

Does the morphology of the mandibular lingula affect the location of the mandibular foramen?

Atapol Yongvikul

Bangkokthonburi University

Manop Khanijou

manak427@gmail.com

Bangkokthonburi University

Nattharin Wongsirichat

Bangkokthonburi University

Thongnard Kumchai

Bangkokthonburi University

Natthamet Wongsirichat

Bangkokthonburi University

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Abstract

Background

Accurate localization of the mandibular foramen (MF) is essential for successful inferior alveolar nerve block and for minimizing complications during mandibular surgical procedures. The mandibular lingula (ML), a bony projection partially overlying the MF, is commonly used as an anatomical landmark; however, its morphology exhibits considerable variation. The extent to which ML morphology influences MF localization remains unclear. This study aimed to evaluate the relationship between ML morphology and the spatial position of the MF using cone-beam computed tomography (CBCT).

Materials and Methods

This retrospective CBCT-based study analyzed 288 scans (144 males, 144 females; mean age 51.0 ± 19.4 years) acquired between March 2023 and March 2025. ML morphology was classified into truncated, nodular, assimilated, and other types. Vertical and horizontal relationships between the ML, MF, mandibular borders, and oblique ridges were measured using multiplanar reconstruction. MF dimensions and the presence of accessory mandibular canals were also assessed. Inter- and intra-examiner reliability were evaluated. Statistical analysis included one-way ANOVA and independent t-tests, with significance set at $P < 0.05$.

Results

The nodular ML was the most prevalent morphology (60.76%). ML type did not significantly influence the vertical position or dimensions of the MF ($P > 0.05$). However, significant differences were observed in horizontal localization, particularly relative to the internal oblique ridge, with the assimilated ML type demonstrating a more posteriorly positioned MF ($P < 0.05$). Accessory mandibular canals, present in 5.56% of cases, were associated with significantly reduced horizontal distances to the MF.

Conclusion

While ML morphology does not affect the vertical position of the MF, it significantly influences its horizontal localization. Assimilated lingula types and accessory mandibular canals may compromise the reliability of conventional landmarks, underscoring the value of CBCT-based individualized assessment for optimizing anesthetic and surgical outcomes.

Introduction

Local anesthesia of the inferior alveolar nerve is one of the most frequently performed procedures in dental practice, and its success obviously depends on accurate localization of the mandibular foramen(MF).[1, 2] Failure to achieve effective anesthesia remains a common clinical problem, often attributed to anatomical variations of the mandibular ramus. Among these variations, differences in the morphology and position of the mandibular lingula may play a significant role in influencing anesthetic outcomes. [3, 4] The mandibular lingula(ML) is a bony projection located on the medial surface of the mandibular ramus and partially overlies the mandibular foramen,

making it an important surrogate landmark for identifying the foramen's position. Both the ML and MF are closely related to the inferior alveolar neurovascular bundle and serve as essential reference points in various oral and maxillofacial procedures. [5] In addition to their importance in inferior alveolar nerve block administration, these structures are critical for safe execution of mandibular surgeries such as sagittal split ramus osteotomy, vertical ramus osteotomy, and management of mandibular trauma. [4, 5]

Earlier anatomical investigations of the ML and MF relied predominantly on measurements obtained from dry mandibles. [6] Although valuable, these studies are limited by the absence of soft tissues, potential postmortem distortion, and restricted demographic information, which reduce their direct clinical applicability. Advances in cone-beam computed tomography (CBCT) have enabled accurate three-dimensional assessment of mandibular anatomy in living individuals, allowing more precise evaluation of morphological variations and spatial relationships. [7]

Recent imaging-based observations have demonstrated considerable interindividual variation in the morphology of the ML and the position of the MF. Such variability may influence the reliability of traditional anatomical landmarks used during inferior alveolar nerve block administration. [5, 8] However, the extent to which ML morphology affects the location of the MF remains insufficiently clarified. Therefore, the present study aims to investigate whether the morphology of the ML affects the location of the MF using CBCT. Improved understanding of this relationship may enhance the accuracy of inferior alveolar nerve block techniques and contribute to safer and more predictable outcomes in mandibular surgical procedures.

Materials and Method

This retrospective study analyzed CBCT records obtained at our institution between March 2023 and March 2025. The research protocol was approved by the Human Research Ethics Committee of the Faculty of Health Sciences, Bangkokthomburi University (Approval No. BTU-IRB-44/2568), and was conducted in full accordance with the principles of the Declaration of Helsinki. The inclusion criteria were as follows: (1) participants aged over 18 years; (2) absence of craniofacial syndromes; (3) no history of facial surgery; (4) no history of facial trauma; and (5) CBCT images of sufficient quality for anthropological analysis. Sample selection was limited to scans demonstrating superior image quality and a comprehensive view of the entire mandibular structure to ensure diagnostic accuracy. All radiographic data were captured using a single Orthophos S 3D unit (Dentsply Sirona, Bensheim, Germany) equipped with a Csl Plus technology-integrated flat-panel detector. To maintain technical consistency, a single qualified oral and maxillofacial radiology technician performed all scans, orienting subjects based on the interpupillary midline and the Frankfurt horizontal plane.[9] The acquisition parameters were standardized across the sample, utilizing a tube voltage of 85 kV, a field of view (FOV) of 11 × 10 cm, and a 0.5 mm focal spot size. Specific temporal settings included an exposure time of 14.4 seconds, a scanning duration of 2–5 seconds, and a reconstruction timeframe of 12–14 seconds.

The resulting CBCT datasets were processed and evaluated by two researchers using SIDEXIS 3D and GALILEOS software suites. Initial identification of the ML and MF was conducted through three-dimensional reconstruction and multiplanar reconstruction (MPR) of each hemi-mandible. In three-dimensional reconstruction mode, the morphology of ML was assessed and classified into 4 groups in the Fig. 1 including truncated, nodular, assimilated, and others types.[10] Other linear metrics were digitally recorded in millimeters using the MPR mode. To determine the vertical relationship between landmarks, an ML plane was established at the most prominent tip of the lingula in a tangential view, while an MF plane was defined at the level where the foramen was completely

circumscribed by cortical bone in an axial view. The vertical interval between these two planes was designated as the D-distance. Additionally, a lower border (LB) plane was identified as the final axial slice containing the mandible before its disappearance during inferior scrolling; the distance from the MF plane to this LB plane was defined as the W-distance. (Fig. 2) Morphometric evaluation of the MF comprised measurements of mediolateral width (A distance) and anteroposterior length (B distance) within the MF plane, along with assessment for the presence of an accessory canal.[11] (Fig. 3) Further anatomical variables measured in this plane included the thickness of the mandibular ramus (C-distance), the distance from the posterior MF border to the posterior ramus border (Y-distance), and the distances from the anterior MF border to both the external (X-E) and internal (X-I) oblique ridges.(Fig. 4) Positional indices were subsequently calculated by determining the ratio of the distance from each oblique ridge to the foramen relative to the total length (X-E/Length-E and X-I/Length-I). To ensure the reliability of the data, two independent examiners performed all assessments, with the entire measurement process repeated after a minimum interval of two weeks to evaluate intra- and inter-examiner consistency.

Statistical Analysis

All data were analyzed using Jamovi software (version 2.6; The Jamovi Project, Sydney, Australia). Inter- and intra-rater reliability were evaluated, and the mean of repeated measurements was used for subsequent analyses. Descriptive statistics were calculated for all variables. One-way analysis of variance (ANOVA) was used to evaluate differences among the four types of mandibular lingula. An independent t-test was used to compare measurements between groups with and without an accessory canal. Statistical significance was set at $P < 0.05$.

Result

The retrospective analysis of 288 CBCT datasets revealed a balanced sex distribution of 144 males and 144 females, with a mean cohort age of 51.0 ± 19.4 years. Assessment of ML morphology identified the nodular variant as the most prevalent type (60.76%), followed by the truncated (17.36%), assimilated (15.97%), and other variants (5.91%). Accessory canals were identified in 5.56% of the sample, with a significantly higher frequency observed in male subjects compared to females ($P = 0.01$). The demographic data was showed in the Table 1. Regarding the primary research question, the results indicated that the morphological type of the ML does not exert a significant influence on the vertical localization of the MF. Specifically, no significant differences were observed across D-distance ($P = 0.4$) or the W-distance ($P = 0.7$). Similarly, foramen dimensions, including A-distance ($P = 0.2$) and B-distance ($P = 0.3$), as well as C-distance ($P = 0.2$), remained consistent regardless of lingular shape. (Table 2) In contrast, horizontal positioning relative to internal anatomical landmarks showed significant variation based on lingular morphology. The distance from the anterior border of the X-I varied significantly ($P = 0.02$), with the assimilated type exhibiting the greatest distance (12.64 ± 3.36 mm) and the "others" group showing the shortest (11.03 ± 3.54 mm). This trend was mirrored in the total distance of L-I ($P = 0.004$), where the assimilated group again demonstrated higher mean values (33.54 ± 4.09 mm). (Table 2) Visual analysis of the positional indices indicated that the assimilated variant tended toward a lower mean Ratio-E compared to nodular, truncated, and other variants. (Fig. 5)

Table 1
Demographic characteristics of the study sample according to mandibular lingula morphology and presence of accessory canal

Variables	All	Sex		P-value	Age	P-value
	N(percent)	Male	Female		Means (SD)	
		(N)	(N)			
All	288	144	144	0.9	51.0(19.4)	
Lingula Morphology						
Assimilated	46 (15.97%)	31	15	0.06	51.8(16.9)	0.9
Nodular	175 (60.76%)	80	95		51.0(15.4	
Truncated	50 (17.36%)	23	27		50.1(13.6)	
Others	17 (5.91%)	10	7		50.4(15.0)	
Accessory canal						
With	16 (5.56%)	13	3	0.01	48.7(19.1)	0.5
Without	272 (94.44%)	131	141		51.1(15.2)	
P-values for sex distribution were calculated using the chi-square test.						
P-values for age comparisons were calculated using one-way ANOVA (lingula morphology) and independent t-test (accessory canal).						
Statistical significance was set at P < 0.05.						

Table 2
Comparison of mandibular foramen and lingula morphometric measurements according to mandibular lingula morphology

A	All (n = 288)	Assimilated (n = 46)	Nodular (n = 175)	Truncated (n = 50)	Others (n = 17)	P-value
	2.85(0.47)	2.78(0.54)	2.87(0.45)	2.80(0.45)	3.04(0.51)	0.2
B	4.60(0.92)	4.86(1.13)	4.57(0.86)	4.53(0.91)	4.37(0.93)	0.3
C	9.02(1.46)	8.69(1.31)	8.99(1.45)	9.26(1.55)	9.44(1.65)	0.2
D	9.75(2.03)	10.18(2.21)	9.74(2.02)	9.46(1.92)	9.51(1.51)	0.4
W	22.82(3.35)	23.24(3.52)	22.76(3.37)	22.82(3.35)	22.27(2.68)	0.7
X-I	12.23(2.91)	12.64(3.36)	12.47(2.82)	11.40(2.32)	11.03(3.54)	0.02*
X-E	14.54(2.23)	13.90(2.93)	14.73(2.09)	14.42(1.89)	14.65(2.16)	0.3
Y	16.09(2.45)	16.92(3.04)	15.84(2.28)	16.23(2.38)	15.91(2.16)	0.2
L-I	31.91(3.88)	33.54(4.09)	31.96(3.82)	30.92(3.14)	29.92(4.44)	0.004*
L-E	34.10(3.45)	34.99(4.08)	34.07(3.39)	33.57(2.94)	33.58(3.46)	0.2
Abbreviations: A: mediolateral width of the mandibular foramen, B: anteroposterior length of the mandibular foramen, C: mandibular ramus thickness, D: vertical distance between the mandibular lingula and mandibular foramen, W: vertical distance from the mandibular foramen to the lower border of the mandible, X-I: distance from the anterior border of the mandibular foramen to the internal oblique ridge, X-E: distance from the anterior border of the mandibular foramen to the external oblique ridge, Y: distance from the posterior border of the mandibular foramen to the posterior border of the mandibular ramus, L-I: distance from the internal oblique ridge to the posterior border of the mandibular ramus, L-E: distance from the external oblique ridge to the posterior border of the mandibular ramus						
P-values were calculated using one-way analysis of variance (ANOVA).						
Statistically significant differences are indicated by an asterisk (*P < 0.05).						

The presence of an accessory mandibular canal was also found to be a significant factor in the horizontal localization of the MF. Subjects with an accessory canal displayed significantly shorter X-I ($P = 0.049$) and X-E ($P = 0.004$) compared to those without. Specifically, the mean X-E distance was 12.98 ± 2.41 mm in the presence of an accessory canal, compared to 14.63 ± 2.19 mm in its absence. Furthermore, L-E was significantly reduced in the accessory canal group (32.30 ± 2.24 mm vs. 34.21 ± 3.49 mm, $P = 0.032$). The data was showed in the Table 3.

Table 3
Comparison of mandibular foramen and lingula measurements according to the presence of an accessory mandibular canal

	Accessory canal		P-value
	With (n = 16)	Without (n = 272)	
A	2.80(0.46)	2.85(0.46)	0.7
B	4.69(0.87)	4.59(0.93)	0.7
C	9.04(2.25)	9.02(1.41)	0.9
D	9.71(2.49)	9.75(2.01)	0.9
W	23.87(2.79)	22.7(3.37)	0.2
X-I	10.83(2.87)	12.31(2.90)	0.049*
X-E	12.98(2.41)	14.63(2.19)	0.004*
Y	15.43(2.71)	16.12(2.43)	0.3
L-I	30.64(4.00)	31.99(3.87)	0.2
L-E	32.30(2.24)	34.21(3.49)	0.032*
Abbreviations: A: mediolateral width of the mandibular foramen, B: anteroposterior length of the mandibular foramen, C: mandibular ramus thickness, D: vertical distance between the mandibular lingula and mandibular foramen, W: vertical distance from the mandibular foramen to the lower border of the mandible, X-I: distance from the anterior border of the mandibular foramen to the internal oblique ridge, X-E: distance from the anterior border of the mandibular foramen to the external oblique ridge, Y: distance from the posterior border of the mandibular foramen to the posterior border of the mandibular ramus, L-I: distance from the internal oblique ridge to the posterior border of the mandibular ramus, L-E: distance from the external oblique ridge to the posterior border of the mandibular ramus			
P-values were calculated using independent samples t-tests.			
Statistically significant differences are indicated by an asterisk (*P < 0.05).			

Discussion

The present CBCT-based study was undertaken to determine whether variations in ML morphology influence the spatial location of the MF, with particular relevance to the inferior alveolar nerve block and mandibular surgical procedures. The findings demonstrate that although considerable interindividual variation exists in ML morphology, the vertical position and basic dimensions of the MF are not significantly affected by ML type. Measurements assessing the vertical relationship between the ML and the MF, as well as the height of the MF relative to the inferior mandibular border, remained consistent across all morphological categories. These results suggest that, contrary to common clinical assumptions, ML shape alone may not be a reliable predictor of vertical MF localization during inferior alveolar nerve block administration. However, the present study identified meaningful variation in the horizontal positioning of the MF associated with ML morphology. Specifically, the “assimilated type” exhibited a greater distance between the MF and the internal oblique ridge, indicating a more posteriorly positioned MF relative to this anatomical landmark. This finding has direct clinical implications, as horizontal misjudgment of needle placement is a recognized cause of inferior alveolar nerve block failure. In cases where the ML is assimilated and poorly defined, reliance on conventional surface landmarks may be less

dependable, potentially necessitating modification of injection angulation or the use of alternative anesthetic techniques. These observations revealed the importance of understanding three-dimensional anatomical variability rather than depending solely on prominent bony landmarks when performing procedures involving the mandibular foramen.

Several previous investigations have reported comparable trends regarding the influence of mandibular landmarks on the localization of the MF. Studies conducted in Brazil demonstrated that the MF is positioned, on average, 13.5 mm superior to the occlusal plane (15.5 mm in males and 11.7 mm in females), 14.6 mm inferior to the mandibular notch, and 14.2 mm posterior to the anterior border of the mandibular ramus. [12] Similarly, Vietnamese studies reported that the distance from the mandibular notch to the MF ranged between approximately 25–30 mm, while the distance from the posterior border of the ramus to the MF ranged from 13–17 mm. [13] Collectively, these findings indicate that although CBCT provides highly accurate three-dimensional visualization of the MF, substantial population-specific anatomical variation persists. This variability underscores the importance of utilizing region- or ethnicity-specific reference data when planning mandibular procedures such as inferior alveolar nerve blocks and ramus osteotomies. [13, 14] In addition, studies in the Thai population have demonstrated a correlation between the location of the MF and the gonial angle. One such investigation analyzed 61 dry adult mandibles, the position of the MF was assessed using both vertical and horizontal measurements, with the horizontal distance defined as the distance from the MF to the anterior border of the mandibular ramus. The results revealed that the mean horizontal distance from the MF to the anterior border of the ramus was 18.07 ± 3.07 mm. [15] Our findings corroborate these observations, highlighting that horizontal variability may affect the reliability of conventional anatomical landmarks such as the internal and external oblique ridges during inferior alveolar nerve block. Additionally, the present study demonstrated that the presence of an accessory mandibular canal further modifies horizontal distances, suggesting that both lingular morphology and accessory canals should be considered when planning anesthetic injections or surgical interventions. Collectively, these results emphasize the clinical importance of preoperative imaging and individualized assessment to optimize nerve block efficacy and minimize the risk of inadvertent nerve injury during mandibular procedures.

Despite the strengths of this study, including the use of high-resolution CBCT imaging and standardized measurement protocols, certain limitations should be acknowledged. First, the retrospective design and use of existing CBCT scans may introduce selection bias, as only patients requiring imaging for clinical reasons were included. Second, while CBCT provides excellent spatial resolution, soft tissue structures such as the neurovascular bundle and surrounding musculature were not directly visualized, which may affect clinical translation of landmark relationships during live anesthetic procedures. Third, the sample, although balanced for sex, may not fully represent diverse populations with differing mandibular morphologies and the presence of the accessory canal. Future research should consider prospective studies incorporating larger, multiethnic cohorts to enhance generalizability. Integration of CBCT with three-dimensional modeling or virtual surgical simulations could provide more precise mapping of the mandibular foramen in relation to lingular morphology. Additionally, studies correlating anatomical variations with clinical outcomes of inferior alveolar nerve block or mandibular surgery would strengthen the evidence for personalized anesthetic and surgical planning. Such approaches may ultimately improve procedural success rates and minimize complications related to anatomical variability.

The findings of this CBCT-based study indicate that while ML morphology does not significantly affect the vertical position or dimensions of the MF, it is associated with notable variations in its horizontal localization. Assimilated lingula types and the presence of accessory mandibular canals tend to shift the foramen posteriorly, which may impact the accuracy of inferior alveolar nerve block administration.

Declarations

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Author Contribution

A. Yongvikul and M. Khanijou contributed to the conception, study design, data acquisition, and drafting and critical revision of the manuscript. T. Kumchai and N. Wongsirichat contributed to the conception, study design, and critical revision of the manuscript. N. Wongsirichat and N Wongsirichat also contributed to the conception, study design, and critical revision of the manuscript. All authors approved the final manuscript and agree to be accountable for all aspects of the work.

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Figures

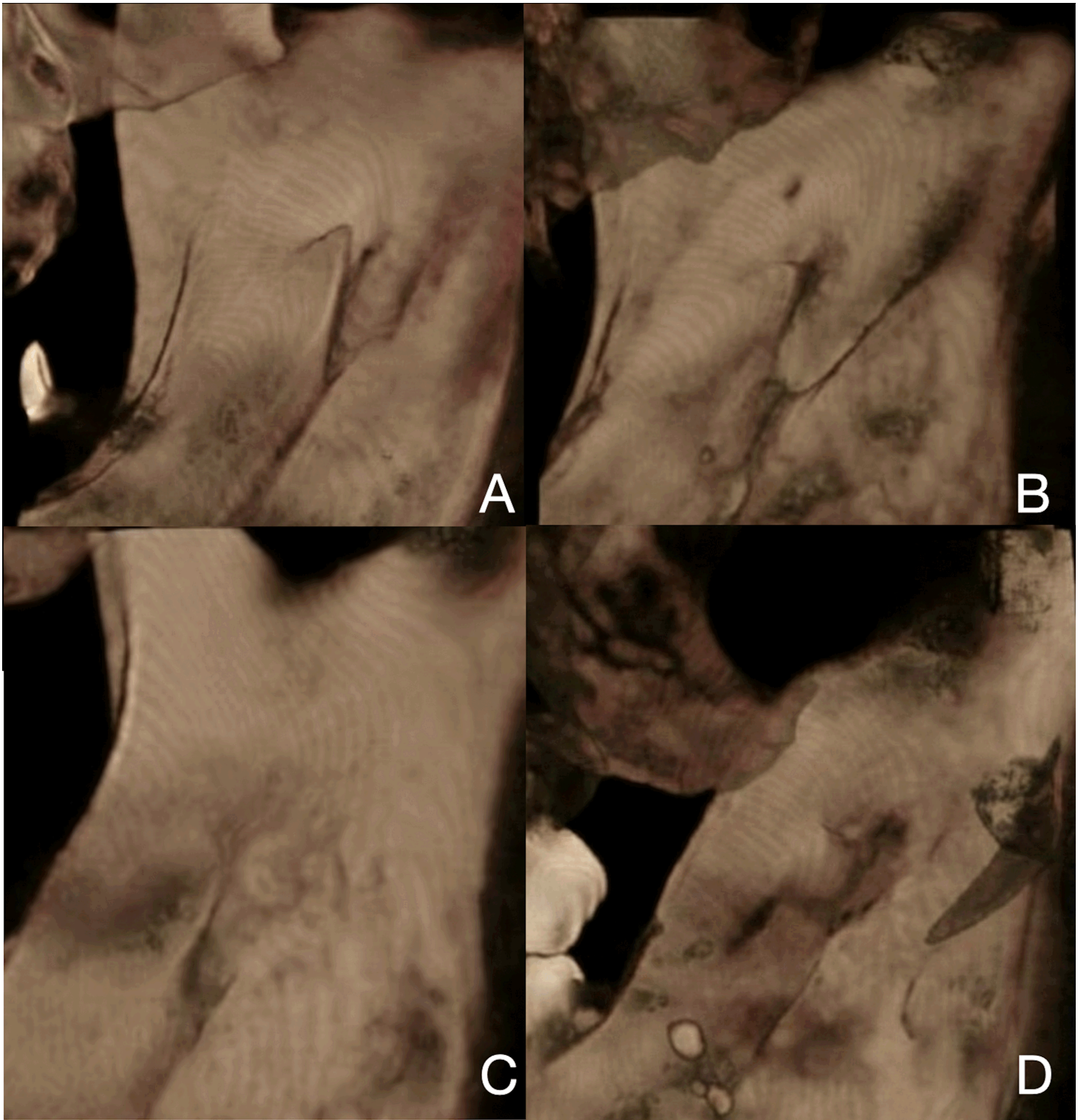


Figure 1

Three-dimensional CBCT reconstruction showing the morphological classification of the mandibular lingula: truncated(A), nodular(B), assimilated(C), and other types(D).

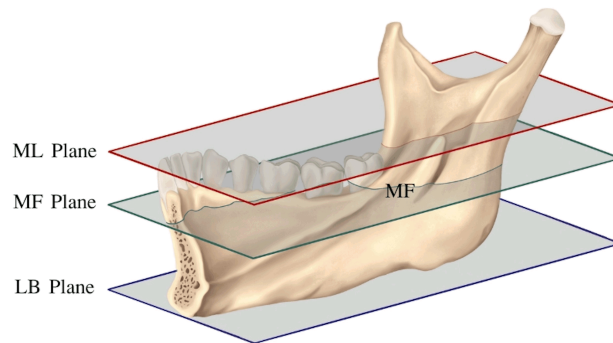


Figure 2

Multiplanar reconstruction (MPR) views illustrating the measurement of vertical distances. The ML plane is defined at the most prominent tip of the mandibular lingula, the MF plane at the level where the mandibular foramen is completely surrounded by cortical bone, and the lower border (LB) plane at the inferior limit of the mandible. The vertical distance between the ML and MF planes represents the D-distance, and the distance between the MF and LB planes represents the W-distance.

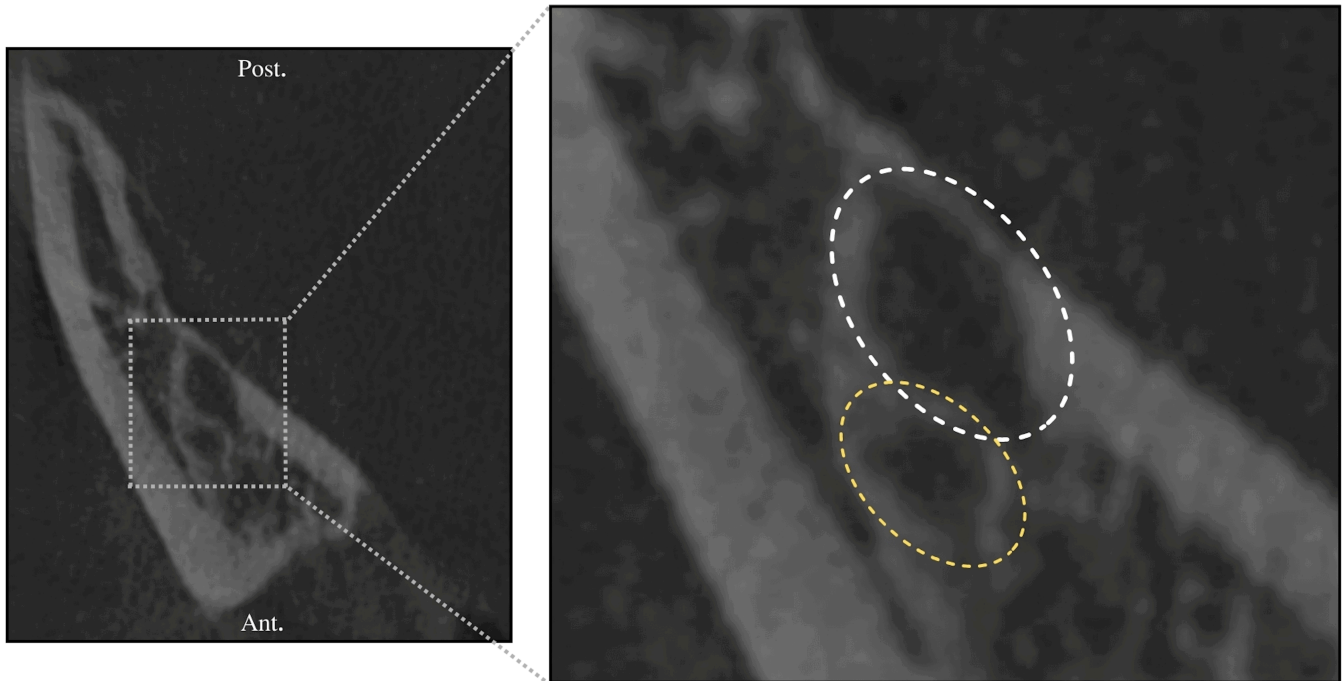


Figure 3

Axial CBCT images demonstrating the presence of an accessory mandibular canal (small yellow circle) in relation to the mandibular foramen (white large circle).

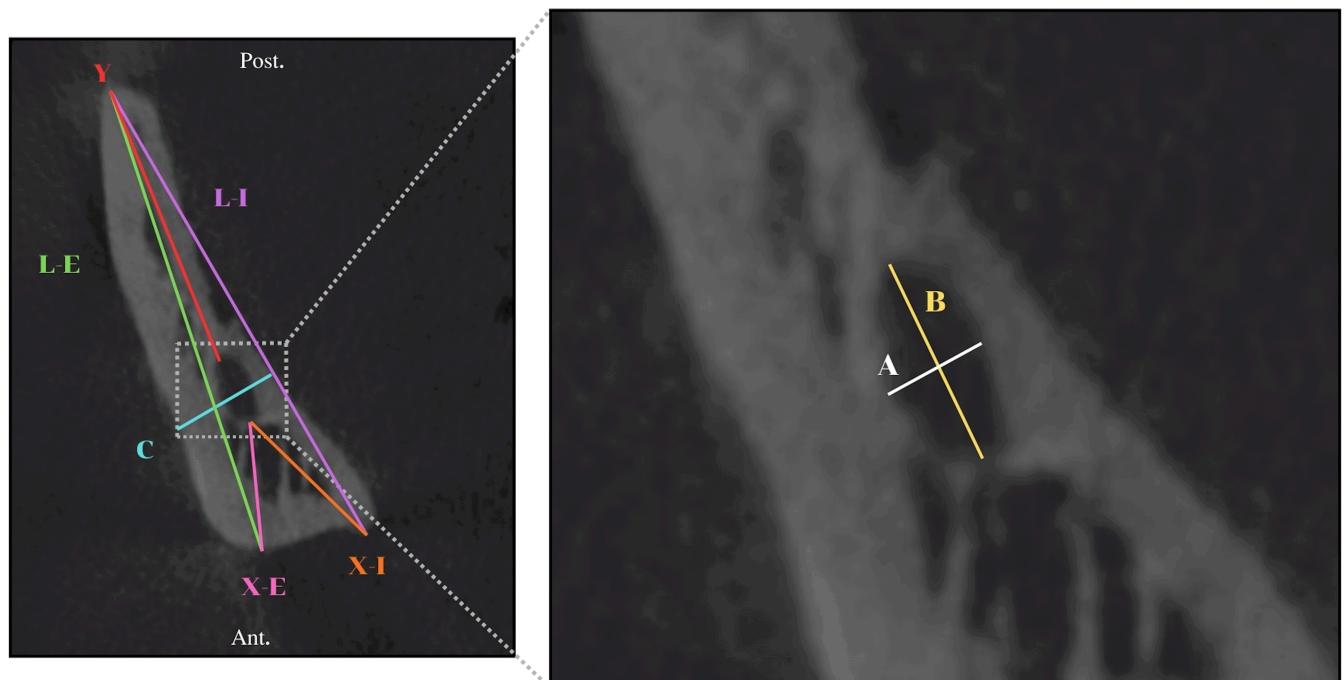


Figure 4

Axial CBCT images illustrating horizontal linear measurements of the mandibular foramen and ramus, including mandibular ramus thickness (C-distance), distance from the posterior border of the mandibular foramen to the posterior border of the mandibular ramus (Y-distance), and distances from the anterior border of the mandibular foramen to the internal (X-I) and external (X-E) oblique ridges.

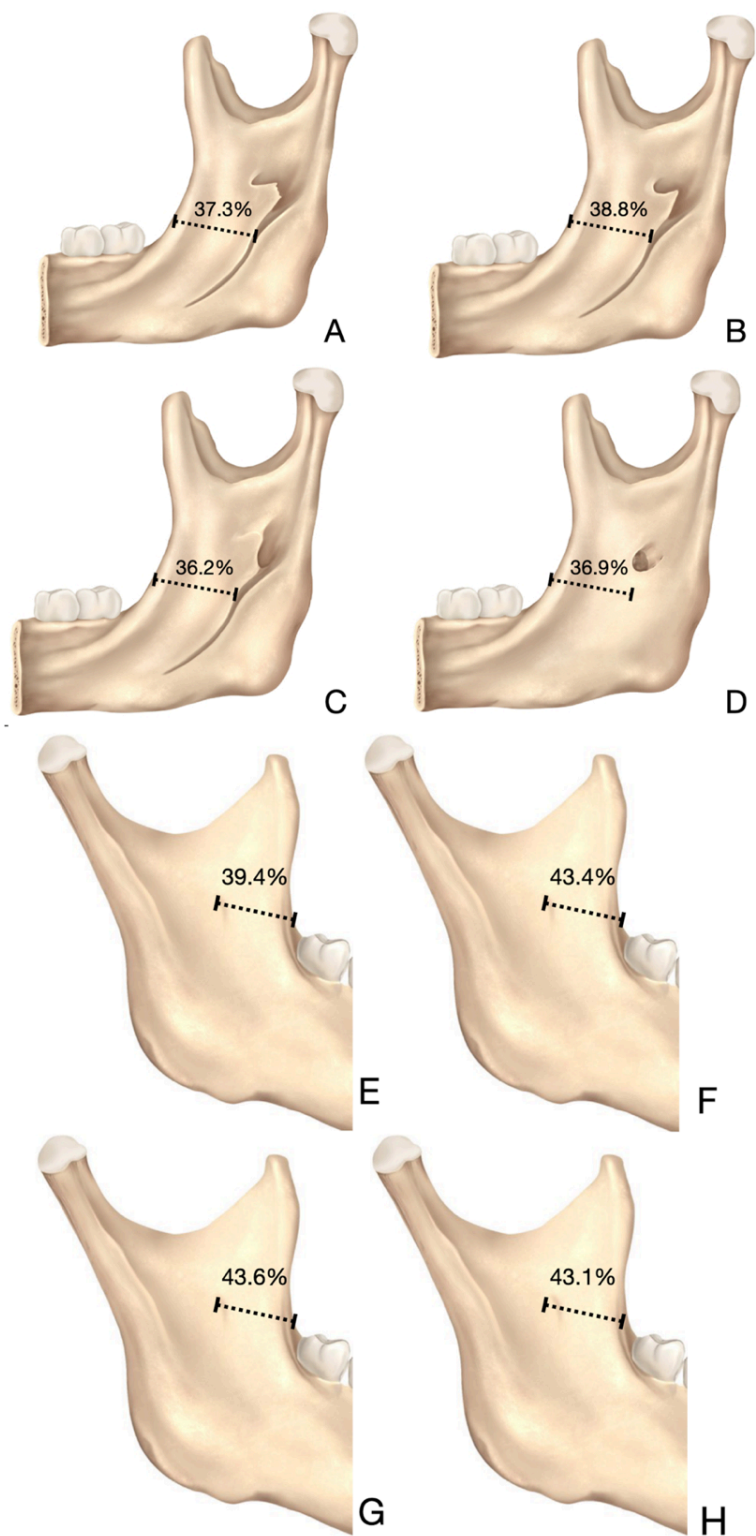


Figure 5

Graphical comparison of positional indices (Ratio-E and Ratio-I) among mandibular lingula morphological types, including truncated (A, E), nodular (B, F), assimilated (C, G), and other types (D, H). Ratio-I is presented in panels A–D, and Ratio-E is presented in panels E–H.