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Original Article

Cone-Beam Computed Tomography Assessment of Implant-Related Anatomy Landmarks of the Anterior Mandible in a Local Population

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ABSTRACT

Objective: To examine the frequency, morphology, and location of the mandibular lingual foramen (MLF) lateral lingual foramen (LLF), and mandibular incisive canal (MIC) in a Pakistani population using cone-beam CT (CBCT).

Study Design: A descriptive cross-sectional study.

Place and Duration of Study: Department of Prosthodontics, Armed Forces Institute of Dentistry, Rawalpindi, from Sep 2023 to Aug 2024.

Methodology: CBCT images of patients who presented to the Prosthodontics Department and fulfilled the inclusion criteria were enrolled consecutively in the study. NNT viewer software was used to analyze the MLF, LLF and MIC through the images. The analysis involved determining the presence and length of MIC and MLF. Along with this the position and classification of MLF, its distance relative to the alveolar crest and bottom part of mandible were also explored.

Results: MLF was present in 707 subjects, of which the presence of a single medial LF was predominant. 401 patients had lateral lingual foramen observed; 76.31% had a single foramen, 21.45% had two foramina, and 2.24% had three foramina. Mandibular Incisive Canal (MIC) was present on both sides in 68.16% of the patients, while 71.29% of the samples had MIC on the left side.

Conclusion: The results of this study reflect upon the higher frequency of MLF, LF and MIC in the local population of Pakistan.

Keywords: Cone-Beam Computerized Tomography (CBCT), Dental Implants, Lingual Foramen, Mandibular Incisive Canal.

How to Cite This Article: *Sherazi S, Sharif M, Khattak S, Khalid S, Shahbaz M, Parveen W. Cone Beam Computed Tomography Assessment of Implant-Related Anatomy Landmarks of the Anterior Mandible in a Local Population. Pak Armed Forces Med J 2026; 76(Suppl-8): S1239-S1243.*
DOI: https://doi.org/10.51253/pafmj.v76iSUPPL-8.13066

INTRODUCTION

The mandible is the only movable bone of the craniofacial skeleton and consists of multiple networks of canals, foramina, and other intricate structures.[1,2] Different surgical procedures and interventions can put the patient at risk of acute emergencies or long-term disabilities due to the close vicinity of these structures.[3] Presence of lingual foramen (LF) has attracted a lot of attention due to an increased inclination towards implant-based dentistry.[4] The area around the mental foramen is now regarded as a critical zone for implant placement, due to multiple reports of life-threatening hemorrhage cases.[5] This is attributed to the vessel damage of the mandibular lingual canal (MLC) region.[6] Cone beam computed tomography (CBCT) is proven as a high-end technology to analyze complex anatomical features of the MIC, and mandibular lingual foramina (MLF).[7]

A number of population-based studies have pointed to important anatomical differences between these structures, and region-specific data have been emphasized. As an example, Elmasry *et al*. found a 100% frequency of the mandibular lingual canal in an Egyptian subpopulation, with notable variability for location and number, directly affecting surgical risk in implant therapy.[8] Shaikh *et al*.'s local CBCT-based study in Karachi, Pakistan, reported the mental foramen was 67.5% and 68.1% on the right and left side respectively, emphasized the importance of localized data towards ensuring safe implant placement.[9]

In spite of the existing studies, there is still limited research on the frequency and morphology of MLF, LLF, and MIC among the Pakistani population. Correct identification of these structures with CBCT is needed to prevent surgical complications, including hemorrhage or nerve injury, especially in situations like implant placement or other surgical interventions. Hence, the present study was aimed to evaluate the frequency, morphology, and site of these significant anatomical landmarks in a representative local Pakistani population with CBCT.

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Received: 02 Feb 2025; revision received: 17 Sep 2025; accepted: 19 Sep 2025

METHODOLOGY

This cross-sectional descriptive study was conducted in Armed Forces Institute of Dentistry (AFID), Rawalpindi Pakistan from September 2023 to August 2024. The research was conducted after ethical approval by the Ethical Committee of AFID (vide Ref no. 918/Trg dated 13 May 2020). Sample size of 679 subjects was calculated using the OpenEpi Sample Size Calculator, with 83.9%[9] frequency of mandibular incisive canal, 95% confidence level and 3% margin of error. To allow for potential exclusions (poor-quality records/radiographs, incomplete data, or ineligible cases) and to increase precision, we recruited 707 patients in total (4.1% more than required). A non-probability consecutive sampling method was used for patients undergoing CBCT scanning at AFID during the study period. Informed consent was obtained from all participants.

Inclusion Criteria: Images of patients aged between 18 or 65, good quality scans with all the necessary details and complete mandible reproduced in images. Scans of both dentate and partially edentulous patients were included.

Exclusion Criteria: Patients with incomplete record (name, age, and gender); any anatomical deformities in the mandibles, history of trauma or fracture, and pathologic diseases. Images of those patients who had a completely edentulous mandibular region were also excluded from this study.

All the patients were scanned using a Kodak (Carestream) CBCT Imaging Unit (Carestream, USA) with following technical settings; exposure time 3.6 seconds, 110 kVp and 3.05 mA, voxel size 0.3 mm, and 20 cm × 25 cm fields of view (FOV) with a 14-bit grey scale signal. The NNT CBCT viewing software (version 6.0, NNT, USA) was used for analyzing scans.

The anatomical features of medial lingual foramen (MLF) and medial lingual canal (MLC) were carefully identified as radiolucent canals, traversing the middle region of the mandible. This sagittal-view examination was done using the Multi-Planar Reconstruction (MPR) feature of the CBCT software NNT. Proper labelling of the medial lingual foramina and canals in all the images of the patients was done carefully and their description was as follows: if only one foramen was identified, it was labelled F1 foramen; if more than one foramen found in a patient, the superior most was still identified as F1 foramen, the next one was labelled F2 foramen, and the additional foramen were indicated as F3, F4 and so on. Calculations involved determining the length and measuring the distances between the medial lingual foramen (B) to the middle region of the alveolar crest labio-lingually (A) and to lower part of the mandible(C) Figure-1.

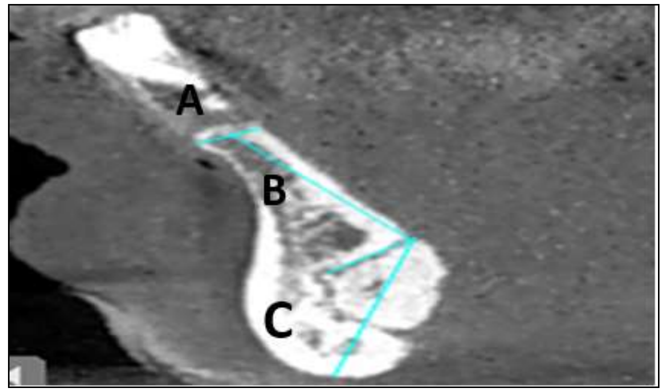

Figure-1: Length and Measurement of Distances Between the Landmarks (n=707)

Foramina were grouped based on their vertical location with reference to the mental spine. The superior-most or the single upper medial lingual foramen was referred to as Z1, the second upper foramen, if present, as Z2, and the third upper foramen, if present, as Z3. The length of the canal (Z1/2/3-C), the distance from the foramen to the alveolar crest (Z1/2/3-A), and from the foramen to the mandibular base (Z1/2/3-B) were measured. The division of foramen location was based on Thompson's classification system, which identified the vertical location of the foramen superior to the genial spine as supraspinous foramen (SF). If located inferior to the genial spine, the foramen was identified as the infraspinous foramen (IFF). Interspinous foramen (ITF) was classified when the foramen was located at a level similar to the genial spine.

On CBCT scans, the proper identification of the lateral lingual foramen (lateral LF) and canal was conducted through the appearance of distinct radiolucent canals with interfering signal. The length and distance measurement of the canals were taken from the mid region of the alveolar crest to the lateral lingual foramen (LF) in a labial-lingual direction, and also from the lateral LF to the bottom region of the mandible. For determining the situated position of the lateral lingual foramen, its relative vertical alignment to specific tooth positions was recorded. A total of nine categories were established based on the position of the foramen: lateral incisor referred to type 1, between the canine and the lateral incisor was type 2, canine was type 3, between the first premolar and canine was type 4, first premolar was type 5, between the first and the second premolars was type 6, second premolar was type 7, between the first molar and second premolar was type 8 and first molar was type 9. The MPR viewing feature of the imaging software allowed the measurement of the mandibular incisive canal's length. A horizontal line drawn along the incisive canal region helped determine the full length of the canal. Measurement was taken from the opening point of the mental foramen up till the radiolucency emanating from the last visible canal.

Data collected were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 25.0. Chi-square test for categorical variable, such as the distribution of MLF types among males and females. Normality of the data was assessed using Shapiro-Wilk test. Independent samples t-test was used to compare size measurements of medial and lateral lingual foramina and length of the mandibular incisive canal. Statistical significance was set at p-value <0.05.

RESULTS

A total of 707 subjects were found eligible for this study and of which 414(58.56%) were males and 293 (41.44%) were females. The subject's mean age was 40.29±13.01 years. All the subjects had Medial lingual foramina (MLF) of which single MLF was found in 524 (74.12%) subjects, two MLF were found in 151 (21.36%) subjects and three MLF were found in 32 (4.53%) subjects. The distribution of three types of Z1 foramina showed a significant difference of p<0.001 among gender. While no significant difference was observed in the three types of Z2 and Z3 foramina distribution between both genders (Table-I). The distance measure of three different classifications of MLF (SFF, ITF and IFF) in both genders is shown in Figure 2. Difference between MLF among genders was greater in Z1A (21.05 mm in males vs 18.63 mm in females), Z2 A (23.82 mm in males vs 22.78 mm in females) and Z3 A (30.72 mm vs 18.36 mm in females). Whereas, females had a greater distance of MLF in Z1B (15.52 mm) compared to (14.75 mm) males and in Z2 C (6.53 mm in females) compared to (5.49 mm) males.

Z1= the first or the only upper MLF, Z2= the second upper MLF, Z3=the third upper MLF, SF= supraspinous foramen, IFF= infraspinous foramen and ITF interspinous foramen.

Table-I: Classification of Different Medial Lingual Foramina (MLF) In Both Genders (n=707)

Gender	Medial Lingual Foramina Classification						
	Z1 (n = 524)			Z2 (n = 151)		Z3 (n = 32)	
	SF	ITF	IFF	SF+ITF	IFF	SF+ITF	IFF
Male n (%)	235 (64.56%)	47 (44.00%)	12 (36.72%)	23 (67.65%)	72 (61.54%)	5 (71.43)	20 (80.00%)
Female n (%)	129 (35.44%)	81 (63.28%)	20 (62.50%)	11 (32.35%)	45 (38.46%)	2 (28.57%)	5 (20.00%)
p-value	<0.001			0.579		0.970	

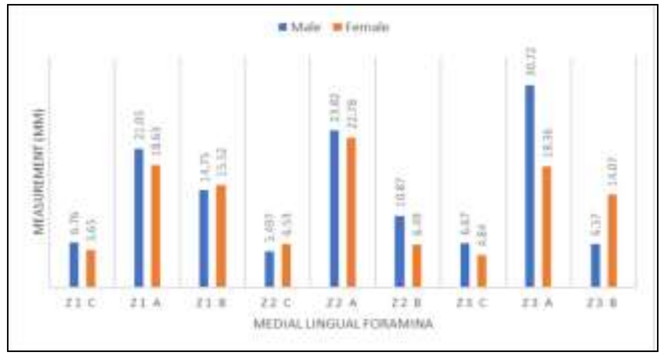

Figure-2: Measurement Distribution (mm) of Three Types of MLF Across Gender (n=707)

Lateral lingual foramina were observed in 401 subjects and of which 306(76.31%) had single foramen, 86(21.45%) had two foramina and 9 (2.24%) had three foramina. Significant difference was observed in the RL-A, LL-A and LL-B in both genders (p<0.001, p<0.001 and p=0.014 respectively). 68.16% (482) subjects had Mandibular Incisive Canal (MIC) on both sides. MIC on the left side was found in 71.29% (504) subjects with an average length of 8.36±0.68 in males and 8.21±0.70 in females and on the right side was found in 70.58% (499) subjects with an average length of 8.64±0.83 in males and 7.92±0.58 in females. No significant difference was observed in the distance of the incisive canal in both genders (Table-II).

Table-II: Length (mm) of Various Lateral Lingual Foramina and Incisive Canal in Both Genders (n=707)

Measure of Distance	Gender		p-value
	Male (n=414)	Female n=293	
RL-A (Mean±SD)	22.73±0.90	22.23±0.58	<0.001
RL-B (Mean±SD)	8.13±0.69	7.89±1.28	0.314
RL-D(Mean±SD)	8.32±0.65	8.04±1.20	0.094
LL-A(Mean±SD)	25.53±14.85	23.05±0.60	<0.001
LL-B(Mean±SD)	9.95±0.5	9.67±0.71	0.014
LL-D(Mean±SD)	6.45 ± 0.65	6.33 ± 0.91	0.542
LIC(Mean±SD)	8.36 ± 0.68	8.30 ± 0.70	0.368
RIC (Mean±SD)	8.64 ± 0.83	8.61 ± 0.58	0.659

DISCUSSION

A single medial LF was the most common type of MLF, which was found in 707 patients. A lateral lingual foramen was seen in 401 patients; 76.31% of them had one foramen, 21.45% had two and 2.24% had three. 71.29% of the samples had a mandibular incisive canal (MIC) on the left side, whereas 68.16% of the individuals had MIC on both sides.

The existence of one or more MLFs was verified in all the subjects, where a single foramen was found in 74.12%, two foramina in 21.36%, and three in 4.53%. These results concur with those obtained by Yildirim *et al.,* where the most common subjects had mono-lingual canal arrangements, with 76.8% presenting a solitary canal, further reflecting the frequency of a single MLF among various populations.[10] In the present research, the frequency of medial lingual foramen (MLF) contrasts significantly from the findings of Assari *et al*., who found a 100% incidence of MLF, though just 23.1% of the cases had a single foramen, while most exhibited multiple foramina: 38.8% with two foramina, 26.9% with three, and a lesser number with four or five foramina.[11] Also, the present study revealed a statistically significant gender difference in the distribution of Z1 foramina suggesting sexual dimorphism of this area. In contrast, Assari *et al*.[11] found no difference in the pattern of MLF distribution between women and men (χ^2=1.958, p=0.754). Once more, this difference could be explained by population-specific anatomical variability.

In the current research, the mandibular incisive canal (MIC) was found to be present bilaterally in the majority of the subjects with a higher frequency on the left side compared to the right side. These observations suggest that the MIC is a fairly uniform anatomical structure in our population. Notably, the rate found here is significantly greater than that of Ayesha *et al*., who recorded a 43.9% rate of MIC in their CBCT study.[12] Since both studies used the same imaging method, the discrepancies could have arisen due to heterogeneity of the populations under study, variation in sample size, and possible inconsistencies in the radiographic features employed to diagnose the MIC. Our greater detection rate implies that if CBCT scans are assessed using strict anatomical landmarks and standardized imaging protocols, the MIC can be seen more often than in the past. Clinically, it emphasizes the necessity for dental surgeons to anticipate the existence of the MIC routinely in procedures in the interforaminal area to reduce the risk of neurovascular complications. Clinical significance of the presence of LLF is to reduce complications like bleeding during implant placement in the lateral aspects of the mandible. CBCT continues to be the modality of choice for precise localization of such structures, as evidenced by Peer *et al*.[13]

The findings of the current study are in part consistent with those of Martins *et al*., who found a MIC frequency of more than 76% in various anatomic regions evaluated by CBCT. In addition, Martins *et al*. provided a continuous decrease in MIC diameter from 1.29 mm to 0.86 mm, and a downward inclination of the canal from the lingual cortical bone surface, emphasizing the three-dimensional nature of MIC morphology.[14] The findings of Zhang *et al*., using a large sample size of 1,070 hemimandibles, indicated a much greater MIC frequency of 92.8%. Their research also showed no significant variation in MIC frequency between right and left sides, similar to the present study's results. Regarding MIC morphology, Zhang *et al.,* had a mean length of 13.4 ± 3.3 mm,[15] significantly greater than the mean lengths in the sample population (about 8–9 mm) of the current study. Baghele *et al*., also described a high incidence of MLF in their study based on CBCT, with 154 medial lingual foramina (MLF) identified in 100 subjects, or 89.5% of all identified foramina being medial.[16]

In the case of lateral lingual foramina (LLF), Baghele *et al*., presented 18 LLFs, which represented 10.4% of total foramina, and the majority (94.44%) being between the region of canine and first premolar. A comparison with the current study showed LLF in 56.7% of the subjects and variable occurrence of single, double, or triple foramina. This significant variation in LLF frequency could be due to population-specific anatomical dissimilarities or varying detection levels during image interpretation. Notably, our MIC observations are consistent with those of Moorpani et al., where 66.9% of mandibular lateral incisors were seen, each with a single canal, whereas 33.1% presented with two canals.[17] In additional support of the anatomical variation of the anterior mandible among the Pakistani population, Motiwala *et al*., determined that the mental foramen (MF) was the most frequently found along the long axis of the second premolars bilaterally (52.1% right, 51% left), followed by between the first and second premolars.[18] They also described a low incidence of anterior loops (3.2% right, 5.2% left), highlighting the importance of adequate radiographic evaluation during implant placement in this area.

LIMITATIONS OF STUDY

The interobserver variability in the interpretation of CBCT images could be associated with a few inconsistencies in measurements as a part of the study's limitation. Along with this, while CBCT provides a comprehensive 3D insight, anatomical measurements can be impacted due to image resolution and patient movement.

CONCLUSION

This research highlights a high frequency of medial lingual foramen, lateral lingual foramen, and mandibular incisive canal in the Pakistani population with significant anatomical differences from other populations. These results underline the necessity of proper CBCT evaluation to guarantee safe implant placement and surgical planning in the anterior mandible.

ACKNOWLEDGEMENT

The study was accomplished due to the resources present within AFID, Pakistan.

Conflict of Interest: None.

Discolure:

Funding Source: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

SS & MS: Data acquisition, data analysis, critical review, approval of the final version to be published.

SK & SK: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

MS & WP: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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