The CBCT measuring tool used had a 1:1 ratio.

The CBCT scans were assessed by an oral radiologist and two endodontists guided by the oral radiologist. The examiners were adjusted for tomographic interpretation of the scans, repeating the assessment twice within one week to check intraexaminer reliability. Additionally, the comparison of the three examiners' readings showed reliability between them, and a mean was obtained. Any conflicts about the measurements were discussed by the examiners until a consensus was reached (interexaminer reliability). The examiners were allowed to modify the images for better interpretation. Contrast, filtration, zooming, and brightness tools were used to enhance the measuring procedures.

By using the Dental Volume Reformat (DVR) module, the IAC was located and the IAN was traced from its origin by the reconstructed panoramic view using the nerve tracing option, first manually and then by the option of nerve modification, to confirm its proper position in the cross-sectional view and every single view in the DVR, including axial, reconstructed panorama, cross-sectional, and 3D view (Figure 1). Cross-sectional slices from the DVR view mode were processed to conclude all measurements at the

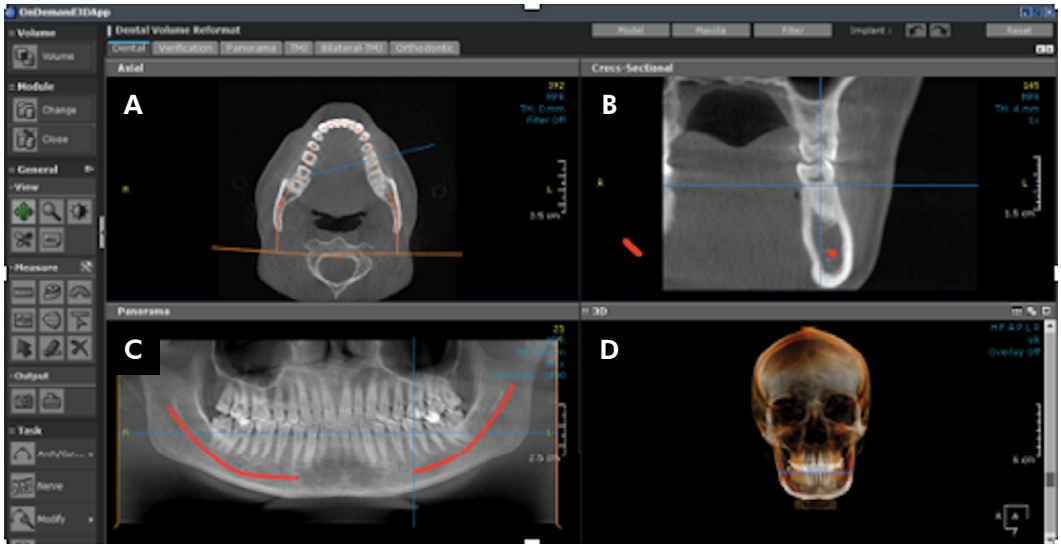

Figure 1. (A) Axial view of a representative CBCT scan, (B) cross-sectional slice illustrating the distance of the root apex to the IAC (C) reconstructed thin-slice panoramic image section showing well-defined bilateral IAC and nerve tracing along the superior border of the IAC, (D) 3D reconstruction.

radiographic apex of each mandibular molar root, in addition to recordings of the IAC position. The CBCT slices were registered at a thickness between 0.2 mm and 0.3 mm. Measurements were also taken from coronal sections in the dynamic light box module to confirm measurements in the cross-sectional view of the DVR module.

Distances were estimated at 3 mm away from the radiographic apex on both sides of mandibular first and second molar roots for each patient. The coronal planes were then located according to the long axis of each root and the measurements were calculated as follows: distance from the outer border of the buccal cortical bone plate to the buccal root area at 3 mm from the radiographic apex (M1) (Figure 2); distance from the outer border of the lingual cortical bone plate to the lingual root area at 3 mm from the radiographic apex (M2) (Figure 3); and distance from the outer border of the cortical boundary of the IAC to the root surface (M3) (Figure 4). The total bone width including the root was then determined at 3 mm from the radiographic apex (M4) (Figure 5).

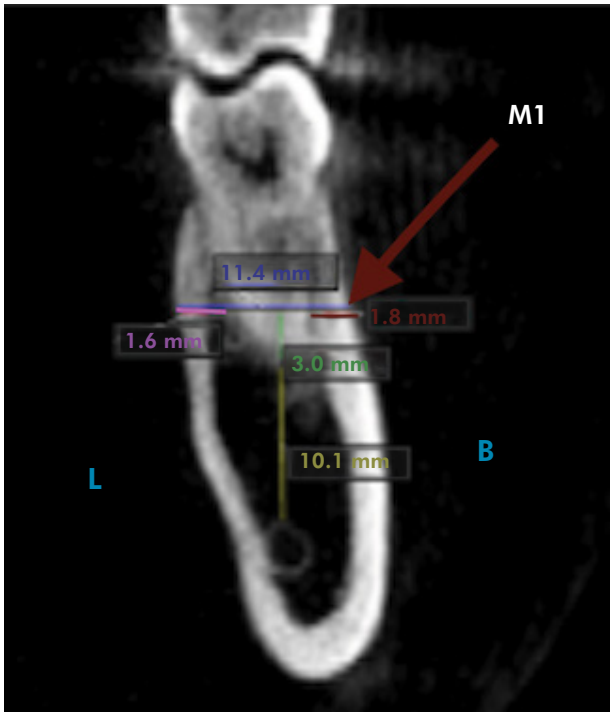

Figure 2. Representative cross-sectional slice showing M1, distance between the outer border of the buccal cortical plate and the buccal root surface, B: buccal side, L: lingual side.

Statistical analysis

Intraexaminer and interexaminer reliability was assessed to detect the validity of the measurements taken in this study. By using intraclass correlation coefficient (ICC) statistics, the correlation coefficient ranged between 0.91 and 0.94.

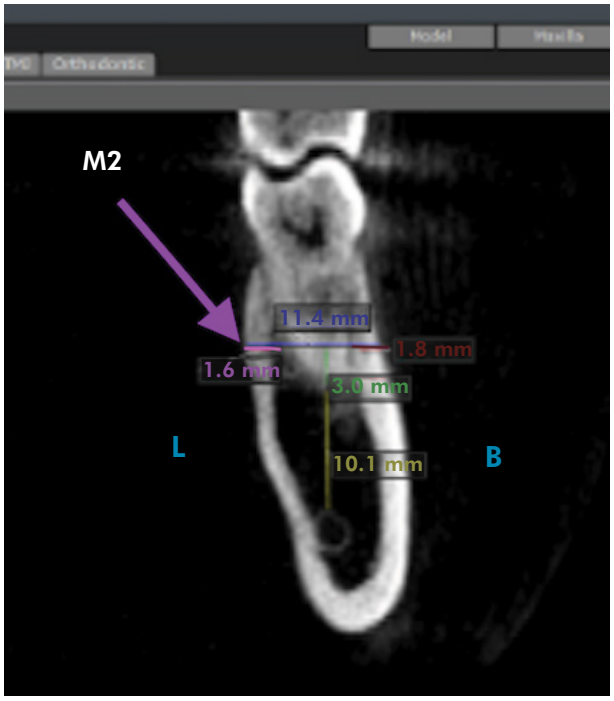

Figure 3. Representative cross-sectional slice showing M2, distance between the outer border of the lingual cortical plate and the lingual root surface, B: buccal side, L: lingual side.

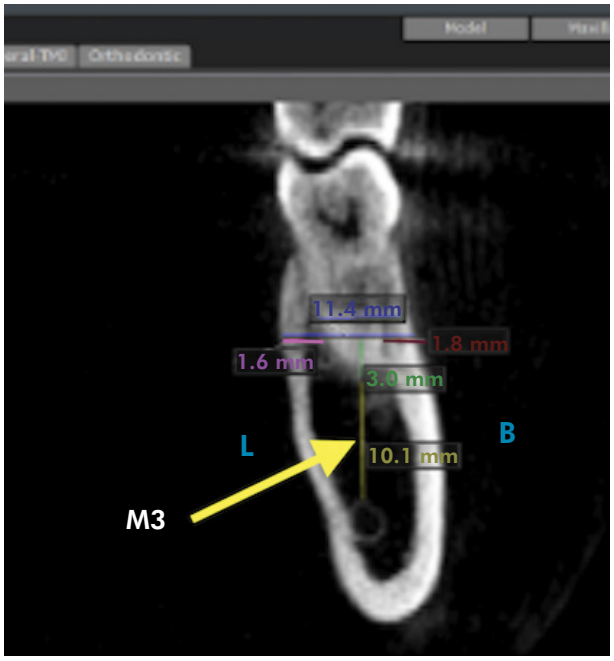

Figure 4. Representative cross-sectional slices showing M3, closest distance between the IAC and the root apex, B: buccal side, L: lingual side.

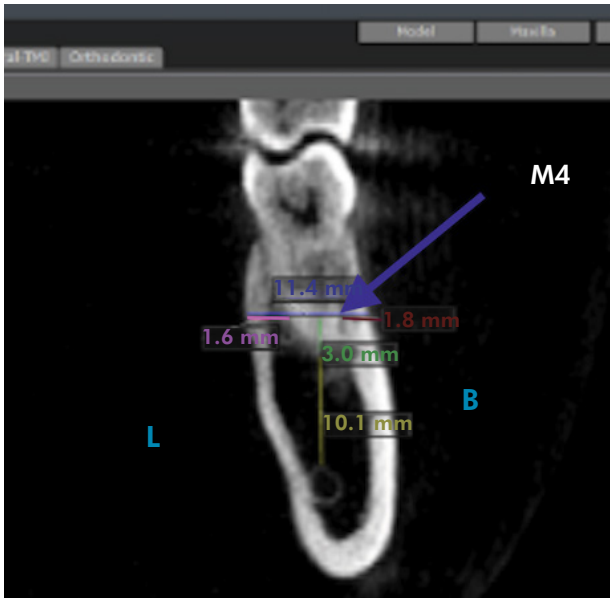

Figure 5. Representative cross-sectional slices showing M4, with total bone width, including the root. B: buccal side, L: lingual side.

Numerical data were checked for normality by exploring the distribution of data using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data displayed normal (parametric) distribution. Data were presented as mean, standard deviation (SD), and 95% confidence interval (95% CI) for the mean value. ANOVA was used to compare the mesial and distal roots for each molar in comparison to different molars. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA was significant. The significance level was set at $p \leq 0.05$. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 23.0. (IBM Corp., Armonk, USA).

Results

The present study was conducted on 84 females (70%) and 36 males (30%). Range of measurements (M1) from the outer surface of the buccal cortical plate to the buccal root surface was between 1.74 and 2.11 mm. Range of measurements (M2) from the outer surface of the lingual cortical plate to the lingual root surface was between 1.63 and 2.09 mm. Range of measurements (M3) between the root apices of

mandibular molars and the IAC was between 2.11 and 3.95 mm (Figure 6). Range of measurements (M4) from the outer surface of the lingual cortical plate to the outer surface of the buccal cortical plate was between 12.17 and 13.57 mm (Table 1). The mesial root of the first molar was in contact with the IAC in three cases (1.25%). Similarly, the distal root was in contact with the IAC in three cases (1.25%). The mesial root of the second molar was in contact with the IAC in 41 cases (17%) and the distal root was in contact with the IAC in 24 cases (10%) (Figure 7).

At measurement point M1, there was a statistically significant difference between different roots (P-value = 0.031, Effect size = 0.032). Pair-wise comparisons between roots revealed the right second molar distal root recorded the largest distance from the IAC with a non-statistically significant difference from the right second molar mesial root and a statistically significant difference from the other roots. The left second molar mesial root recorded the smallest distance from the IAC with a non-statistically significant difference from all left first molar roots and second molar distal roots (Table 1).

At measurement point M2, there was a statistically significant difference between different roots (p-value = 0.004, Effect size = 0.044). Pair-wise comparisons between roots revealed the left second molar distal root recorded the largest distance from the IAC with a non-statistically significant difference from the left second molar mesial root and from the left first molar mesial root, and a statistically significant difference from the other roots. The right second molar mesial root recorded the smallest distance from the IAC with a non-statistically significant difference from right first molar mesial and distal roots, left first molar distal root, and right second molar distal root (Table 1).

At measurement point M3, there was a statistically significant difference between different roots (p-value < 0.001, Effect size = 0.368). Pair-wise comparisons between the roots revealed the left first molar distal root recorded the largest distance from the IAC with a non-statistically significant difference from the right and left first molar distal roots and a statistically significant difference from the other roots. The right first molar mesial root showed a statistically significantly smaller distance followed by the left second molar distal root. There was no statistically significant difference between

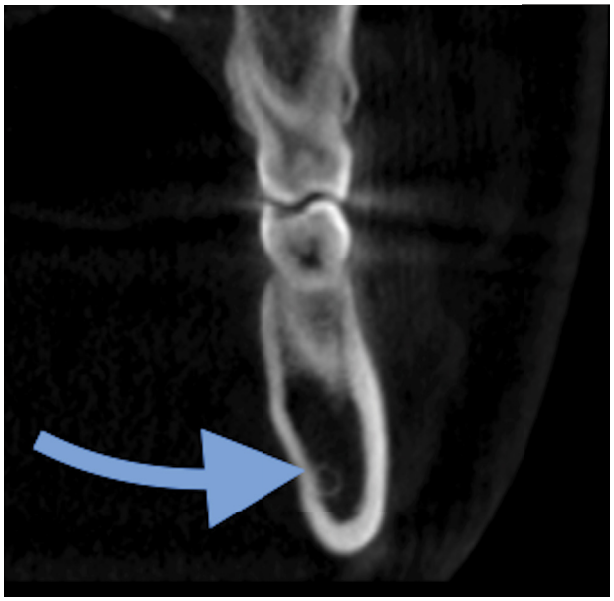

Figure 6. Representative coronal slice showing moderate distance between the IAC and the root apex.

Figure 7. Representative coronal slice showing direct contact between the IAC and the root apex.

Table 1. Mean measurements of the mandibular first and second molars to the buccal and lingual cortical plates and the IAC.

Measurement point / Tooth and root	Mean	SD	95%CI		p-value	Effect size (Partial Eta Squared)
			Lower bound	Upper bound		
M1						
First molar (right mesial)	1.88 ^{B}	0.58	1.77	1.99	0.031*	0.032
First molar (right distal)	1.78 ^{B}	0.54	1.68	1.88		
First molar (left mesial)	1.76 ^{B}	0.56	1.65	1.86		
First molar (left distal)	1.77 ^{B}	0.48	1.68	1.85		
Second molar (right mesial)	2.07 ^{A}	0.71	1.94	2.2		
Second molar (right distal)	2.11 ^{A}	0.66	1.99	2.28		
Second molar (left mesial)	1.69 ^{B}	0.74	1.55	1.82		
Second molar (left distal)	1.74 ^{B}	0.67	1.61	1.86		
M2						
First molar (right mesial)	1.72 ^{B}	0.5	1.62	1.81	0.004*	0.044
First molar (right distal)	1.76 ^{B}	0.49	1.67	1.85		
First molar (left mesial)	1.92 ^{A}	0.62	1.81	2.03		
First molar (left distal)	1.76 ^{B}	0.54	1.66	1.85		
Second molar (right mesial)	1.63 ^{B}	0.69	1.51	1.76		
Second molar (right distal)	1.67 ^{B}	0.66	1.55	1.79		
Second molar (left mesial)	2.05 ^{A}	0.76	1.91	2.18		
Second molar (left distal)	2.09 ^{A}	0.71	1.96	2.22		
M3						
First molar (right mesial)	3.68 ^{B}	2.21	3.28	4.09	< 0.001*	0.368
First molar (right distal)	3.87 ^{A}	2.2	3.47	4.27		
First molar (left mesial)	3.8 ^{A}	2.06	3.43	4.17		
First molar (left distal)	3.95 ^{A}	1.93	3.6	4.3		
Second molar (right mesial)	2.11 ^{E}	2.09	1.73	2.49		
Second molar (right distal)	2.56 ^{D}	2.06	2.18	2.93		
Second molar (left mesial)	2.43 ^{D}	2.01	2.07	2.8		
Second molar (left distal)	2.97 ^{C}	2.05	2.6	3.35		
M4						
First molar (right mesial)	12.71 ^{B}	1.72	12.4	13.02	< 0.001*	0.305
First molar (right distal)	12.17 ^{C}	1.64	11.87	12.47		
First molar (left mesial)	12.7 ^{B}	1.66	12.4	13		
First molar (left distal)	12.17 ^{C}	1.6	11.88	12.46		
Second molar (right mesial)	13.33 ^{A}	1.99	12.97	13.69		
Second molar (right distal)	13.49 ^{A}	1.94	13.14	13.84		
Second molar (left mesial)	13.55 ^{A}	1.87	13.21	13.89		
Second molar (left distal)	13.57 ^{A}	1.87	13.23	13.91		

*Significant at $p \leq 0.05$, Different superscripts in each column within each measurement point indicate a statistically significant difference between roots. IAC: inferior alveolar canal, M1: distance between the outer border of the buccal cortical plate and the buccal root surface, M2: distance between the outer border of the lingual cortical plate and the lingual root surface, M3: closest distance between the IAC and the root apex, M4: total bone width, including the root.

the right second molar distal roots and left mesial roots; both showed statistically significantly lower mean distances. The right second molar mesial root recorded the smallest statistically significantly distance from the IAC (Table 1).

At measurement point M4, there was a statistically significant difference between different roots (p-value < 0.001, Effect size = 0.305). Pair-wise comparisons between the roots revealed the left first molar distal root recorded the largest distance from the IAC with a non-statistically significant difference from all other second molar roots and a statistically significant difference from the other roots. There was no statistically significant difference between right and left first molar mesial roots; both showed statistically significantly lower mean distances. There was no statistically significant difference between right and left first molar distal roots; both recorded the smallest statistically significantly distance from the IAC (Table 1).

At measurement points M1 and M2, there was no statistically significant difference between IAC distances from mandibular first and second molar apices between males and females (Table 2).

At measurement point M3, there was no statistically significant difference between mandibular canal distances from mandibular first and second molar roots in males and females, except for left mesial and distal roots of the first and second molars, as males showed a statistically significantly higher mean distance than did females (p-value = 0.014, Effect size = 0.013), (p-value < 0.001, Effect size = 0.032), (p-value < 0.001, Effect size = 0.035) and (p-value = 0.001, Effect size = 0.023), respectively (Table 2).

At measurement point M4, there was no statistically significant difference between mandibular canal distances from the mandibular first and second molar roots in males and females, except for the right mesial root of the first molar, mesial and distal roots of the second molar, as males showed a statistically significantly higher mean distance than did females (p-value = 0.017, Effect size = 0.012), (p-value = 0.004, Effect size = 0.017), (p-value = 0.030, Effect size = 0.010), (p-value = 0.001, Effect size = 0.025) and (p-value = 0.013, Effect size = 0.013), respectively (Table 2).

Discussion

The decision to shift to an endodontic surgical procedure occurs whenever periapical healing cannot be obtained by primary or secondary orthograde treatment. The surgical intervention consisted of root-end resection and retrograde filling, in addition to apical curettage to get rid of the lesion.[18] In order to perform an adequate endodontic surgery in the mandibular posterior region, the clinician should be acquainted with the relation of mandibular molar apices with the IAC and with the amount of bone available buccally and lingually. In the current study, CBCT was used to assess these measurements because it is a non-destructive, reliable, and accurate method. A crucial merit of CBCT is that it provides all the required data and reconstruction of the image in a single step.[17-19] In order to obtain a clear image, the reconstruction slice thickness was between 0.2 and 0.3 mm according to the examined root. To exclude the effect of age and for the sake of standardization, the patients included in the study were aged between 18 and 25 years. In the present study, the data showed the proximity of mandibular second molar apices to the IAC was significantly closer than those of the mandibular first molars. This result was in accordance with previous studies.[3,20,21] Furthermore, Aksoy et al.[21] also found the second molar was in direct contact with the IAC in 16% of cases, but only 3.3% of the first molars were in contact with the IAC. Bürklein et al.[20] have also observed direct contact of the second molar with the IAC. Our results showed comparable measurements, as the mandibular second molar was in direct contact with the IAC in 17.92% of the cases. Besides, the proximity of the mandibular first molar was in direct contact with the IAC in 1.67% of the cases. Moreover, there was direct contact of the mesial and distal roots of the mandibular second molars with the IAC in 17% and 10% of the cases, respectively. Conversely, Aljarbou et al.[3] demonstrated close contact of the distal root of the mandibular second molar in 38.3% of the cases with the IAC. Likewise, they showed proximity of the mesial root of the mandibular second molar in 25% of the cases with

Table 2. Mean measurements of the mandibular first and second molars to the buccal and lingual cortical plates and the IAC in males and females.

Measurement point / Tooth and root	Males		Females		p-value	Effect size (Partial Eta Squared)
	Mean	SD	Mean	SD		
M1						
First molar (right mesial)	2.16	0.61	1.76	0.53	0.167	0.004
First molar (right distal)	1.96	0.46	1.7	0.56	0.367	0.002
First molar (left mesial)	1.81	0.53	1.73	0.58	0.768	0.0002
First molar (left distal)	1.89	0.49	1.72	0.47	0.508	0.001
Second molar (right mesial)	2.41	0.64	1.92	0.69	0.109	0.005
Second molar (right distal)	2.45	0.61	1.96	0.63	0.096	0.006
Second molar (left mesial)	1.79	0.74	1.64	0.73	0.610	0.001
Second molar (left distal)	1.79	0.56	1.71	0.71	0.772	0.0002
M2						
First molar (right mesial)	1.77	0.52	1.69	0.49	0.798	0.0001
First molar (right distal)	1.88	0.51	1.71	0.47	0.552	0.001
First molar (left mesial)	2.17	0.64	1.81	0.58	0.191	0.004
First molar (left distal)	1.83	0.64	1.72	0.5	0.676	0.0004
Second molar (right mesial)	1.71	0.7	1.6	0.69	0.701	0.0003
Second molar (right distal)	1.78	0.71	1.63	0.64	0.617	0.001
Second molar (left mesial)	2.43	0.79	1.88	0.69	0.055	0.008
Second molar (left distal)	2.43	0.71	1.94	0.65	0.088	0.006
M3						
First molar (right mesial)	3.68	2.42	3.68	2.13	0.997	0.000001
First molar (right distal)	4.05	2.36	3.79	2.14	0.361	0.002
First molar (left mesial)	4.27	2.36	3.59	1.89	0.014*	0.013
First molar (left distal)	4.65	2.15	3.64	1.75	<0.001*	0.032
Second molar (right mesial)	2.19	2.19	2.08	2.06	0.731	0.0003
Second molar (right distal)	2.66	2.05	2.51	2.08	0.609	0.001
Second molar (left mesial)	3.25	2.33	2.08	1.76	<0.001*	0.035
Second molar (left distal)	3.64	2.25	2.68	1.89	0.001*	0.023
M4						
First molar (right mesial)	13.19	1.49	12.5	1.78	0.017*	0.012
First molar (right distal)	12.32	1.52	12.1	1.69	0.436	0.001
First molar (left mesial)	12.98	1.45	12.58	1.74	0.151	0.004
First molar (left distal)	11.99	1.58	12.24	1.62	0.333	0.002
Second molar (right mesial)	13.93	1.94	13.07	1.97	0.004*	0.017
Second molar (right distal)	13.94	2.21	13.3	1.79	0.030*	0.010
Second molar (left mesial)	14.25	1.96	13.25	1.75	0.001*	0.025
Second molar (left distal)	14.07	1.96	13.35	1.79	0.013*	0.013

*Significant at $p \leq 0.05$. IAC: inferior alveolar canal, M1: distance between the outer border of the buccal cortical plate and the buccal root surface, M2: distance between the outer border of the lingual cortical plate and the lingual root surface, M3: closest distance between the IAC and the root apex, M4: total bone width, including the root.

the IAC. For the first molar, direct contact with the IAC was observed only in one mesial root and one distal root.[3] Denio et al.[1] examined the root apices of cadavers to find the distance between the apices and the IAC. They concluded the mesial roots of the first molars exhibited the longest distances (mean of 6.9 mm). Second molars had the shortest distances to the canal with a mean of 3.7 mm.[1] Contrary to the previous study, current data show that the mean distance of mandibular molar apices from the IAC ranged from 2.11 mm to 3.95 mm. Variations in this distance could be due to the age of the patients in the study, given that all of the 120 patients were aged between 18 and 25 years. That could be the reason why mean measurements in general are lower than those obtained by a recent Saudi study, in which a wider age range was used.[3] Previous studies have revealed age changed the closeness of the IAC to the roots of mandibular teeth. Younger patients have smaller distances between the roots and the IAC that would increase with age due to changes in the craniofacial complex throughout life.[20-23] Kovisto et al.[22] conducted a CBCT study to investigate the proximity of the IAC to tooth apices and found the second premolar was the farthest away from the mandibular canal, whereas the distal root of the second molar was closest to the IAC, with an average distance of 2.64 mm and 1.42 mm, respectively. In the present study, the mesial root of the second molar was the nearest one to the IAC at a farther distance than that reported in the previous study, which could be due to ethnic differences among the various studies conducted in different countries.[22] None of the earlier studies examined total bone thickness, including root or the buccal and lingual cortical bone plates separately. It is important to identify these measurements accurately before conducting endodontic surgery. The right side showed a significant increase in the amount of buccal bone plate over the second molar. On the other hand, the left side displayed a significantly increased amount of lingual bone plate over the second molar. Second molars showed the thickest bone width, including root and buccal and lingual cortical plates, with no differences between the right and left sides. On the other hand, for first molars, there were differences between both sides. For the amount of buccal bone plate, there was variation in symmetry for the second molar, but not for the first molar. For the amount of lingual bone plate, there was variation in symmetry for both the first and second molars. Aljarbou et al.,[3] Bürklein et al.,[20] and Kawashima et al.,[23] found symmetrical distances of the mandibular first and second molars on the right and left sides. Conversely, our results displayed variations in symmetry on both sides, which should be considered when dealing with two opposite molars in the same patient, because their anatomy may vary. Regarding sex-specific influences, there were no differences between males and females regarding the amount of buccal and lingual bone plates. However, total bone width, including the roots of mandibular second molars, was significantly higher in male than in female patients. This means the mandibular second molar roots are bulkier in males than in females. When comparing the distance between root apices and the IAC, no significant difference was noted between males and females regarding the right first and second molars. This result was inconsistent with the findings of some studies that have shown females demonstrated proximity of the IAC to the roots of mandibular molars as compared to males.[20-24] Although the results for the right side were nonsignificant for the first and second molars, the rates were lower for females than for males. Interestingly, as pointed out by the results, root apices in females show significant proximity to the IAC for the left first and second molars when compared to males. This could be attributed to the thinner horizontal mandibular bone width in female patients.[24,25] Limitations of this study were mainly related to imaging parameters such as FOV, voxel size, and slice thickness. Although the study relied on previous CBCT scans deemed irrelevant to the current investigation, a further study including smaller FOV, reduced voxel size, and thinner slice thickness is recommended. Sex distribution was considerably unequal, and further investigation is suggested with larger samples from different areas of Egypt and with the inclusion of different age groups, with a more equal sex distribution.

Conclusion

Direct communication between mandibular first and second molar apices and the IAC is not rare and may be underestimated. There was closer proximity of mandibular second molar apices to the IAC when compared with mandibular first molars. Besides, mandibular second molars revealed the thickest total bone width, including the root.

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