Anatomical Analysis of Mandibular Posterior Teeth using CBCT: An Endo-Surgical Perspective

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ABSTRACT

Objective: This study sought to analyse the relationship between mandibular posterior teeth and the surrounding anatomical structures.

Methods: A total of 170 CBCT images were examined to obtain measurements regarding the following: buccolingual (BL) and mesiodistal (MD) root thickness at the standard level of resection (3 mm from the apex), the thickness of the overlying buccal and lingual bone at the same level, the proximity of the mandibular canal (MC) to the apices of the mandibular posterior teeth, as well as the horizontal location of the mental foramen (MF).

Results: The BL root width at 3 mm from the apex was the broadest at the mesial roots of the first molars with males: 5.33±0.99 mm and females: 5.16±0.88 mm (mean±SD). The root width was narrowest at the second premolars (males: 3.80±0.83 mm; females: 3.61±0.60 mm). At the same level; the buccal bone was thickest over the distal roots of the second molars (males: 6.92±1.85 mm; females: 6.95±1.95 mm) and thinnest over the first premolars (males: 1.73±0.93 mm; females: 1.49±1.01 mm), while the lingual bone was thickest over the distal roots of the first molars (males: 5.58±1.36 mm; females: 4.52±1.24 mm) and thinnest over the distal roots of the second molars (males: 3.13±1.50 mm; females: 2.60±1.46 mm). The nearest root apices to the MC were the distal roots of the second molars (male: 1.21±1.45 mm; female: 1.75±1.97 mm), while the furthest were the mesial roots of the first molars (male: 4.00±2.39 mm; female: 4.77±2.58 mm). The most common horizontal location of the MF was between the first and second premolars (51.8%). The lingual bone was significantly thinner over both roots of first molars in females (P<0.05).

Conclusion: As the position of the teeth became more posterior, the buccal bone thickness increased, the lingual bone thickness decreased, and the distance to the MC became closer. CBCT analysis provides distortion- and superimposition-free images of the relevant anatomic structures.

Keywords: Endodontic surgery, mandible, mandibular canal, mental foramen, microsurgery, osteotomy, posterior teeth, root resection

HIGHLIGHTS

- CBCT is a dependable, precise tool for preoperative anatomic analysis of the surgical site during planning Endodontic Microsurgery.

- As the position of the teeth become posterior, the buccal bone thickness increases, while both the lingual bone thickness and the distance to the mandibular canal decrease.

- As the position of the planned apical surgery goes posteriorly, alternative options, such as intentional replantation and bony lid technique, should be considered.

INTRODUCTION

When nonsurgical root canal treatment or orthograde retreatment is not appropriate or fails, endodontic microsurgery (EMS) becomes the treatment modality of choice to address persistent apical periodontitis (1, 2). EMS has been shown to have a high success rate and a predictable outcome (3). However, EMS in the mandibular posterior region can be technically challenging, possibly due to the limited visibility and accessibility, the considerable thickness of the buccal cortical plate, the lingual inclination of the roots, and their proximity to the mandibular canal (MC) (4). In addition, Libersa et al. (5) illustrated a higher incidence of procedural errors and a higher probability of persistent neurosensory disturbances with root-end surgeries in the posterior mandible. Thus, some clini-

cians deter from EMS in the posterior mandible to avoid these complications, despite recent improvements in the surgical armamentaria (6).

Cone-beam computed tomography (CBCT) is a valuable tool in EMS pre-surgical assessment and treatment planning (4). It allows for three-dimensional reconstruction of the dento-maxillofacial complex in an accurate 1:1 anatomic representation (7) while exposing the patient to a low radiation dose (8), thus acquainting the surgeon with the anatomic landmarks and structures adjacent to the surgical site as well as tooth dimensions and anatomy. Therefore, CBCT has been recommended as the imaging modality of choice for pre-surgical assessment by the American Association of Endodontists, the American Association of Oral and Maxillofacial Radiology and the European Society of Endodontics (ESE) (8, 9). However, CBCT is not always available or affordable for the patients (10). Therefore, descriptive morphologic studies are required to provide information about the relationship between mandibular posterior teeth and the surrounding anatomical structures (4, 11). Such data is notably lacking for the Egyptian population. Therefore, we aim in this study to use CBCT to:

1. Acquire normative information regarding the buccolingual (BL) root thickness and the thickness of the overlying buccal and lingual bone at the 3 mm resection level,

2. The proximity of the MC to the apices of the mandibular posterior teeth,

3. The horizontal location of the MF, and,

4. Compare the measurements between male and female patients.

The null hypothesis was there was no difference between the tested groups.

MATERIALS AND METHODS

Sample size calculation
A power analysis was performed to apply a two-sided statistical test with an alpha level of .05 and beta levels .95, and an effect size of 1.24, calculated based on the results of Jeon et al. (12), the predicted sample size (n) was a total of (36) cases. The sample size was increased to 170 cases. The sample size calculation was performed using G*Power version 3.1.9.7.® (Heinrich-Heine-Universität, Düsseldorf, Germany).

Subjects
A research Ethics Committee approved the study in Ain Shams University (Protocol number: FDASU-RecEM061705). CBCT images of 170 patients were included in the study. Scans were collected from a private maxillofacial imaging centre along with the demographic data of the anonymous patients and were acquired using a CBCT machine (Cranex PP3-1; Soredex, Tuusula, Finland) with exposure settings of 90 kV, 10 mA, 6.1 seconds, a field of view of 6×8 cm (one side of the mandible), and voxel size: 200 µm.

Inclusion and exclusion criteria
All included patients had to have all their mandibular posterior teeth on the examined side, except for the third molars,

i.e., four posterior teeth were examined per patient. Patients with radiographic evidence of periapical lesions, periodontal disease, resorbed roots, immature molars, or mixed dentition were excluded. A periapical lesion was defined as a periapical radiolucent area that was in contact with the radiographic apex of the root and measured at least twice the width of the periodontal ligament space (13). Periodontal disease was identified according to its earliest signs as a break in the continuity of lamina dura and a wedge-shaped radiolucent area at the mesial or distal aspect of the periodontal ligament space (14). A resorbed root was detected when three authors, including the radiologist, had a consensus (15).

Calibration and measurements
All data from the CBCT examinations were acquired in a digital DICOM format, imported to OnDemand3D® App software (Cybermed, Seoul, Korea), and viewed on an 18.5-inch HD LED monitor with a resolution of 1366×768. Three examiners (two endodontists and one oral radiologist with more than 10 years of experience) evaluated all the scans twice. The examiners were calibrated at the beginning of the study by evaluating 15% of the scans, and the interclass correlation coefficient (ICC) scores were determined (ranged from 0.87-0.92, with a 95% confidence interval). A break was taken after evaluating 3 consecutive scans to avoid eye strain. The examiners could change the viewer settings such as contrast, density, and sharpness. In addition, they were able to magnify the images for better identification and visualisation of the measured structures.

Measuring the buccal and lingual bone thickness and root dimensions 3 mm from the apex (Figs. 1, 2)
For the premolars, the coronal plane was realigned to divide the tooth into mesial and distal halves and the sagittal cut was adjusted to be passing through the buccal cusp tip and the root apex. For the molars, the coronal cut was again adjusted to divide the tooth mesiodistally and the sagittal cut was adjusted to be passing through the central fossa and the root apex.

For premolars, the axial plane was first adjusted to pass through the cementoenamel junction on the axial view. Next, the reference planes were adjusted so that the sagittal plane bisects the tooth BL and the coronal plane bisects the tooth MD. Next, the axial plane was adjusted for the molars below the furcation area, and each root was measured separately. Reference planes were adjusted so that the sagittal plane bisects the root BL and the coronal plane bisects the root MD.

On the sagittal view: The coronal plane was adjusted to pass through the apical third of the tooth and bisect the root M-D.

On the coronal view: For the first premolar, the sagittal plane was adjusted to pass along their long axis, passing by the root apex and the buccal cusp tip. For the second premolar, the sagittal plane was adjusted to be passing along the long axis of the tooth passing by the root apex and the central fossa, while for molars, it was adjusted to bisect the root along the long axis passing by the root apex.
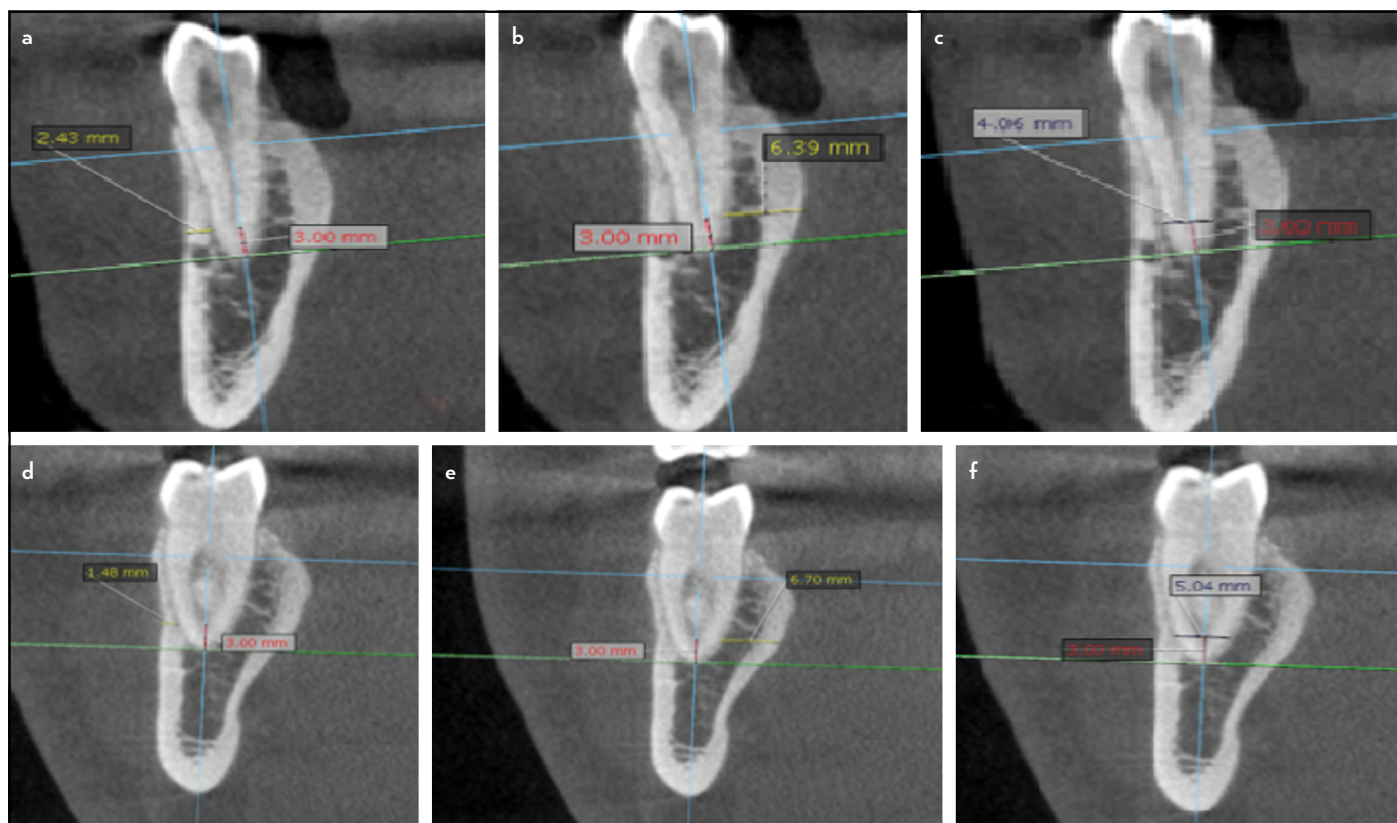
Figure 1. Anatomical measurements done after Reference planes (axial, coronal and sagittal) calibration for a premolar (a–c) and a molar (d–f) as detailed in the methodology
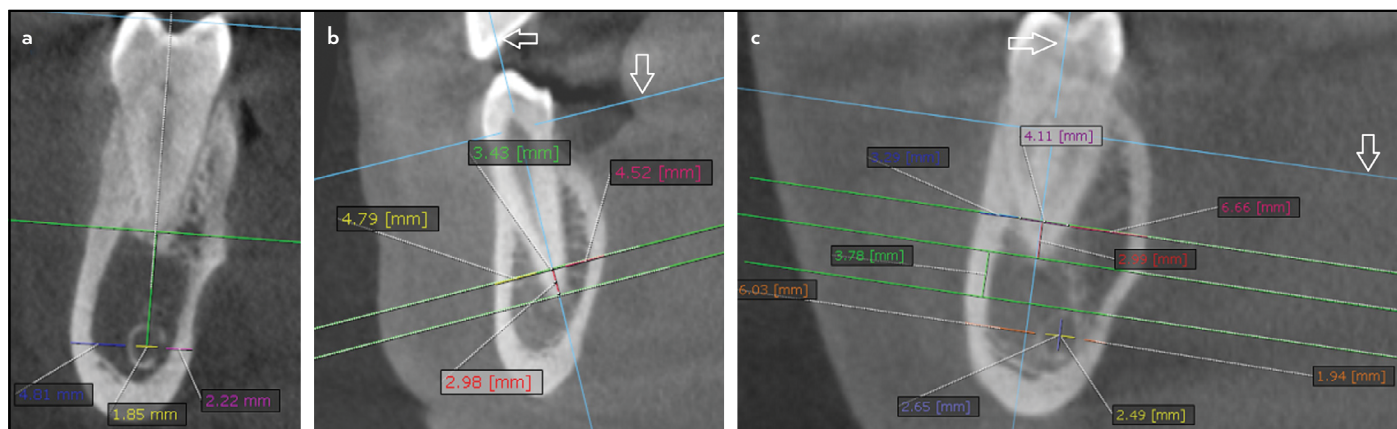

Figure 2. Representative samples of the extensive images' analysis done: (a) Mandibular canal diameter: 1.85 mm, buccal and lingual bone thicknesses relative to the mandibular canal: 4.81 and 2.22 mm, (b) Arrows denote reference planes. Root thickness at resection level: 3.43 mm, buccal and lingual bone thicknesses relative to the root at resection level: 4.79 and 4.52 mm respectively, (c) Arrows denote reference planes. Root thickness at resection level: 4.11 mm. Buccal and lingual bone thicknesses relative to the root at resection level: 3.29 and 6.66 mm respectively. Horizontal and vertical diameters of the mandibular canal: 2.65 and 2.49. Buccal and lingual bone thicknesses relative to the mandibular canal: 6.03 and 1.94 mm respectively. Distance between the apex and mandibular canal: 3.78 mm

Detection of the horizontal position of mental foramen (MF)
The MF was detected on the reconstructed panoramic view (Fig. 3) according to the classification of Chkoura et al. (16) as follows:

1. Located between the long axis of the mandibular canine and mandibular first premolar

2. In the same line with the long axis of the lower first premolar

3. Between the long axis of the mandibular first premolar and mandibular second premolar

4. In line with the long axis of the mandibular second premolar

5. Between the long axis of the second mandibular premolar and the first mandibular molar

6. In the same line with the long axis of the mesial root of the mandibular first molar.
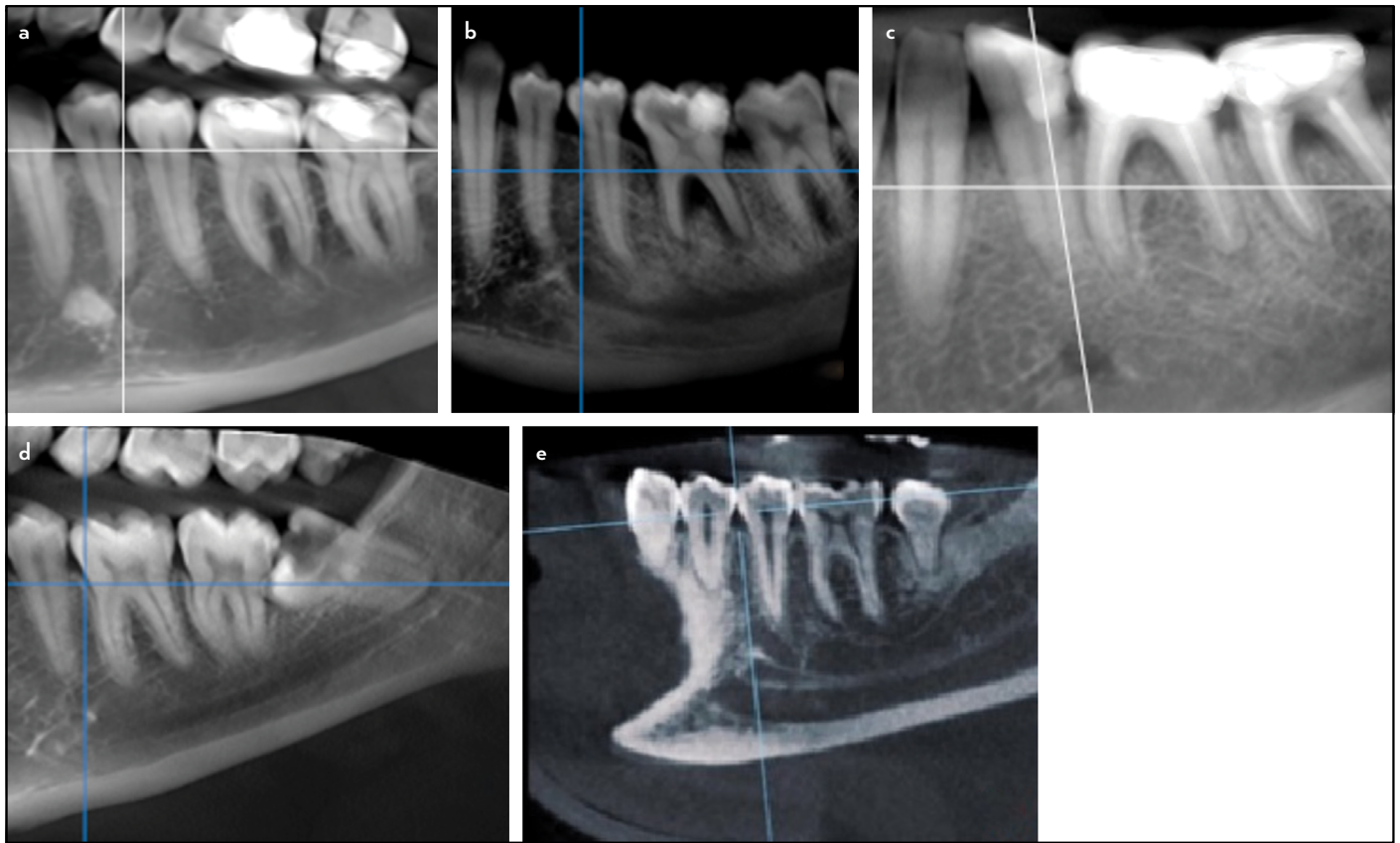
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Figure 3. Different possibilities of mental foramen location & reference planes adjustment: (a) Directly below the mandibular first premolar, (b) Between mandibular premolars, (c) Directly below the mandibular second premolar, (d) Between the mandibular second premolar and the first molar, (e) Proper reference planes adjustments before identifying the location

Statistical analysis

Categorical data were presented as frequencies and percentages and were analysed using Fisher's exact test. Numerical data were explored for normality by checking the data distribution, calculating the mean and median values using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution and were presented as mean and standard deviation (SD) values. One-way ANOVA followed by Tukey's post hoc test was used for the statistical analysis. The significance level was set at $P \leq 0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.0.3 for Windows.

RESULTS

A total of 170 CBCT scans (680 teeth) were evaluated. In addition, inter- and intra-reliability tests were performed and showed a high ICC score (>0.9) between the different readings. From the 170 CBCT scans, 69 (40.6%) of the patients were males, and 101 (59.4%) were females.

The total resection depth (BL root thickness and buccal cortical plate thickness), the lingual cortical plate thickness at the standard level of resection at 3 mm from the apex, and the distance between the teeth apices and the MC are presented in Table 1. The B-L root width at 3 mm from the apex was broadest at the mesial roots of the first molars (males: 5.33±0.99 mm and females: 5.16±0.88 mm (mean±standard deviation), and narrowest at the second premolars (males: 3.80±0.83 mm and

females: 3.61±0.60 mm). The buccal bone was thickest over the distal roots of the second molars (males: 6.92±1.85 mm and females: 6.95±1.95 mm) and thinnest over the first premolars (males: 1.73±0.93 mm and females: 1.49±1.01 mm).

The thickness of the lingual bone overlying the roots and the distance between their apices and the mandibular canal is presented in Table 2. The lingual bone was thickest over the distal roots of the first molars (males: 5.58±1.36 mm and females: 4.52±1.24 mm) and thinnest over the distal roots of the second molars (males 3.13±1.50 mm and females: 2.60±1.46 mm). Root apices nearest to the MC were the distal roots of the second molars (males: 1.21±1.45 mm and females: 1.75±1.97 mm), while the furthest were the mesial roots of the first molars (males: 4.00±2.39 mm and females: 4.77±2.58 mm).

Statistics concerning MF location are presented in Table 3. It mainly was located between the first and second premolars (51.8%), followed by apical to the second premolar (35.9%), then between the second premolar and the mesial root of the first molar (7.1%). The least common location of the MF was apical to the first premolar (5.3%).

As regard gender-based differences, the total resection depth (bone thickness+BL root width) was significantly more in males at the first premolar and the distal roots of the first molars (P<0.05). The lingual bone was significantly thinner in the molar area in females (P<0.05). Also, the distance between the

TABLE 1. Thickness of the buccal bone overlaying the mandibular posterior teeth, their buccolingual root thickness and the total resection depth needed for endodontic microsurgery

Tooth	Buccal thickness (mean±SD, mm)			Root thickness (mean±SD, mm)			Total thickness (mean±SD, mm)		
	Male	Female	P value	Male	Female	P value	Male	Female	P-value
First premolar	1.49±1.01	1.73±0.93	0.119	3.76±0.72	3.90±0.71	0.216	5.26±1.24	5.63±1.11	0.042*
Second premolar	1.93±1.08	1.85±0.94	0.634	3.61±0.60	3.80±0.83	0.113	5.54±1.19	5.65±1.14	0.543
Mesial root canal of first molar	1.73±1.05	1.52±0.93	0.202	5.16±0.88	5.33±0.99	0.291	6.89±1.16	6.85±1.10	0.815
Distal root of first molar	3.03±1.36	2.41±1.31	0.006*	4.28±0.74	4.44±0.82	0.240	7.31±1.36	6.85±1.44	0.049*
Mesial root of second molar	5.80±1.83	5.46±1.95	0.295	4.64±0.92	4.92±0.92	0.074	10.44±1.98	10.38±1.77	0.856
Distal root of second molar	6.95±1.95	6.92±1.85	0.915	3.82±0.62	4.10±0.76	0.020*	10.78±1.94	11.02±1.68	0.42

Means with different superscript letters are statistically significantly different within the same column and parameter*; significant (P≤0.05), SD: standard deviation

root apices and the MC was significantly shorter at the distal root of the first molar in females (P<0.05).

DISCUSSION
The results of this study provide valuable clinical data essential before surgical intervention. Understanding these measurements will help the operator choose the best surgical approach and prevent unnecessary bone destruction leading to more postoperative complications and delayed or incomplete bony healing (17). This study attempted to measure the bone and root thickness in the BL dimension separately and combined to help clinicians understand the depth needed to locate and resect the root entirely and assess the case difficulty level (16). While locating lingually-positioned roots may be feasible, adequate resection and retro-preparation can be challenging due to the limited accessibility and visibility, as the osteotomy extends posteriorly. In these cases, clinicians may consider other surgical options such as guided surgery, the "bone-lid" technique, or intentional replantation (18-20). The cortical plate's thickness may also help predict the postoperative pain level following endodontic surgery. It has been recently shown that patients with thicker bone covering the apex are significantly more likely to develop severe postoperative pain (21).

The precision and credibility of CBCT in diagnosing spatial relationships between anatomic structures are well documented in the literature (22). Previous studies, however, either lacked a large sample size or used larger fields of view scans, which may affect the visibility of anatomical structures (23). Before CBCT, only cadaver studies could be used to obtain similar information (24). However, cadaver studies do not allow for sufficient sample sizes, normal data distribution, and sufficient numbers of specimens to calculate gender and age differences (24, 25). While some discrepancies may exist between the values calculated using CBCT and direct clinical measurements, they may not be of clinical relevance (26). All measurements of the bone thickness and root dimensions were assessed at the standard resection depth of 3 mm from the root apex, as previously suggested (4, 11, 16). At that level, the preliminary osteotomy is often initiated to access the root. Also, root resection at this level removes most of the lateral and accessory canals (27). Our results showed that the combined BL thickness of the buccal plate and root increases in a posterior direction, supporting the findings of previous studies (4, 11, 20).

In this study, our results showed that the mean buccal bone thickness increased as the tooth became more posteriorly located. The buccal bone supporting the distal root of the second molar was the thickest, with a mean average thickness of 6.9 mm. Various measurements have been reported in the literature regarding the buccal plate thickness opposite to the distal root of the second molars ranging between 6 to 12 mm (4, 11, 22). The difference in results might be due to the methodologies or the populations studied. On the other hand, the buccal bone was remarkably thin over the premolars and the mesial roots of the first molars ranging between 1.2 to 1.5 mm, making them more accessible and predictable for surgical manipulation using microsurgical techniques. At the resection level, the mesial roots of the first molars had the largest

TABLE 2. Thickness of the lingual cortex overlaying the mandibular posterior teeth and the distance from their apices to the mandibular canal

Tooth	Lingual cortex to the root (mean±SD, mm)			Distance from root apex to the canal (mean±SD, mm)		
	Male	Female	P-value	Male	Female	P-value
First premolar	4.18±1.19	3.98±1.20	0.296	3.07±2.23	3.98±2.01	0.299
Second premolar	4.97±1.40	4.60±1.39	0.097	3.29±2.48	2.88±2.17	0.286
Mesial root of first molar	5.02±1.24	4.28±1.21	<0.001*	4.77±2.58	4.00±2.39	0.067
Distal root of first molar	5.58±1.36	4.52±1.24	<0.001*	4.46±2.60	3.48±2.33	0.021*
Mesial root of second molar	3.26±1.48	3.01±1.37	0.301	2.19±1.98	1.90±2.04	0.383
Distal root of second molar	3.13±1.50	2.60±1.46	0.037*	1.75±1.97	1.21±1.45	0.077

Means with different superscript letters are statistically significantly different within the same column and parameter*; significant (P≤0.05). SD: standard deviation

TABLE 3. Summary statistics for demographic data concerning the location of the mental foramen

	Parameter (n=170)	n	%
Mental foramen location	Between first and second premolars	88	51.7
	Between second premolar and first molar	12	7.1
	Inferior to first premolar	9	5.3
	Inferior to second premolar	61	36.0

BL dimension, while the second premolar was the smallest among all teeth. The mean BL dimension of the mesial roots was also more prominent than the distal roots of all molars. These results agree with previously published data (4, 11, 16).

A shorter distance between the root apex and the MC was noted as the tooth became more posteriorly positioned. The roots of the second molars were the closest to the MC, with 38% of the mesial roots and 54% of the distal roots located ≤1 mm to the MC. Similar findings were reported by former studies (28-30).

In the study herein, the most common horizontal location of the MF was between the first and second premolars (51.8%), followed by being apical to the second premolar (35.9%) with no significant differences in regards to age or sex (P>0.05). These results agree with previously published data for Polish, Nigerian, Kosovarian, and Iranian populations (31-34) and disagree with other studies in Malawian, Zimbabwean, Turkish, Kenyan, and Indian populations, which found that the most typical location of the MF was apical to the second premolars (35-40). These differences can be attributed to the ethnic variances, different sample sizes, and methodologies.

Not all studies investigated gender-based differences. For example, while a significant difference based on gender was found in an Indian population (34), it was reported neither in the Moroccan population (18) nor in this study among the Egyptian population.

The thinnest lingual bone thickness was measured over the distal roots of the mandibular first and second molars. This agrees with Chiona et al. (41) and Aydin et al. (11), even in the numerical range. Although a surgical intervention in the posterior mandible is usually restricted to a buccal approach, limited visibility towards the lingual part of the osteotomy during surgery may result in iatrogenic extension and damage to the lingual plate resulting in a through-and-through lesion and damage to the lingual artery or nerve (42, 43).

Considering gender-related differences, males generally showed a thicker buccal plate of bone compared to females. However, the differences were not statistically significant. Only the distance between the root apices and the MC was significantly shorter at the distal roots of first molars in females (P<0.05) in accordance with Bürklein et al. (44). Therefore, it can also be concluded from this study that CBCT is a reliable tool to determine anatomical measurements needed for surgical intervention.

The strengths of this study include a large sample size, detailed and reproducible methodology in terms of measurement acquisition and reference planes adjustments, and statistical analysis of gender-based differences, whereas many of the previous studies would often provide only descriptive statistics (10, 12). However, the study has its limitations, as the results only represent the population investigated. Due to the minor variation between patients, it is still more appropriate to consider scanning patients before surgical intervention in the posterior mandible whenever possible or accessible to allow proper assessment and treatment planning.

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REFERENCES

1. Lui JN, Khin MM, Krishnaswamy G, Chen NN. Prognostic factors relating to the outcome of endodontic microsurgery. J Endod 2014; 40(8):1071–6.
2. Pinto D, Marques A, Pereira JF, Palma PJ, Santos JM. Long-term prognosis of endodontic microsurgery-a systematic review and meta-analysis. Medicina (Kaunas) 2020; 56(9):447. [CrossRef]
3. Kohli MR, Berenji H, Setzer FC, Lee SM, Karabucak B. Outcome of endodontic surgery: a meta-analysis of the literature-part 3: comparison of endodontic microsurgical techniques with 2 different root-end filling materials. J Endod 2018; 44(6):923–31. [CrossRef]
4. Zahedi S, Mostafavi M, Lotfirikan N. Anatomic study of mandibular posterior teeth using cone-beam computed tomography for endodontic surgery. J Endod 2018; 44(5):738–43. [CrossRef]
5. Libersa P, Savignat M, Tonnel A. Neurosensory disturbances of the inferior alveolar nerve: a retrospective study of complaints in a 10-year period. J Oral Maxillofac Surg 2007; 65(8):1486–9. [CrossRef]
6. Palma PJ, Marques JA, Casau M, Santos A, Caramelo F, Falacho RI, et al. Evaluation of root-end preparation with two different endodontic microsurgery ultrasonic tips. Biomedicines 2020; 8(10):383. [CrossRef]
7. Simonton JD, Azevedo B, Schindler WG, Hargreaves KM. Age- and gender-related differences in the position of the inferior alveolar nerve by using cone beam computed tomography. J Endod 2009; 35(7):944–9.
8. European Society of Endodontology, Patel S, Durack C, Abella F, Roig M, Shemesh H, Lambrechts P, et al. European Society of Endodontology position statement: the use of CBCT in endodontics. Int Endod J 2014; 47(6):502–4. [CrossRef]
9. Special Committee to Revise the Joint AAE/AAOMR Position Statement on use of CBCT in Endodontics. AAE and AAOMR Joint Position Statement: Use of cone beam computed tomography in endodontics 2015 update. Oral Surg Oral Med Oral Pathol Oral Radiol 2015; 120(4):508–12.
10. Lavasani SA, Tyler C, Roach SH, McClanahan SB, Ahmad M, Bowles WR. Cone-beam computed tomography: anatomic analysis of maxillary posterior teeth-impact on endodontic microsurgery. J Endod 2016; 42(6):890–5. [CrossRef]
11. Uğur Aydın Z, Göller Bulut D. Relationship between the anatomic structures and mandibular posterior teeth for endodontic surgery in a Turkish population: a cone-beam computed tomographic analysis. Clin Oral Investig 2019; 23(9):3637–44. [CrossRef]
12. Jeon KJ, Lee C, Choi YJ, Han SS. Anatomical analysis of mandibular posterior teeth for endodontic microsurgery: a cone-beam computed tomographic evaluation. Clin Oral Investig 2021; 25(4):2391–7. [CrossRef]
13. Uraba S, Ebihara A, Komatsu K, Ohbayashi N, Okiji T. Ability of cone-beam computed tomography to detect periapical lesions that were not detected by periapical radiography: a retrospective assessment according to tooth group. J Endod 2016; 42(8):1186–90. [CrossRef]
14. Lima TF, Gamba TO, Zaia AA, Soares AJ. Evaluation of cone beam computed tomography and periapical radiography in the diagnosis of root resorption. Aust Dent J 2016; 61(4):425–31. [CrossRef]
15. Carranza F. Radiographic and other aids in the diagnosis of periodontal disease. In: Newman MG, Takei HH, Klokkevold PR, Carranza FA, editors. Carranza's Clinical Periodontology. 8th ed. Philadelphia, Pa, USA: Saunders; 1996. p. 364–5.
16. Chkoura A, El Wady W. Position of the mental foramen in a Moroccan population: A radiographic study. Imaging Sci Dent 2013; 43(2):71–5.
17. von Arx T, Jensen SS, Hänni S. Clinical and radiographic assessment of various predictors for healing outcome 1 year after periapical surgery. J Endod 2007; 33(2):123–8. [CrossRef]
18. Khoury F, Hensher R. The bony lid approach for the apical root resection of lower molars. Int J Oral Maxillofac Surg 1987; 16(2):166–70. [CrossRef]
19. Lee SM, Yu YH, Wang Y, Kim E, Kim S. The application of "bone window" technique in endodontic microsurgery. J Endod 2020; 46(6):872–80.
20. Kratchman S. Intentional replantation. Dent Clin North Am 1997; 41(3):603–17.
21. Malagise CJ, Khalighinejad N, Patel YT, Jalali P, He J. Severe pain after endodontic surgery: an analysis of incidence and risk factors. J Endod 2021; 47(3):409–14. [CrossRef]
22. Kim TS, Caruso JM, Christensen H, Torabinejad M. A comparison of cone-beam computed tomography and direct measurement in the examination of the mandibular canal and adjacent structures. J Endod 2010; 36(7):1191–4. [CrossRef]
23. Hassan BA, Payam J, Juyanda B, van der Stelt P, Wesselink PR. Influence of scan setting selections on root canal visibility with cone beam CT. Dentomaxillofac Radiol 2012; 41(8):645–8. [CrossRef]
24. Sato I, Ueno R, Kawai T, Yosue T. Rare courses of the mandibular canal in the molar regions of the human mandible: a cadaveric study. Okajimas Folia Anat Jpn 2005; 82(3):95–101. [CrossRef]
25. Narayana K, Vasudha S. Intraosseous course of the inferior alveolar (dental) nerve and its relative position in the mandible. Indian J Dent Res 2004; 15(3):99–102.
26. Timock AM, Cook V, McDonald T, Leo MC, Crowe J, Benninger BL, et al. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. Am J Orthod Dentofacial Orthop 2011; 140(5):734–44. [CrossRef]
27. Kim D, Ha JH, Jin MU, Kim YK, Kim SK. Proximity of the mandibular molar root apex from the buccal bone surface: a cone-beam computed tomographic study. Restor Dent Endod 2016; 41(3):182–8. [CrossRef]
28. Lvovsky A, Bachrach S, Kim HC, Pawar A, Levinzon O, Ben Itzhak J, et al. Relationship between root apices and the mandibular canal: a cone-beam computed tomographic comparison of 3 populations. J Endod 2018; 44(4):555–8. [CrossRef]
29. Littner MM, Kaffe I, Tamse A, Dicapua P. Relationship between the apices of the lower molars and mandibular canal-a radiographic study. Oral Surg Oral Med Oral Pathol 1986; 62(5):595–602. [CrossRef]
30. Koivisto T, Chiona D, Milroy LL, McClanahan SB, Ahmad M, Bowles WR. Mandibular canal location: cone-beam computed tomography examination. J Endod 2016; 42(7):1018–21. [CrossRef]
31. Zmyslowska-Polakowska E, Radwanski M, Ledzion S, Leski M, Zmyslowska A, Lukomska-Szymanska M. Evaluation of size and location of a mental foramen in the Polish population using cone-beam computed tomography. Biomed Res Int 2019; 2019:1659476. [CrossRef]
32. Olasoji HO, Tahir A, Ekanem AU, Abubakar AA. Radiographic and anatomic locations of mental foramen in northern Nigerian adults. Niger Postgrad Med J 2004; 11(3):230–3.
33. Kqiku L, Weiglein A, Kamberi B, Hoxha V, Meqa K, Städtler P. Position of the mental foramen in Kosovarian population. Coll Antropol 2013; 37(2):545–9.
34. Haghanifar S, Rokouei M. Radiographic evaluation of the mental foramen in a selected Iranian population. Indian J Dent Res 2009; 20(2):150–2.
35. Igbigbi PS, Lebona S. The position and dimensions of the mental foramen in adult Malawian mandibles. West Afr J Med 2005; 24(3):184–9.
36. Mbajiorgu EF, Mawera G, Asala SA, Zivanovic S. Position of the mental foramen in adult black Zimbabwean mandibles: a clinical anatomical study. Cent Afr J Med 1998; 44(2):24–30.
37. Sekerci A, Sahman H, Sisman Y, Aksu Y. Morphometric analysis of the mental foramen in a Turkish population based on multi-slice computed tomography. J Oral Maxillofac Radiol 2013; 1(1):2. [CrossRef]
38. Alam MK, Alhabib S, Alzarea BK, Irshad M, Faruqi S, Sghaireen MG, et al. 3D CBCT morphometric assessment of mental foramen in Arabic population and global comparison: imperative for invasive and non-invasive procedures in mandible. Acta Odontol Scand 2018; 76(2):98–104. [CrossRef]
39. Mwaniki DL, Hassanali J. The position of mandibular and mental foramina in Kenyan African mandibles. East Afr Med J 1992; 69(4):210–3.
40. Sankar DK, Bhanu SP, Susan PJ. Morphometrical and morphological study of mental foramen in dry dentulous mandibles of South Andhra population of India. Indian J Dent Res 2011; 22(4):542–6. [CrossRef]
41. Chiona D, Koivisto T, Milroy LL, Roach SH, McClanahan SB, Ahmad M, et al. CBCT analysis of mandibular posterior teeth: Impact on endodontic microsurgery. Available at: https://www.mndental.org/news/2017/07/cbct-analysis-of-mandibular-posterior-teeth-impact-on-endodontic-microsurgery/. Accessed Nov 23, 2021.
42. Jin GC, Kim KD, Roh BD, Lee CY, Lee SJ. Buccal bone plate thickness of the Asian people. J Endod 2005; 31(6):430–4. [CrossRef]
43. Lata J, Tiwari AK. Incidence of lingual nerve paraesthesia following mandibular third molar surgery. Natl J Maxillofac Surg 2011; 2(2):137–40.
44. Bürklein S, Grund C, Schäfer E. Relationship between root apices and the mandibular canal: a cone-beam computed tomographic analysis in a German population. J Endod 2015; 41(10):1696–700. [CrossRef]