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Original Article

Mandibular canal assessment in dentate and edentulous ridges of 400 Iraqi Arab and Kurdish populations using cone beam computed tomography

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ABSTRACT

Objectives: This study aims to compare differences in mandibular canal (MC) location between dentate and edentulous ridges, in the second premolar region as well as the first, second, and third molar regions using cone beam computed tomography (CBCT) of Arabic and Kurdish Iraqi populations.
Materials and Methods: CBCT images of 400 subjects (200 Arabs, 200 Kurds) were collected from radiological archives. RadiAnt DICOM software (Medixant, Poland) was used for image analyses. Measurements were performed from MC to buccal and lingual alveolar crests and to buccal, lingual, and inferior aspect of the mandible for both dentate and edentulous ridges. Additionally, distance to the most superior aspect of residual edentulous ridge were performed. Independent *t*-test and Mann-Whitney *U* Test were performed utilising SPSS v.26.
Results: Distances from MC to buccal and lingual alveolar crests were consistently lower in edentulous ridge compared to dentate ridge across all teeth regions. Distances to lingual and inferior border of the mandible were higher in edentulous ridge compared to dentate ridge of all teeth regions. Distances to buccal surface of the mandible varies with fluctuations of dentate and edentulous ridges displaying higher measurements. Distance to superior aspect of residual edentulous ridge revealed mean values in the range of 13.45 to 15.69 mm in Arabs and 13.96 to 16.37 mm in Kurds.
Conclusions: Discrepancy in vertical position of MC was observed between dentate and edentulous ridges within Arab and Kurd populations. Horizontal position of MC was unaffected by tooth loss and found to be closer to lingual surface of all molars. The residual alveolar ridge was sufficient to accommodate the common length and width of dental implants.
Clinical significance: The findings could play a crucial role in planning surgical interventions of the mandible, helping to prevent complications that might arise due to inadequate preoperative assessments.

1. Introduction

Dental implant was a popular and effective treatment option for tooth loss replacement because of its high success rate (Kandavalli et al., 2021). Successful dental implant installation requires adequate quantity of bone of the alveolar ridge. After tooth extraction, the healing socket is susceptible to modelling and remodelling processes resulting in dimensional changes of the residual alveolar ridge (del Canto-Díaz et al., 2019). These dimensional changes may diminish bone's height and width, making it more difficult to insert a dental implant with the required length and diameter (Jung et al., 2018).

Anatomical knowledge of the mandible particularly at the implant site is crucial to perform dental implant procedures to avoid complications such as numbness, tingling, complete loss of sensation, functional impairment, neuropathic pain, and haemorrhage due to injury to the inferior alveolar neurovascular bundle (Bano et al., 2021; Kim, 2011). This neurovascular bundle travels within the mandibular canal (MC) after it enters the mandible via the mandibular foramen.

Precise location of the MC needs to be determined prior to dental implant placement. Radiographic investigations are needed to locate the MC accurately. The radiographic technique has to be precise enough to show anatomical features in detail, as well as details regarding diseases

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or other abnormalities (Fiorellini et al., 2021).

Computed tomography (CT) has been suggested by the American Academy of Oral and Maxillofacial Radiology (AAOMR) for assessing implant sites which provided detailed information of structures in all three dimensions (3D) (Elnadoury et al., 2022; Reddy et al., 1994; Shekhar et al., 2023; Tomomi et al., 2004; Yu et al., 2016). While CT scans provide valuable diagnostic information, their radiation dose are rather high which pose potential risk to the patients.

Cone beam computed tomography (CBCT) is a specialised form of radiography that is well-suited for dental and maxillofacial imaging. CBCT provides high-resolution 3D images of the oral and maxillofacial structures, allowing detailed visualisation of at a lower radiation dose compared to traditional CT. Advantages of CBCT in dental implant treatment planning have been established in prior studies, including ease of linear measurements, 3D assessment of alveolar ridge topography, representation of crucial anatomical features, and surgical guide development (Benavides et al., 2012; Nagy et al., 2023).

The present investigation aims to compare the differences of MC location in the mandible between the dentate and edentulous ridges, in the region of the mandibular second premolar as well as the first, second, and third molar regions using CBCT of two Iraqi populations i.e., the Arabs and the Kurds.

2. Materials and methods

2.1. Study population

CBCT image of subjects from the Arabic and Kurdish Iraqi populations were analysed. Images were acquired from radiological archive of two private facilities i.e., GAMA clinics, Baghdad and FOTON Maxillofacial Imaging Centre, Sulaymaniyah. The period of study was from September 2021 to September 2022. Following sample size calculation, 400 subjects comprising 200 Arabs and 200 Kurds were chosen. This research was approved by the Jawatankuasa Etika Penyelidikan Manusia (JEPeM-USM) with the protocol code of USM/JEPeM/21110743.

2.2. Inclusion and exclusion criteria

The inclusion criteria were subjects between 20 and 50 years old, fully dentate and partially dentate in the posterior part of mandibular arch, visible cortication of the MC, and complete view of the mandible. The exclusion criteria were subjects with existing pathological disorder of the mandible, syndromic patients, patients with congenital disorders that affect the size of the mandible, and CBCT images that were distorted or blurred.

The dentate ridge was characterised by the presence of all teeth in the posterior region of the mandible, whereas the edentulous ridge was identified at a particular area of the mandibular ridge where the tooth was missing.

The images of the subjects were randomly selected utilising a stratified random sampling technique.

2.3. Data collection procedure

The RadiAnt DICOM software (Medixant, Poland) was used for image analyses, enabling the display of data in axial, coronal, and sagittal perspectives as well as in 3D reconstruction. Calibration of the software was already performed to verify the accuracy of the linear values (Tolentino et al., 2018).

3D multiplanar reconstruction option of the software was used for image analyses. Firstly, the tooth root was aligned in axial and sagittal views. Then the coronal view was used to achieve alignment with the most inferior aspect of the apex of tooth root. Images were enlarged to enhance visual clarity and then measurements were taken in the coronal view.

Linear distances to MC were taken at the location of second premolar and all molars (Fig. 1). For the molars, the distal root alignment was used in the measurements whereas for the edentulous ridge, the centre of the residual ridge was used (Fig. 2). Measurements were performed by clicking on the linear measurements option of the software. Then a line was drawn between two reference points for each measurement and the distances were calculated automatically.

The linear distances were:

MC-BC: Distance from the most superior aspect of MC to the most superior aspect of buccal alveolar crest.
MC-LC: Distance from the most superior aspect of MC to the most superior aspect of lingual alveolar crest.
MC-BB: Horizontal distance from the most buccal aspect of MC to buccal aspect of the mandible.
MC-LB: Horizontal distance from the most lingual aspect of MC to lingual aspect of the mandible.
MC-IB: Distance from the most inferior aspect of MC to inferior border of the mandible.
MC-C: Distance from the most superior aspect of MC to the most superior aspect of the residual alveolar crest.

All measurements were carried out based on an earlier study (Kovisto et al., 2011).

2.4. Statistical analysis

Normality test was performed prior to comparing the measurements. Independent *t*-test and Mann-Whitney *U* test were used to compare measurements between dentate and edentulous groups. All statistical analyses were carried out using SPSS v.26 with a significance level of 5%.

2.5. Reliability of the methods

Intra-examiner reliability was performed by measuring 10% (n=40) of images, selected randomly, with a two-week interval between measurements. Inter-examiner reliability was examined using the same 40 images. The examiners were the first author and a specialist in craniofacial imaging. Intraclass correlation coefficients (ICC) was used for

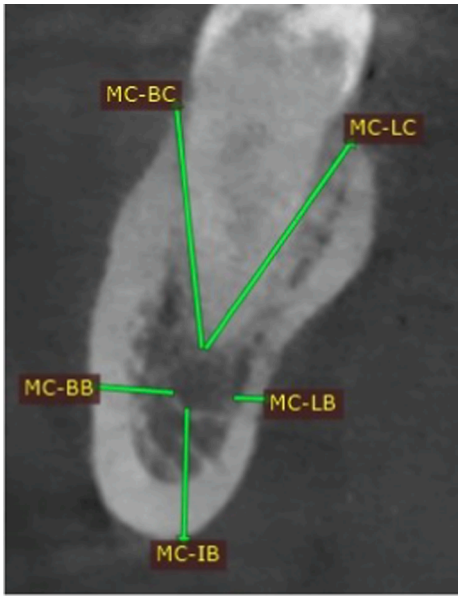

Fig. 1. Cross section of distal root of mandibular first molar showing the position of MC and all measurements.

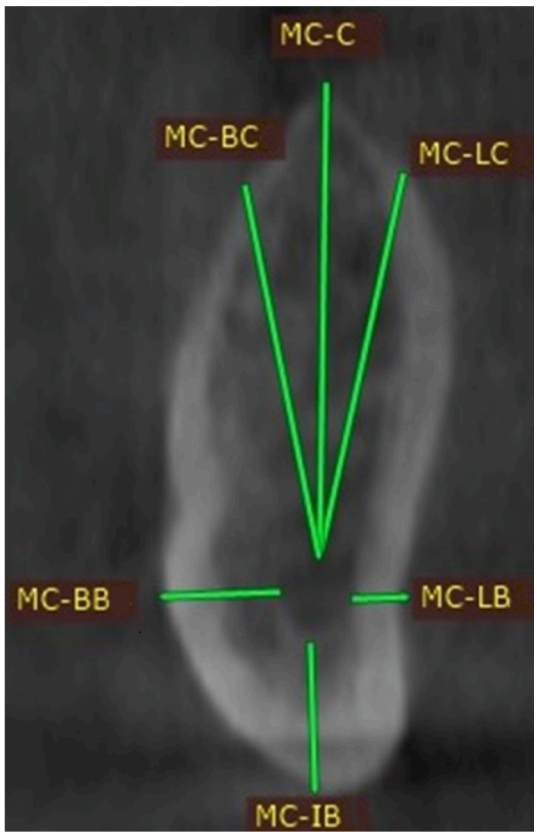

Fig. 2. Cross section of residual ridge of mandibular second molar showing the position of MC and all measurements.

comparisons. Results revealed strong agreement for both intra- and inter-examiner reliability with ICC values of 0.80 to 0.84 and 0.80 to 0.82 respectively.

3. Results

Dentate regions of all teeth showed higher MC-BC and MC-LC measurements than the corresponding edentulous regions in both Arabs and Kurds populations. MC-BC and MC-LC measurements of dentate ridge were higher in the second premolar and first molar regions in both populations. These measurements were almost similar in the edentulous ridge of all teeth regions.

Edentulous residual ridge of all teeth exhibited higher MC-LB and MC-IB measurements than the corresponding dentate regions in both Arabs and Kurds populations except for the third molar region. MC-BB measurements displayed fluctuations of dentate and edentulous regions having higher or smaller values. MC-BB distances in the second premolar and third molar regions tended to be shorter than the first and second molar regions for both dentate and edentulous ridges in both populations. On the contrary, MC-LB distances in the second premolar region is longer than all molar regions. MC-BB distances tended to be higher than MC-LB distances in all molar regions for both dentate and edentulous ridges in both populations. MC-IB distances in the second premolar and third molar regions tended to be longer than the first and second molar regions for both dentate and edentulous ridges in both populations (Tables 1 and 2).

MC-C measurements revealed mean values in the range of 13.45 to 15.69 mm in Arabs and 13.96 to 16.37 mm in Kurds (Table 3).

4. Discussion

Iraq has a total population of 40,150,000 people with major ethnic groups of Arabs and Kurds. The Arabs primarily reside in the central and southern regions of Iraq while the Kurds inhabit the northern region. In this study, CBCT images of Iraqi Arabs were collected from the clinic in Baghdad (central region), while those of the Kurdish population were obtained from the facility in Sulaymaniyah (northern region).

Surgical interventions involving posterior aspect of the mandible, such as impacted tooth extraction, implant surgery, orthognathic procedures, and fracture treatment, necessitate the use of appropriate radiological techniques for thorough pre-operative assessment. CBCT provides high-resolution 3D images of the oral and maxillofacial structures allowing image analyses in three different directions as well as 3D reconstruction at a lower radiation compared to conventional CTs.

Evaluation of the bony space of the mandibular residual alveolar ridge is important prior to placement of dental implants particularly to avoid injury to the inferior alveolar neurovascular bundle and to ensure the long-term stability of the implant. This neurovascular bundle passes within the MC in the mandible extending from the mandibular foramen until the mental foramen. The MC is a significant anatomical landmark that poses challenges in implant therapy due to the potential risk of being harmed (Nimigean et al., 2018b).

Following tooth loss, some degree of bone resorption commonly occurs in the surrounding alveolar bone, leading to changes in the jaw structure over time. This condition is observed in this study where the distances from MC to the buccal and lingual alveolar crests (MC-BC, MC-LC) were consistently lower in the edentulous ridge compared to the dentate ridge across all teeth regions under investigation for both Arabs and Kurds. A few studies reported similar findings (Bressan et al., 2017a, 2017b; Park, 1999). Differences in MC-BC and MC-LC measurements of dentate ridge in different teeth regions were also diminished when the teeth were lost which were demonstrated by almost similar measurements of the edentulous ridge of all teeth regions.

Komal et al. (2020) stated that the buccolingual location of MC within the mandible is an essential parameter that needs to be evaluated before surgical procedures. In the present study, distances from MC to the buccal aspect of the mandible (MC-BB) demonstrated elevated values in the edentulous ridge compared to the dentate ridge, particularly in the second and third molar regions for both Arabs and Kurds. In contrast, this distance was greater in the dentate ridge for the second premolar and first molar regions, although the differences in measurements were small, albeit statistically significant. The distance from MC to lingual aspect of the mandible (MC-LB) was consistently higher in edentulous ridge compared to dentate ridge across all teeth regions for both Arabs and Kurds with differences of only about 1 mm.

This observation may indicate that the location of MC is stable in buccolingual direction regardless of tooth loss. Previous studies reported that distances between MC and the buccal and lingual borders were unaffected by tooth loss (Nimigean et al., 2018a; Ulm et al., 1993; Kavarthapu & Thamaraiselvan, 2018; Saeed et al., 2022). This phenomenon may be attributed to either the buccolingual aspect of MC was less affected by bone resorption as it is located below the socket of missing tooth or increased bone deposition in the edentulous region (Kavarthapu & Thamaraiselvan, 2018).

Horizontally, MC was identified to be closer to the buccal surface of the mandible in the second premolar and third molar regions for both dentate and edentulous ridges of Arabs and Kurds. Conversely, MC was located closer to the lingual surface of the mandible of all molar regions than the second premolar region for both dentate and edentulous ridges of both populations. MC was also revealed to be closer to the lingual surface than to the buccal surface of all molars presented by MC-BB distances having higher values than MC-LB. Hwang et al. (2005) reported that the MC was closer to the lingual surface in the posterior two-third of the mandible but closer to the buccal surface in the anterior one-third of the mandible.

The distances between MC and inferior border of the mandible (MC-IB) were higher in edentulous ridge compared to dentate ridge apart from third molar region of the Arabs. Similar findings were found in a

Table 1
Comparison of the dentate and edentulous mandibular ridge in Arab population.

		Second premolar area				First molar area			Second molar area			Third molar area		
	Ridge	N	IQR	Median (mm)	Z (*p*)	N	Mean (mm) ± SD	*t*-test (*p*)	N	Mean (mm) ± SD	*t*-test (*p*)	N	Mean (mm) ± SD	*t*-test (*p*)
Right MC-BC	Dentate	69	6.15	18.10	528.50 (<0.001) **	94	17.54 ± 3.605	6.213 (<0.001) **	131	14.90 ± 3.004	4.901 (<0.001) **	90	14.98 ± 2.923	4.092 (<0.001) **
	Edentulous	33	4.40	11.90		106	14.27 ± 3.781		69	12.78 ± 2.703		110	13.33 ± 2.794	
Right MC-LC	Dentate	69	3.95	18.80	457.50 (<0.001) **	94	19.472.964	8.680 (<0.001) **	131	17.49 ± 2.633	8.002 (<0.001) **	90	16.59 ± 3.513	4.041 (<0.001) **
	Edentulous	33	4.13	15.90		106	15.70 ± 3.143		69	14.35 ± 2.664		110	14.87 ± 2.512	
Right MC-BB	Dentate	69	1.40	3.96	846.50 (0.037) *	94	5.28 ± 1.272	1.525 (0.129) *	131	5.50 ± 1.493	-0.536 (0.593) **	90	3.85 ± 1.216	−3.437 (0.001) **
	Edentulous	33	1.39	3.330		106	5.01 ± 1.185		69	5.61 ± 1.262		110	4.49 ± 1.407	
Right MC-LB	Dentate	69	1.76	3.05	1557.00 (0.003) *	94	1.97 ± 0.926	−6.034 (<0.001) **	131	2.00 ± 0.922	−4.921 (<0.001) **	90	2.02 ± 1.088	−1.421 (0.157) *
	Edentulous	33	1.23	4.35		106	2.97 ± 1.353		69	2.83 ± 1.466		110	2.25 ± 1.184	
Right MC-IB	Dentate	69	2.40	7.64	1667.00 (<0.001) **	94	6.58 ± 1.892	−4.315 (<0.001) **	131	7.36 ± 2.324	−1.723 (0.086) **	90	9.89 ± 2.903	1.257 (0.210)
	Edentulous	33	2.86	9.25		106	7.70 ± 1.761		69	7.92 ± 1.833		110	9.40 ± 2.572	
Left MC-BC	Dentate	78	6.15	17.55	573.50 (<0.001) **	83	17.51 ± 3.453	8.457 (<0.001) **	119.	14.78 ± 3.345	6.410 (<0.001) **	103	15.00 ± 3.405	3.417 (0.001) *
	Edentulous	32	6.55	14.05		117	13.35 ± 3.425		81	11.91 ± 2.607		97	13.56 ± 2.497	
Left MC-LC	Dentate	78	3.95	18.90	562.0 (<0.001) **	83	19.05 ± 3.016	8.034 (<0.001) **	119	17.19 ± 3.446	7.264 (<0.001) **	103	15.30 ± 2.695	0.737 (0.462)
	Edentulous	32	1.13	15.60		117	15.41 ± 3.254		81	13.79 ± 2.855		97	15.01 ± 2. 794	
Left MC-BB	Dentate	78	1.4	3.32	1530.50 (0.063) \	83	5.50 ± 1.213	3.594 (<0.001) **	119	5.29 ± 1.364	−1.318 (0.189)	103	3.72 ± 1.497	−2.569 (0.011) **
	Edentulous	32	1.52	3.86		117	4.73 ± 1.652		81	5.57 ± 1.514		97	4.24 ± 1.383	
Left MC-LB	Dentate	78	1.76	3.13	1783.0 (<0.001) **	83	2.06 ± 0.996	−5.080 (<0.001) **	119	2.00 ± 0.913	−4.444 (<0.001) **	103	1.79 ± 0.986	−3.000 (0.003) *
	Edentulous	32	4.30	4.10		117	2.81 ± 1.1075		81	2.60 ± 0.956		97	2.21 ± 1.057	
Left MC-IB	Dentate	78	2.4	8.05	1695.0 (<0.001) **	83	6.96 ± 1.624	−3.762 (<0.001) **	119	7.81 ± 2.903	−1.295 (0.197)	103	11.05 ± 3.488	2.828 (0.005) *
	Edentulous	32	2.27	9.39		117	7.97 ± 2.033		81	8.32 ± 2.377		97	9.81 ± 2. 2.705	

*Significant at $p < 0.05$ **Significant at $p < 0.001$ Independent *t*-test, Mann-Whitney *U* test.

few studies (Park, 1999; Saeed et al., 2022). They suggested that increased in bone deposition inferior to the MC as a potential reason.

The distances from MC to the residual alveolar crest (MC-C) have values in the range of 13.45 to 15.69 mm in Arabs and 13.96 to 16.37 mm in Kurds. These distances were higher than the MC-IB measurements suggesting the MC is located more inferiorly within the mandible. Kieser et al. (2005) also reported the position of MC in the inferior region of the mandible. On the other hand, contrasting results were presented in which MC was in the superior part of the mandibular body's edentulous ridge (Kieser et al., 2005; Nimigean et al., 2018a). This disparity can be attributed to racial differences or the inclusion of significantly resorbed mandibles in their study.

After placement, dental implants have higher stability with increased bone density and increased bone-to-implant contact. Increased bone-to-implant contact is achieved by using longer and wider implants. The most common dental implant lengths are between 8 mm and 15 mm, which resemble the natural root lengths and the diameter of about 3.5 mm (Bedrossian, 2020). The available space for placing dental implants in the edentulous ridges in this study is sufficient to accommodate the implants without the risk of injuring the MC and the neurovascular bundle within it.

The current study encountered several limitations, notably regarding edentulous ridge. There was lack of information regarding the history of tooth extraction and the duration of edentulous ridge as longer duration is associated with increased bone resorption. The reasons of tooth loss were unknown. Extraction due to periodontal disease can lead to more bone resorption. Some medical and medication status such as hyperthyroidism can lead to increased bone density whereas the use of corticosteroids can cause more bone resorption (Komal et al., 2020). Comparisons between populations and sexes were not performed because no information was available regarding the history of tooth loss of the subjects. In this study, the subjects aged between 20 and 50 years. No smaller age grouping was done hence the effect of age was not taken into consideration. Narrower age categories could result in smaller sample sizes for each group.

5. Conclusion

There is a discrepancy in the vertical position of the MC between the dentate and edentulous ridges within the Arab and Kurd populations which were evidenced by reduction in its distances to the buccal and lingual crests in edentulous ridges. The horizontal position of the MC was unaffected even after tooth loss and revealed to be closer to the lingual surface of all molars. Interestingly, there were little increases of alveolar bone thickness in the buccolingual and inferior aspect of MC in edentulous ridge. The residual alveolar ridge was sufficient to accommodate the common length and width of dental implants. These anatomical findings and variations of MC locations in relation to

Table 2
Comparison of the dentate and edentulous mandibular ridge in Kurd population.

			Second premolar area			First molar area			Second molar area			Third molar araea		
	Ridge	N	IQR	Median (mm)	Z (*p*)	N	Mean ± SD (mm)	*t*-test (*p*)	N	Mean ± SD (mm)	*t*-test (*p*)	N	Mean ± SD (mm)	*t*-test (*p*)
Right MC-BC	Dentate	111	4.00	17.90	1260.00 (<0.001) **	97	17.26 ± 2.895	4.750 (<0.001) **	125	15.06 ± 2.434	5.144 (<0.001) **	104	15.75 ± 3.486	2.640 (0.020)*
	Edentulous	53	7.36	13.50		103	14.92 ± 3.954		75	13.15 ± 2.454		96	14.52 ± 3.024	
Right MC-LC	Dentate	111	3.76	18.50	1038.00 (<0.001) **	97	18.19 ± 2.774	5.431 (<0.001) **	125	16.71 ± 2.534	6.370 (<0.001) **	104	16.10 ± 2.827	3.284 (0.0002)*
	Edentulous	53	7.46	14.59		103	15.66 ± 3.734		75	14.23 ± 2.897		96	14.78 ± 2.844	
Right MC-BB	Dentate	111	1.47	3.27	2620.00 (0.259)	97	5.06 ± 1.233	2.416 (0.017)*	125	4.81 ± 1.365	−3.938 (<0.001) **	104	3.74 ± 1.654	−3.135 (<0.001) **
	Edentulous	53	1.15	3.21		103	4.65 ± 1.194		75	5.58 ± 1.314		96	4.40 ± 1.355	
Right MC-LB	Dentate	111	1.97	2.85	3885.50 (0.001)*	97	1.91 ± 0.735	−7.009 (<0.001) **	125	2.15 ± 0.873	−4.561 (<0.001) **	104	1.99 ± 0.696	−3.135 (0.006)*
	Edentulous	53	3.08	4.03		103	2.80 ± 1.048		75	2.85 ± 1.297		96	2.55 ± 1.384	
Right MC-IB	Dentate	111	2.85	6.71	4406.50 (<0.001) **	97	5.36 ± 1.488	−8.508 (<0.001) **	125	5.59 ± 1.604	−8.056 (<0.001) **	104	8.35 ± 2.777	0.023 (0.888)
	Edentulous	53	3.34	8.72		103	7.42 ± 1.906		75	7.68 ± 2.027		96	8.34 ± 2.633	
Left MC-BC	Dentate	105	3.55	17.80	935.00 (<0.001) **	94	17.24 ± 2.894	7.310 (<0.001) **	121	15.24 ± 2.514	6.541 (<0.001) **	105	15.58 ± 3.163	2.120 (0.003)*
	Edentulous	48	4.54	13.97		105	13.93 ± 3.445		79	12.88 ± 2.456		95	14.28 ± 2.975	
Left MC-LC	Dentate	105	2.95	18.00	1204.00 (<0.001) **	94	18.18 ± 2.614	7.888 (<0.001) **	121	16.69 ± 2.552	6.345 (<0.001) **	105	15.10 ± 3.446	2.979 (0.035)*
	Edentulous	48	4.46	15.90		105	14.77 ± 3.383		79	14.37 ± 2.504		95	14.18 ± 2.583	
Left MC-BB	Dentate	105	5.70	3.65	1955.00 (0.026)*	94	5.37 ± 1.322	4.927 (<0.001) **	121	5.03 ± 1.296	−5.444 (<0.001) **	105	3.58 ± 1.157	−4.032 (<0.001) **
	Edentulous	48	1.20	3.06		105	4.53 ± 1.096		79	6.05 ± 1.313		95	4.34 ± 1.502	
Left MC-LB	Dentate	105	2.10	3.35	3500.00 (<0.001) **	94	2.04 ± 1.047	−4.734 (<0.001) **	121	2.08 ± 0.867	−5.138 (<0.001) **	105	2.06 ± 0.866	−1.853 (0.065)
	Edentulous	48	1.67	4.12		105	2.71 ± 0.954		79	2.71 ± 0.869		95	2.31 ± 1.0043	
Left MC-IB	Dentate	105	2.90	7.26	3977.00 (<0.001) **	94	5.53 ± 1.663	−7.857 (<0.001) **	121	5.78 ± 1.596	−8.695 (<0.001) **	105	8.55 ± 2.722	−1.325 (0.187)
	Edentulous	48	2.69	9.23		105	7.52 ± 1.892		79	8.12 ± 2.224		95	9.02 ± 2.324	

*Significant at $p < 0.05$ **Significant at $p < 0.001$ Independent *t*-test, Mann-Whitney *U* test.

Table 3
Distance from the most superior aspect of MC to the most superior aspect of the residual alveolar crest (MC-C) in Arabic and Kurdish populations.

		Arab			Kurd		
		Mean ± SD (mm)	**Minimum** (mm)	**Maximum** (mm)	**Mean ± SD (mm)**	**Minimum (mm)**	**Maximum (mm)**
Second premolar	**Right**	15.57 ± 3.15	10.00	21.00	15.35 ± 3.17	8.90	21.44
	Left	15.58 ± 2.9	10.00	22.30	15.82 ± 2.58	11.00	20.70
First molar	**Right**	15.69 ± 3.19	8.88	22.80	16.37 ± 3.87	8.94	23.80
	Left	14.96 ± 3.16	10.00	23.80	15.71 ± 3.26	10.00	23.90
Second molar	**Right**	14.18 ± 2.52	8.66	20.30	14.28 ± 2.93	7.99	18.92
	Left	13.45 ± 3.08	7.00	23.30	15.08 ± 2.73	9.00	20.90
Third molar	**Right**	14.27 ± 2.57	9.99	20.90	13.96 ± 2.52	9.00	20.91
	Left	14.48 ± 2.58	9.50	23.50	14.72 ± 2.97	9.56	23.54

posterior teeth, offer some valuable insights into its path within the mandibular body. The findings could play a crucial role in planning surgical interventions of the mandible, helping to prevent complications that might arise due to inadequate preoperative assessments. Additionally, they may be valuable in forensic dentistry, contributing to more effective analyses and identifications.

CRediT authorship contribution statement

Omar Basheer Taha: Conceptualization, Formal analysis, Methodology, Investigation, Supervision, Validation, Writing – original draft. **Mohamad Arif Awang Nawi:** Formal analysis. **Johari Yap Abdullah:** Writing – review & editing, Validation. **Matheel AL-Rawas:** Validation, Writing – review & editing. **Asilah Yusof:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2024.02.016.

References

Bano, A.M., Ganapathy, D., Pandurangan, K.K., 2021. Inferior alveolar nerve injury during implant placement-A review. Ann. Romanian Soc. Cell Biol. 15592–15603. https://doi.org/10.5037/jomr.2011.2101.

Edmond Bedrossian(2020). Do Dental Implant Width and Length Matter?. *Compendiumof Continuity Education in Dentistry,* Volume 41, Issue 7.

Benavides, E., Rios, H.F., Ganz, S.D., An, C.-H., Resnik, R., Reardon, G.T., Feldman, S.J., Mah, J.K., Hatcher, D., Kim, M.-J., 2012. Use of cone beam computed tomography in implant dentistry: the international congress of oral implantologists consensus report. Implant Dent. 21 (2), 78–86. https://doi.org/10.1097/ID.0b013e31824885b5.

Bressan, E., Ferrarese, N., Pramstraller, M., Lops, D., Farina, R., Tomasi, C., 2017a. Ridge dimensions of the edentulous mandible in posterior sextants: an observational study on cone beam computed tomography radiographs. Implant Dent. 26 (1), 66–72. https://doi.org/10.1097/ID.0000000000000489.

Bressan, E., Ferrarese, N., Pramstraller, M., Lops, D., Farina, R., Tomasi, C., 2017b. Ridge dimensions of the edentulous mandible in posterior sextants: an observational study on cone beam computed tomography radiographs. Implant Dent. 26 (1), 66–72. https://doi.org/10.1097/ID.0000000000000489.

del Canto-Díaz, A., de Elío-Oliveros, J., del Canto-Díaz, M., Alobera-Gracia, M.-A., del Canto-Pingarrón, M., Martínez-González, J.-M., 2019. Use of autologous tooth-derived graft material in the post-extraction dental socket. Pilot study. Med. Oral Patol. Oral Cirugia Bucal 24 (1), e53. https://doi.org/10.4317/medoral.22536.

Elnadoury, E.A., Gaweesh, Y.-S.-E.-D., Abu El Sadat, S.M., Anwar, S.K., 2022. Prevalence of bifid and trifid mandibular canals with unusual patterns of nerve branching using cone beam computed tomography. Odontology 110, 203–211. https://doi.org/10.1007/s10266-021-00638-9.

Fiorellini, J.P., Sourvanos, D., Sarimento, H., Karimbux, N., Luan, K.W., 2021. Periodontal and implant radiology. Dent. Clin. 65 (3), 447–473. https://doi.org/10.1016/j.cden.2021.02.003.

Hwang, K., Lee, W.J., Song, Y.B., Chung, I.H., 2005. Vulnerability of the inferior alveolar nerve and mental nerve during genioplasty: an anatomic study. J. Craniofac. Surg. 16 (1), 10–14. https://doi.org/10.1097/00001665-200501000-00004.

Jung, R. E., Ioannidis, A., Hämmerle, C. H. F., & Thoma, D. S. (2018). Alveolar ridge preservation in the esthetic zone. *Periodontology 2000*, *77*(1), 165–175. DOI: 10.1111/prd.12209.

Kandavalli, S.R., Wang, Q., Ebrahimi, M., Gode, C., Djavanroodi, F., Attarilar, S., Liu, S., 2021. A brief review on the evolution of metallic dental implants: history, design, and application. Front. Mater. 8, 646383 https://doi.org/10.3389/fmats.2021.646383.

Kavarthapu, A., Thamaraiselvan, M., 2018. Assessing the variation in course and position of inferior alveolar nerve among south Indian population: A cone beam computed tomographic study. Indian J. Dent. Res. 29 (4), 405. https://doi.org/10.4103/ijdr.IJDR_418_17.

Kieser, J., Kieser, D., Hauman, T., 2005. The course and distribution of the inferior alveolar nerve in the edentulous mandible. J. Craniofac. Surg. 16 (1), 6–9. https://doi.org/10.1097/00001665-200501000-00003.

Kim, S.-G., 2011. Clinical complications of dental implants. Implant Dent.— Rapidly Evol. Pract. 2, 467–490. https://doi.org/10.5772/17262.

Komal, A., Bedi, R.S., Wadhwani, P., Aurora, J.K., Chauhan, H., 2020. Study of normal anatomy of mandibular canal and its variations in indian population using CBCT. J. Maxillofac. Oral Surg. 19 (1), 98–105. https://doi.org/10.1007/s12663-019-01224-x.

Kovisto, T., Ahmad, M., Bowles, W.R., 2011. Proximity of the mandibular canal to the tooth apex. J. Endod. 37 (3), 311–315. https://doi.org/10.1016/j.joen.2010.11.030.

Nagy, P., Porzse, V., Nemeth, F., Windisch, P., Palkovics, D., 2023. Presentation of a novel surgical technique in periodontally accelerated osteogenic orthodontics. CBCT assessment of the buccal alveolar dimensional changes: a proof-of-concept report of four cases. Quintessence Int. 54 (5) https://doi.org/10.3290/j.qi.b3857209.

Nimigean, V., Sirbu, V.D., Nimigean, V.R., Bădiţă, D.G., Poll, A., Moraru, S.A., Păun, D.L., 2018a. Morphological assessment of the mandibular canal trajectory in edentate subjects. Rom. J. Morphol. Embryol. 59 (1), 235–242. PMID: 29556634.

Nimigean, V., Sirbu, V.D., Nimigean, V.R., Bădiţă, D.G., Poll, A., Moraru, S.A., Păun, D.L., 2018b. Morphological assessment of the mandibular canal trajectory in edentate subjects. Rom. J. Morphol. Embryol. 59 (1), 235–242. PMID: 29940633.

Park, C.-S., 1999. The remodeling of the posterior edentulous mandible as illustrated by computed tomography. J. Korean Acad. Oral Maxillofac. Radiol. 29 (1), 43–53. https://doi.org/10.5051/jpis.2020.50.1.28.

Reddy, M.S., Mayfield-Donahoo, T., Vanderven, F.J.J., Jeffcoat, M.K., 1994. A comparison of the diagnostic advantages of panoramic radiography and computed tomography scanning for placement of root form dental implants. Clin. Oral Implant Res. 5 (4), 229–238. https://doi.org/10.1034/j.1600-0501.1994.050406.x.

Saeed, T.-A., Alansy, A.-S., Abdu, Z.-A., Almaqtari, O., Yu, Z., 2022. Dentulous versus edentulous mandibles: CBCT-based morphometric assessment of mandibular canal and alveolar bone. J. Clin. Exp. Dent. 14 (12), e986.

Shekhar, S., Subash, P., Krishnadas, A., Pullan, S.G., Veeraraghavan, R., Christabel, A., 2023. Computed tomographic analysis of position of mandibular canal and mandibular foramen in patients with mandibular asymmetry. J. Maxillofac. Oral Surg. 1–8 https://doi.org/10.1007/s12663-023-01973-w.

Tolentino, E., Yamashita, F., De Albuquerque, S., Walewski, L., Iwaki, L., Takeshita, W., Silva, M., 2018. Reliability and accuracy of linear measurements in cone-beam computed tomography using different software programs and voxel sizes. J. Conserv. Dent. 21 (6), 607–612. https://doi.org/10.4103/JCD.JCD_314_18.

Tomomi, H., Tsukasa, S., Kenji, S., Tomohiro, O., 2004. Radiologic measurements of the mandible: a comparison between CT-reformatted and conventional tomographic images. Clin. Oral Implant Res. 15 (2), 226–232. https://doi.org/10.1111/j.1600-0501.2004.00991.x.

Ulm, C. W., Solar, P., Blahout, R., Matejka, M., Watzek, G., & Gruber, H. (1993). Location of the mandibular canal within the atrophic mandible. *British Journal of Oral and Maxillofacial Surgery*, *31*(6), 370–375. Ulm, C. W., Solar, P., Blahout, R., Matejka, M., Watzek, G., & Gruber, H. (1993). Location of the mandibular canal within the atrophic mandible. British Journal of Oral and Maxillofacial Surgery, 31(6), 370–375.

Yu, S.-K., Lee, M.-H., Jeon, Y.H., Chung, Y.Y., Kim, H.-J., 2016. Anatomical configuration of the inferior alveolar neurovascular bundle: a histomorphometric analysis. Surg. Radiol. Anat. 38, 195–201. https://doi.org/10.1007/s00276-015-1540-6.