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Original Article

Investigating the relation among the needle insertion plane, occlusal plane, mandibular foramen, and mandibular lingula for inferior alveolar nerve block

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Abstract *Background/purpose:* The success rates and incidence of positive blood aspiration during inferior alveolar nerve blocks (IANB) vary. Understanding the relative positions of the mandibular foramen (MF), mandibular lingula (ML), and occlusal plane (OP) is crucial for the effectiveness and safety of IANB. This study evaluates the relationship among needle insertion levels, ML, and OP for IANB.
Materials and methods: Cone-beam computed tomography images of 90 participants were analyzed to measure ML and MF distances relative to OP. Participants were categorized into skeletal classes (I, II, and III). The distances from ML to the anesthetic needle positioned 5, 6, 7, 8, 9, and 10 mm above OP were assessed. Comparisons based on gender and skeletal classes were conducted, and correlations among variables were evaluated.
Results: The MF and ML were located below OP in 72 (40.0 %) and 5 (2.8 %) sides, respectively. Class II had the highest proportion of MF below OP (16.67 %), followed by Class III (13.33 %) and Class I (10 %). When the needle was inserted 5 mm and 10 mm above OP, ML was below the

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insertion plane in 27 (15 %) and 116 (64.4 %) sides, respectively. ML-OP distances were significantly greater in Class III (9.75 mm) and Class I (9.62 mm) than in Class II (7.29 mm).
Conclusion: Class II exhibited significantly smaller ML-OP and MF-OP distances than Class I and Class III. The needle should be inserted parallel to OP and positioned approximately 6–7 mm above OP for improved safety and anesthesia efficacy.

Introduction

The mandibular foramen (MF) is an opening located on the inner surface of the mandibular ramus, and it serves as the entrance for the inferior alveolar nerve (IAN) and accompanying blood vessels passing into the mandibular canal. The IAN is a branch of the mandibular nerve, which is part of the fifth cranial nerve. The MF has irregular margins, which can be attributed to mandibular development and muscle attachment. Typically, a major ridge is observed along the anterior and superior borders of the MF, forming a bony spine that partially covers the opening of the MF, which is known anatomically as the mandibular lingula (ML).[1,2]

The sphenomandibular ligament is attached to the opening of the MF and ML. This ligament restricts the anterior and inferior movement of the mandible, and it protects the inferior alveolar neurovascular bundle to prevent its direct exposure before entering the MF. As the IAN approaches the ML, it combines with the inferior alveolar vascular bundle before entering the MF. After entering the MF, the IAN passes through the mandibular canal and advances through the mental foramen to innervate the soft tissue of the lower lip. Along its course, the IAN provides sensory innervation to the mandibular teeth and lower lip. Understanding the anatomical features surrounding the ML and MF is crucial for the successful administration of local anesthesia in dental practice. This knowledge is essential for optimizing the effectiveness and duration of anesthesia, which play key roles in successfully managing dental pain.[1]

Conventional IAN block (IANB) remains the most commonly used approach for achieving effective anesthesia in dental procedures.[1] Conventional IANB can be performed using either a direct method or an indirect method. To begin with, the external oblique ridge is palpated, followed by the identification of the pterygomandibular raphe. Subsequently, a syringe is positioned over the opposite premolar, with the needle inserted approximately 10 mm above the occlusal plane (OP) on the side where the injection is to be administered. In the direct method, the needle is carefully inserted as described earlier and is advanced until it makes contact with the surrounding bone of the ML. Once contact is established between the needle and bone, the needle is slightly withdrawn and aspirated without puncturing any blood vessel. If the aspiration result is negative, a single anesthetic cartridge is gradually administered over 1 min. In the indirect technique, the needle is advanced to make contact with the bone on the medial surface of the coronoid notch. The syringe is then slightly withdrawn from the bone, and the needle is advanced parallel to the ramus into the pterygomandibular space, targeting the bone near the ML. After the second contact with this bone at this depth, the needle is slightly withdrawn, aspiration is performed to confirm a negative result, and an anesthetic is administered.[1] When properly executed, both direct and indirect IANB methods can be reliable and effective. Goldberg et al.[3] reported that the success rates for IANB anesthesia were 62 % for premolars, 53 % for molars, and 25 % for lateral incisors. This failure can be attributed to factors such as anatomical variations, improper needle placement, and variations in the depth of the MF. These challenges reaffirm the importance of understanding precise anatomical landmarks, such as the relationship between the MF, ML, and OP, to improve the accuracy and effectiveness of IANB.

The relative positioning of the MF, ML, and OP is a landmark that contributes to the successful administration of anesthesia in dental procedures. By examining these relationships, clinicians can determine the optimal insertion height and depth for safe and effective IANB. In this study, we used cone-beam computed tomography (CBCT) to examine the height and depth parameters for needle insertion for IANB. Our goal was to provide precise data to (1) optimize the insertion plane of anesthesia, (2) reduce failure rates and complications, and (3) ensure an effective and safe anesthetic position. Our findings contribute to the knowledge of anatomical variations and clinical techniques, enhancing the success of anesthesia induction for dental procedures.

Materials and methods

CBCT images were acquired from the Department of Dentistry at Kaohsiung Medical University Hospital (Kaohsiung, Taiwan) for analysis. During imaging, the participants' teeth (Taiwanese population) were positioned in centric occlusion, with a natural head position to ensure an accurate anatomical representation. Participates meeting the following criteria were excluded from the study: (1) having a tumor, (2) having a congenital malformation, or (3) having a history of trauma or surgical procedures affecting the craniofacial area.

Data on the following demographic characteristics were collected: (1) gender, (2) age, and (3) the A point–nasion–B point [ANB] angle. CBCT image files (DICOM, Digital Imaging and Communications in Medicine) were imported into RadiAnt DICOM Viewer version 4.6.9

(Medixant, Poznań, Poland) for three-dimensional image reconstruction. Participants were divided into three skeletal classes (Class I, II, or III) depending on their measured angles in accordance with Riedel's classification[4] as follows: Class I ($0° < ANB < 4°$), Class II ($ANB \geq 4°$), and Class III ($ANB \leq 0°$). The reference horizontal plane, referred to as the FH plane, was defined as the plane passing through the lower margin of the right orbit and the upper margins of both external auditory canals (Fig. 1). Landmark identification and distance measurement were performed using RadiAnt DICOM Viewer version 4.6.9 (Medixant, Poznań, Poland).

With the ML as the reference point (Fig. 2), data on the following landmarks were obtained. The APML distance is the distance between the anterior (A) and posterior (P) borders of the ramus, passing through the ML and parallel to the OP. The AML distance is the distance from the ML to the anterior border of the ramus. The SIML distance is the distance between the sigmoid notch and the inferior border (I) of the ramus, passing through the ML and perpendicular to the OP. The SML distance is the distance from the ML to the sigmoid notch. Additionally, the distances between the ML and MF were measured both vertically (ML-MF-V) and horizontally (ML-MF-H), and the distances from the ML and MF to the OP were also measured. Moreover, the distances from the ML to the anesthetic needle positioned 5, 6, 7, 8, 9, and 10 mm above the OP were measured (Fig. 2).

Data were analyzed using IBM SPSS Statistics 20 (SPSS Inc., Chicago, IL, USA). The comparison between females and males, as well as between the right side and the left side, was analyzed utilizing the Student's t-test. We used the Chi-squared test to analyze the position of the mandibular foramen relative to the occlusal plane and its association with gender and skeletal patterns (Class I, II, and III). The differences among the 3 skeletal patterns were analyzed using an analysis of variance (ANOVA), followed by Tukey's honestly significant difference post hoc test for pairwise comparisons. The relationships among the variables were assessed using the Pearson correlation test. Correlation coefficients (r) are an indicator of the strength of a relationship between 2 variables. In terms of absolute values, correlation coefficients of 0–0.19, 0.20–0.39, 0.40–0.59, 0.60–0.79, and 0.80–1.00 are considered to indicate a very weak relationship, a weak relationship, a moderate relationship, a strong relationship, and a very strong relationship, respectively. For all statistical analysis,

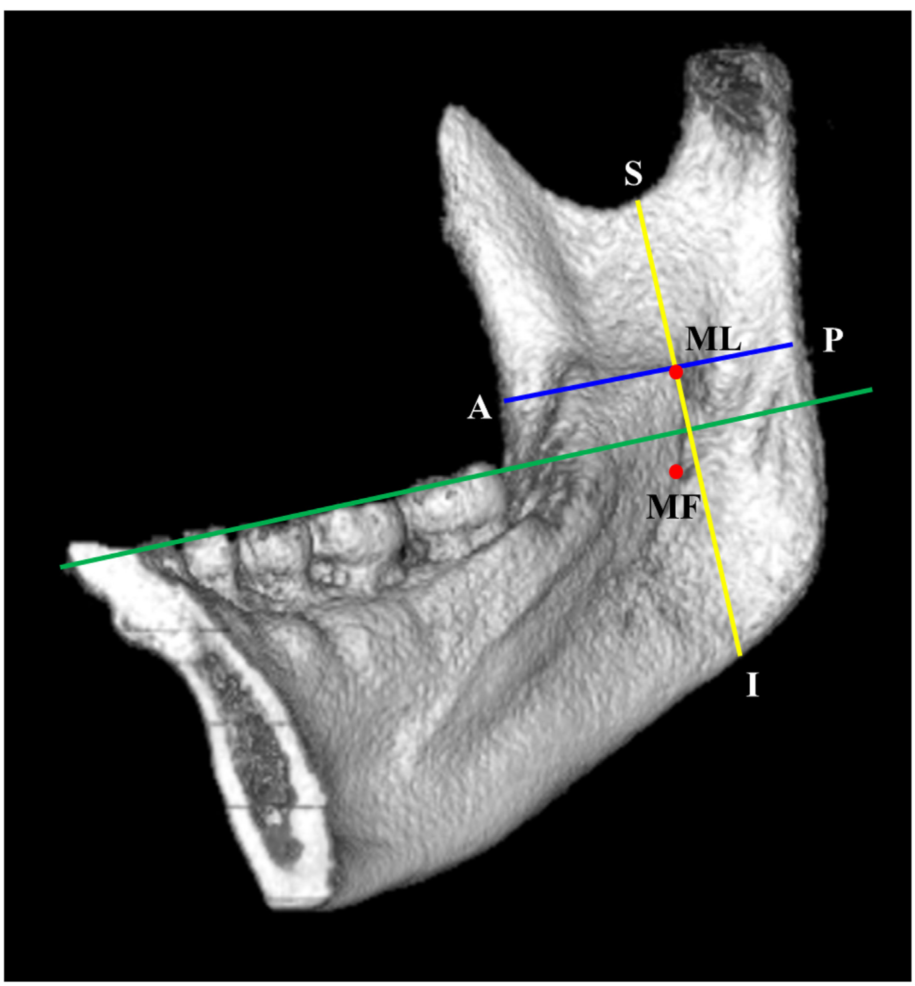

Figure 1 Green line: occlusal plane (OP), Blue line: APML plane through ML and parallel to OP, Yellow line: SIML plane through ML and vertical to OP. ML (red dot): mandibular lingula, MF (red dot): mandibular foramen, A: anterior border of ramus, P: posterior border of ramus, S: superior border of ramus, I: inferior border of ramus

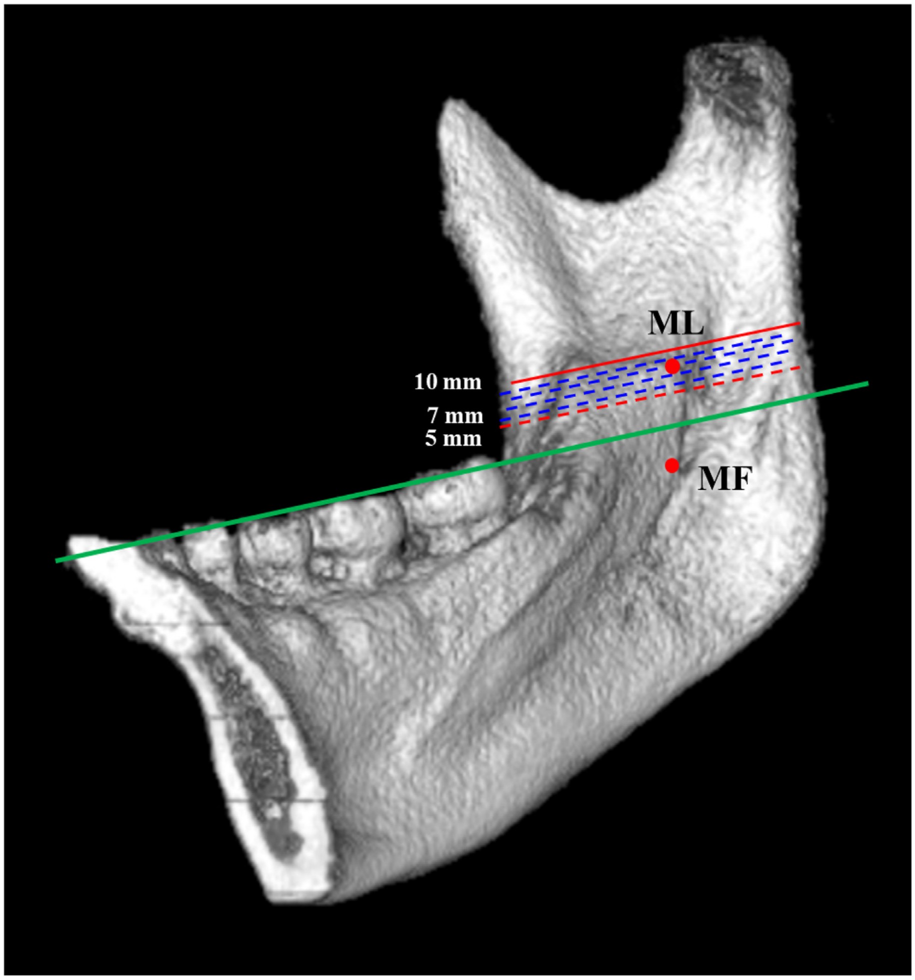

Figure 2 Occlusal plane (OP: green line) and needle insertion plane from 5 to 10 mm above OP. Red dotted line: 5 mm above OP, Blue dotted line:6—9 mm above OP, Red line: 10 mm above OP. ML (red dot): mandibular lingula, MF (red dot): mandibular foramen

a *P* value less than 0.05 was considered statistically significant. This study was approved by the Institutional Review Board of Kaohsiung Medical University Hospital (KMUH-IRB-20160066).

Results

This study included 90 participants (Tables 1 and 2), with a total of 180 sides. These participants were divided into 30 male participants (60 sides) and 60 female participants (120 sides). In the skeletal classification, 30 participants (21 women and 9 men) were categorized into Class I, 30 participants (25 women and 5 men) into Class II, and 30 participants (14 women and 16 men) into Class III. Among all participants, the MF was located below the OP in 72 sides (40.0 %), divided into 52 sides in female participants and 20 sides in male participants. By contrast, the MF was located above the OP in 107 sides (59.4 %). Among all participants, the ML was located above the OP in 175 sides (97.2 %) and below the OP in only 5 sides (2.8 %). Notably, all 5 sides in which the ML was located below the OP were detected in

Table 1 Demographic characteristics of participates.

	Male		Female		Total	
	n	%	n	%	n	%
Skeletal pattern						
Class I	18	10.00 %	42	23.30 %	60	33.33 %
Class II	10	5.60 %	50	27.70 %	60	33.33 %
Class III	32	17.70 %	28	15.60 %	60	33.33 %
Total	60	33.33 %	120	66.67 %	180	100.00 %
MF below OP	20	11.10 %	52	28.89 %	72	40.00 %
MF equal to OP	0	0	1	0.60 %	1	0.60 %
MF above OP	40	22.20 %	67	37.20 %	107	59.40 %
Total	60	33.33 %	120	66.67 %	180	100.00 %
ML below OP	0	0	5	2.80 %	5	2.80 %
ML equal to OP	0	0	0	0	0	0
ML above OP	60	33.33 %	115	63.90 %	175	97.20 %
Total	60	33.33 %	120	66.67 %	180	100.00 %

n: number of sides.
MF: mandibular foramen; OP: occlusal plane; ML: mandibular lingula.

Table 2 The related positions of mandibular foramen and occlusal plane in the gender and skeletal pattern.

	Male		Female		Total	
	n	%	n	%	n	%
MF below OP						
Class I	6	3.33 %	12	6.67 %	18	10.00 %
Class II	2	1.11 %	28	15.56 %	30	16.67 %
Class III	12	6.67 %	12	6.67 %	24	13.33 %
Subtotal	20	11.11 %	52	28.89 %	72	40.00 %
MF equal to OP						
Class I	0	0.00 %	1	0.56 %	1	0.56 %
MF above OP						
Class I	12	6.67 %	29	16.11 %	41	22.78 %
Class II	8	4.44 %	22	12.22 %	30	16.67 %
Class III	20	11.11 %	16	8.89 %	36	20.00 %
Subtotal	40	22.22 %	67	37.22 %	107	59.44 %

Chi-squared test (MF below OP or not).
Gender (*P* value = 0.197).
Skeletal pattern (*P* value = 0.082).

n: number of sides; MF: mandibular foramen; OP: occlusal plane.
Significant, $P < 0.05$.

female participants, whereas the ML was located above the OP in all male participants. As shown in Table 2, the highest proportion of participants with the MF located below the OP had Class II skeletal pattern (16.67 %), followed by Class III (13.33 %) and Class I (10 %) skeletal pattern. The highest proportion of participants with the MF located above the OP had Class I skeletal pattern (22.78 %). Concerning whether the MF is below the OP or not, the Chi-squared test showed no significant differences (gender: *P* value = 0.197, skeletal pattern: *P* value = 0.082).

Table 3 illustrates the influence of needle position in relation to the OP on the probability of the ML being located below the insertion plane. When the needle was inserted 5 mm above the OP, the ML was located below the insertion plane in 27 sides (15 %). When the needle was positioned 8 mm above the insertion plane this number (ML below insertion plane) increased to 81 sides (45 %). These

Table 3 Distribution of mandibular lingula at the needle insertion from 5 mm to 10 mm above occlusal plane (OP) during inferior alveolar nerve block.

Insertion plane	ML				
	Above or equal to plane		Below plane		Total
	N	%	N	%	N
5 mm above OP	153	85.00 %	27	15.00 %	180
6 mm above OP	138	76.67 %	42	23.33 %	180
7 mm above OP	125	69.44 %	55	30.56 %	180
8 mm above OP	99	55.00 %	81	45.00 %	180
9 mm above OP	81	45.00 %	99	55.00 %	180
10 mm above OP	64	35.56 %	116	64.44 %	180

N: number of sides; IANB: inferior alveolar nerve block.
ML: mandibular lingula; OP: occlusal plane.

results indicated a threefold increase in the proportion of patients with the ML below the insertion plane for the 8 mm position compared with the 5 mm position. Furthermore, when the needle was positioned 10 mm above the OP, the ML was located below the insertion plane in 116 sides (64.4 %). Thus, the proportion of patients with the ML below the insertion plane was 4.3 times higher for the 10 mm position than for the 5 mm position. This increase in the percentage of patients having the ML located below the insertion plane with a higher needle position from the OP indicates that, without ML protection, the risk of the needle puncturing a blood vessel is increased. Therefore, the ML serves as a key anatomical landmark for preventing inadvertent vascular injury during anesthesia.

As shown in Table 4, a statistically significant difference was observed in age between the male and female participants. However, the female participants exhibited a significantly larger ANB angle, with 83.3 % (25 of 30) of them assigned to Class II. By contrast, the male participants exhibited a considerably greater ML-OP distance of 10.48 mm compared with the female participants (8.09 mm). Similarly, the male participants exhibited a significantly larger MF-OP distance of 2.59 mm compared with the female participants (only 1.04 mm). Furthermore, the SIML, AML, and APML values were significantly higher in the male participants than in the female participants. No significant differences were observed in the horizontal and vertical distances of ML-MF between the female and male participants. These results indicate that certain anatomical measurements related to the mandible and its surrounding structures may significantly differ between male and female participants, with male participants generally exhibiting greater distances. As shown in Table 5, the MF-OP distance on the right side (1.97 mm) was significantly larger than that on the left side (1.14 mm). However, no significant differences were observed in the measurements between the left and right sides for the other parameters.

As shown in Table 6, the mean age of participants with Class II skeletal pattern (27.33 y) was significantly higher than that of participants with Class III skeletal pattern (22.77 y). In terms of the ML-OP distance, participants with Class III skeletal pattern (9.75 mm) and Class I skeletal pattern (9.62 mm) exhibited a significantly greater ML-OP distance compared with those with Class II skeletal pattern (7.29 mm). In terms of the MF-OP distance, participants with Class I skeletal pattern (2.62 mm) and Class III skeletal pattern (1.98 mm) exhibited significantly greater MF-OP distances compared with those with Class II skeletal pattern (0.06 mm). In terms of ML-MF-H measurements, participants with Class III skeletal pattern (1.99 mm) had significantly greater ML-MF-H distances compared with those with Class I skeletal pattern (1.35 mm). However, no significant differences were observed in ML-MF-V, SML, SIML, AML, and APML values between participants with the 3 skeletal patterns. These results indicated significant differences in age, ML-OP distance, and MF-OP distance between participants with Class II skeletal pattern and participants with Class I or III skeletal pattern. However, no significant differences were observed in other measurements between participants with the 3 skeletal patterns. ML-OP and MF-OP were significantly negatively correlated across the different gender, age, and ANB angle (Table 7).

Table 4 Linear distances in the comparisons of gender.

Variables	Male (M)		Female (F)		Total		Comparison	
	Mean	SD	Mean	SD	Mean	SD	*P* value	Significant
Age (year)	23.73	4.88	25.72	6.85	25.06	6.31	0.027[a]	F > M
ANB (degree)	−0.78	5.13	2.76	4.51	1.58	5.00	<0.001[a]	F > M
Distance (mm)								
ML-OP (mm)	10.48	4.43	8.09	3.89	8.88	4.22	<0.001[a]	M > F
MF-OP (mm)	2.59	4.50	1.04	4.40	1.55	4.48	0.028[a]s	M > F
ML-MF-H (mm)	1.75	1.63	1.64	1.21	1.68	1.36	0.632	—
ML-MF-V (mm)	7.89	3.00	7.11	2.45	7.37	2.67	0.064	—
SML (mm)	17.85	4.51	17.13	3.72	17.37	4.00	0.258	—
SIML (mm)	50.79	5.28	46.13	5.58	47.68	5.89	<0.001[a]	M > F
AML (mm)	16.99	3.35	15.99	2.93	16.33	3.10	0.041[a]	M > F
APML mm)	32.87	3.38	30.61	3.33	31.36	3.50	<0.001[a]	M > F

ANB: A point—nasion—B point; MF: mandibular foramen; OP: occlusal plane; ML: mandibular lingula.
V: vertical; H: horizontal; SML: superior border to ML; SIML: superior to inferior border *via* ML.
AML: anterior border to ML; APML: anterior to posterior border *via* ML.
[a] Significant, $P < 0.05$; —: Not significant.

Table 5 Linear distances among mandibular lingula, mandibular foramen and occlusal plane in the hemiarch comparison.

Variables	Right side		Left side		Hemiarch comparison	
	Mean	SD	Mean	SD	*P* value	Significant
ML-OP (mm)	9.13	3.93	8.63	4.50	0.136	—
MF-OP (mm)	1.97	4.25	1.14	4.69	0.022[a]	Right > left
ML-MF-H (mm)	1.58	1.26	1.78	1.46	0.152	—
ML-MF-V (mm)	7.16	2.47	7.58	2.84	0.143	—
SML (mm)	17.53	4.18	17.21	3.83	0.453	—
SIML (mm)	47.90	5.92	47.47	5.89	0.370	—
AML (mm)	16.52	2.87	16.13	3.32	0.315	—
APML (mm)	31.40	3.55	31.32	3.48	0.816	—

MF: mandibular foramen; OP: occlusal plane V: vertical; H: horizontal.
SML: superior border to ML; SIML: superior to inferior border *via* ML.
AML: anterior border to ML; APML: anterior to posterior border *via* ML.
[a] Significant, $P < 0.05$; —: Not significant; ML: mandibular lingula.

Additionally, ML-MF-H and ML-MF-V were significantly negatively correlated with ANB angle (Table 8). Furthermore, SIML, AML, and APML were significantly negatively correlated with gender (Table 9). These results suggest that variations in ML-OP and MF-OP distances are influenced by gender, age, and ANB angle. Some other measured distances (SIML, AML, and APML) are significantly influenced by gender.

ML-OP and MF-OP exhibited very strong positive correlations ($r = 0.809$, Table 8). Additionally, ML-MF-V exhibited a significant positive correlation with ML-OP and a significant negative correlation with MF-OP. Significant negative correlations were observed between ML-OP and both SML and APML. Furthermore, ML-MF-V was significantly positively correlated with both ML-OP and ML-MF-H, whereas it was significantly negatively correlated with SML, AML, and APML. These findings indicate the presence of significantly correlated relationships among different anatomical distances.

Discussion

Understanding the approach of IANB is essential for achieving effective local anesthesia in dentistry. An improper technique can result in various complications.[1] Patients may experience mild soreness or discomfort at the injection site. This discomfort can arise either from the needle being inserted too quickly or forcefully or from inadvertent contact of the needle with sensitive structures such as the periosteum. Additionally, trauma to the inferior alveolar artery can cause localized bleeding, leading to the formation of a hematoma. Contact with or damage to the nerve can result in an electric shock-like sensation during the procedure.[1] The nerve that is most commonly injured during an inferior alveolar nerve block is the lingual nerve. In a cadaveric investigation conducted by Morris et al.,[5] it was noted that out of 44 IANB performed in the fixed sagittally bisected cadaver heads. Forty-two injections (95.5 %) were delivered laterally to the lingual nerve, while 2 injections (4.5 %) resulted in direct penetration of the nerve itself. Additionally, the study found that 7 injections (16 %) were positioned within 0.1 mm of the nerve. The spatial relationship of the lingual nerve to the bony landmarks within the interpterygoid fascia exhibited significant variability.

Trauma or irritation to the medial pterygoid muscle during the procedure may lead to trismus, which manifests as restricted jaw movement and difficulty in opening the mouth. Furthermore, accidental injection into a blood vessel can result in systemic effects, such as rapid heart rate and dizziness. Alsaegh et al.[6] evaluated the experiences of dental students concerning positive aspirations during the administration of direct inferior alveolar nerve blocks (IANB). Their findings indicated that positive aspiration was observed in 22.7 % of the injections. Frangiskos

Table 6 Linear distances in the comparison of skeletal pattern by the one-way analysis of variance with Tukey HSD post comparison.

Variables	Class I		Class II		Class III		Interclass comparison	
	Mean	SD	Mean	SD	Mean	SD	*P* value	Significant
Age (year)	25.07	6.74	27.33	6.44	22.77	4.84	<0.001[a]	II > III
ANB (degree)	1.72	1.17	7.05	2.03	−4.05	2.79	<0.001[a]	II > I > III
Distance (mm)								
ML-OP (mm)	9.62	4.27	7.29	4.10	9.75	3.89	0.001[a]	I > II, III > II
MF-OP (mm)	2.62	4.36	0.06	4.51	1.98	4.24	0.004[a]	I > II, III > II
ML-MF-H (mm)	1.35	0.87	1.70	1.39	1.99	1.65	0.036[a]	III > I
ML-MF-V (mm)	7.12	2.24	7.22	2.95	7.77	2.76	0.365	—
SML (mm)	16.42	3.67	18.15	3.77	17.55	4.39	0.054	—
SIML (mm)	47.25	5.81	48.05	6.13	47.75	5.80	0.756	—
AML (mm)	16.21	3.03	16.01	2.95	16.75	3.32	0.406	—
APML (mm)	31.37	3.56	31.29	3.33	31.43	3.67	0.978	—

ANB: A point—nasion—B point; MF: mandibular foramen; OP: occlusal plane; ML: mandibular lingula.
V: vertical; H: horizontal; SML: superior border to ML; SIML: superior to inferior border *via* ML.
AML: anterior border to ML; APML: anterior to posterior border *via* ML.
[a] Significant, $P < 0.05$; —: Not significant.

Table 7 The Pearson correlation coefficient between linear distances and demographic characteristics of participates.

Variables	Total sides			
	Gender	Age (year)	Skeletal pattern	ANB (degree)
ML-OP (mm)	−0.268[a]	−0.165[a]	0.013	−0.312[a]
MF-OP (mm)	−0.164[a]	−0.232[a]	−0.059	−0.205[a]
ML-MF-H (mm)	−0.036	0.118	0.192[a]	−0.161[a]
ML-MF-V (mm)	−0.138	0.137	0.099	−0.147[a]
SML (mm)	−0.085	−0.132	0.116	0.034
SIML (mm)	−0.374[a]	−0.09	0.035	−0.016
AML (mm)	−0.152[a]	0.025	0.071	−0.077
APML (mm)	−0.305[a]	0.029	0.006	−0.007

ANB: A point—nasion—B point; ML: mandibular lingula; V: vertical; H: horizontal.
SML: superior border to ML; SIML: superior to inferior border *via* ML.
AML: anterior border to ML; APML: anterior to posterior border *via* ML.
[a] Significant, $P < 0.05$; MF: mandibular foramen; OP: occlusal plane.

Table 8 Linear distances of mandibular foramen and lingula related to occlusal plane and orders of ramus in the Pearson test.

Variables	Total sides			
	ML-OP	MF-OP	ML-MF-H	ML-MF-V
ML-OP (mm)	1	0.809[a]	−0.046	0.211[a]
MF-OP (mm)	0.809[a]	1	−0.323[a]	−0.391[a]
ML-MF-H (mm)	−0.046	−0.323[a]	1	0.472[a]
ML-MF-V (mm)	0.211[a]	−0.391[a]	0.472[a]	1
SML (mm)	−0.286[a]	−0.163[a]	−0.106	−0.209[a]
SIML (mm)	0.077	0.085	−0.139	−0.043
AML (mm)	−0.079	0.074	0.115	−0.245[a]
APML (mm)	−0.150[a]	−0.038	0.031	−0.178[a]

ML: mandibular lingula; V: vertical; H: horizontal.
SML: superior border to ML; SIML: superior to inferior border *via* ML.
AML: anterior border to ML; APML: anterior to posterior border *via* ML.
[a] Significant, $P < 0.05$; MF: mandibular foramen; OP: occlusal plane.

et al.[7] documented a 20 % occurrence of blood vessel penetration during the administration of an inferior alveolar nerve block. Deep injection into the parotid gland may inadvertently affect the facial nerve, causing temporary facial nerve paralysis.[8,9] In rare cases, improper handling or sudden patient movements during the procedure may cause the needle to break, potentially necessitating surgical intervention for the removal of the needle.[10] These complications emphasize the importance of having proper anatomical knowledge, implementing a careful technique, and conducting thorough patient assessments to minimize risks during IANB procedures.

Several studies[11–13] have investigated the position of the ML in relation to the OP across different populations, revealing ethnic and gender differences. Sekerci and Sisman[13] discovered that, in the Turkish population, the ML was on average 3.6 mm above the OP. Zhou et al.[12] reported that, among 121 Korean individuals, 119 (98.3 %) had the ML 3.6 mm above the OP, 1 (0.8 %) had the ML on the OP, and 1 (0.8 %) had the ML 1.9 mm below the OP. Zhao et al.[11] indicated that, in the Chinese population, the ML was positioned 5.03—5.97 mm above the OP, with a significantly higher ML position in male participants than in female participants. In our study, the ML was located above the OP in 97.2 % of the participants, with an average height of 8.88 mm. Male participants had an average ML-OP distance of 10.48 mm, which was significantly higher than the distance of 8.09 mm observed in female participants. In addition, the ML-OP distance in participants with Class III

Table 9 Linear distances related to mandibular lingula in the Pearson correlation test.

Variables	Total sides			
	SML	SIML	AML	APML
Gender	−0.085	−0.374[a]	−0.152[a]	−0.305[a]
Age (year)	−0.132	−0.09	0.025	0.029
Skeletal pattern	0.116	0.035	0.071	0.006
ANB (degree)	0.034	−0.016	−0.077	−0.007
ML-OP (mm)	−0.286[a]	0.077	−0.079	−0.150[a]
MF-OP (mm)	−0.163[a]	0.085	0.074	−0.038
ML-MF-H (mm)	−0.106	−0.139	0.115	0.031
ML-MF-V (mm)	−0.209[a]	−0.043	−0.245[a]	−0.178[a]
SML (mm)	1	0.671[a]	0.001	0.153[a]
SIML (mm)	0.671[a]	1	0.044	0.364[a]
AML (mm)	0.001	0.044	1	0.725[a]
APML (mm)	0.153[a]	0.364[a]	0.725[a]	1

MF: mandibular foramen; OP: occlusal plane.
ML: mandibular lingula; V: vertical; H: horizontal.
SML: superior border to ML; SIML: superior to inferior border *via* ML.
AML: anterior border to ML; APML: anterior to posterior border *via* ML.
[a] Significant, $P < 0.05$; ANB: A point—nasion—B point.

(9.75 mm) and Class I (9.62 mm) was significantly greater than that in participants with Class II (7.29 mm). These findings indicate ethnic and gender differences in the ML position. Although the height of the ML above the OP differs across populations, a consistent trend of male participants having significantly higher ML positions compared with female participants is observed in all studies. Additionally, our study revealed that the ML-OP distance was significantly greater in participants with Class III and Class I than in participants with Class II. This finding suggests the potential influence of skeletal pattern on ML position. Understanding these variations is crucial for optimizing the accuracy of IANB techniques and minimizing complications.

Comparative studies[12,13] on AML have provided valuable insights into variations in mandibular dimensions across different populations and skeletal pattern in males and females. Zhou et al.[12] reported that, in the Korean population, AML was 18.3 mm in male participants, which represented AML in approximately 51.84 % of APML. In addition, AML was 18.2 mm in female participants, which represented AML in approximately 50 % of APML. Sekerci and Sisman[13] indicated that, in the Turkish population, AML was 16.77 mm, which represented AML in approximately 56.29 % of APML. Lupi et al.[14] reported that, in the Italian population, AML was 16.96 mm, which represented AML in approximately 52.61 % of APML. Our research revealed that among the Taiwanese population, the average AML measurement for male participants was 16.99 mm, which is significantly longer than the 15.99 mm recorded for female participants. The average AML among all participants was 52.07 % (16.33/31.36) of APML. No significant differences were observed in AML or APML between participants with the 3 skeletal patterns (Class I, Class II, and Class III). The average AML length and its proportional contribution to APML in our study are consistent with the findings in other ethnic groups. However, a consistent trend is observed where male participants exhibit longer AML compared with female participants. The length of Class III is longer than Class I and Class II. Consistent measurements for AML across populations underscore the reliability of AML as a parameter in mandibular morphometric studies and its potential clinical importance for planning orthognathic surgery.

Studies[12–14] on the SML have provided crucial data for understanding anatomical variations across populations and skeletal pattern in males and females. Lupi et al.[14] reported that, in the Italian population, SML was 13.87 mm and represented in approximately 30.77 % of SIML. Sekerci and Sisman[13] indicated that, in the Turkish population, SML was 15.7 mm and represented in approximately 30.78 % of SIML. Zhou et al.[12] discovered that, in the Korean population, SML was 15.7 mm in male participants and represented in approximately 30.78 % of SIML. They also reported that SML was 15.5 mm in female participants and represented in approximately 33.70 % of SIML. In present study, we noticed that, in the Taiwanese population, SML was 17.37 mm and represented in approximately 36.43 % of SIML. We also observed that SML was 17.85 mm in male participants and was slightly longer than that in female participants (17.13 mm). No significant difference was observed between male and female participants. SML and SIML exhibited no significant differences among the 3 skeletal patterns. Overall, the length of SML in the Taiwanese population is slightly greater than that in other populations, indicating potential ethnic variations in mandibular dimensions. In addition, SML and its proportional contribution to SIML in the Taiwanese population in our study (36.43 %) are higher than those reported in the Italian, Turkish, and Korean populations. Thus, population-specific anatomical variations should be considered when planning clinical and surgical interventions.

Ahn et al.[15] indicated that, in the Korean population, the ML height (ML-MF-V) was 9.3 mm in male participants and 8.2 mm in female participants. Sekerci and Sisman[13] (Turkish population) and Jansisyanont et al.[16] (Thai population) reported ML-MF-V of 7.91 and 8.2 mm, respectively. Our study (Taiwanese population) revealed ML-MF-V of 7.34 mm (male: 7.89 mm, female: 7.11 mm). Moreover, ML-MF-V in male participates and Class III is longer than female participates, Class I and Class II. No significant difference was observed between male and female participants. Similarly, no significant differences were observed in ML-MF-V between participants with the 3 skeletal patterns. The ML-MF-V values obtained in this study are similar to those of Sekerci and Sisman[13] and are slightly lower than those of Ahn et al.[15] and Jansisyanont et al.,[16] suggesting ethnic anatomical variations. This study contributes to ML-MF-V measurements in the Taiwanese population, confirming its similarity to data from the Turkish population and subtle differences from other populations. These findings emphasize that ethnic variations in mandibular anatomy should be considered for clinical applications such as IANB.

Zhou et al.[12] reported variations in the location of the MF in relation to the OP in the Korean population. The average position of the MF was 3.4 ± 3.5 mm below the OP. The distribution of the MF position was as follows: the MF was located below the OP in 84.3 % of the participants, the

MF was located above the OP in 12.4 % of the participants, and the MF was located at the level of the OP in 3.3 % of the participants. Feuerstein et al.[17] reported that, in the French population, the position of the MF ranged from −0.4 to 2.9 mm above the OP in children, adolescents, and adults. Al-Shayyab[18] indicated that, in the Jordanian population, the MF was primarily located above the OP from young adult (12–25 years) to elderly (ages over 60). They also reported that the MF was 4.52 ± 1.18 mm above the OP. In our study, we discovered that the MF was 1.55 mm above the OP. Specifically, the MF was below the OP in 40 % of the participants but above the OP in 60 % of the participants. Notably, male participants exhibited an average measurement of 2.59 mm, which was significantly higher than the measurement of 1.04 mm in female participants. Furthermore, our analysis revealed that the MF-OP distance was significantly greater in participants with Class III (1.98 mm) and Class I (2.62 mm) than in those with Class II (0.06 mm).

Significant variability has been observed in the position of the MF in relation to the OP across different populations. Several factors contribute to this variability. First, in terms of ethnic differences, the ethnic disparity in the MF-OP position observed in the comparison of the Taiwanese population with other populations highlighted genetic and anatomical influences. Second, in terms of gender-related differences, male participants exhibited a significantly greater MF-OP distance compared with female participants, consistent with the significant anatomical differences reported across populations. Third, in terms of skeletal pattern, the Class II were associated with smaller MF-OP distances compared with the Class I and III, potentially reflecting anatomical adaptations or growth variations in these skeletal types. Fourth, in terms of OP factor, variations in mandibular dental alignment, such as crowding, missing teeth, malocclusion, and skeletal growth discrepancies (facial asymmetry), may alter the inclination of OP and subsequently influence the position of the MF. Our study (Taiwanese population) found no significant differences in gender and skeletal pattern, suggesting that these factors do not significantly influence the position of the mandibular foramen. Further studies are needed to explore other factors, such as age, ethnicity, or individual anatomical variations, to assess potential influences.

Considering the insertion depth of the needle during IANB, a 27-gauge dental needle with a length of 30–32 mm is typically used. According to the literature,[12,13] the average AML is 17–18 mm and is slightly shorter (approximately 1 mm) in female participants than in male participants. Soft tissue thickness near the anterior border of the ramus in the retromolar area is estimated to be 2–5 mm when the mouth is open. The needle should penetrate approximately two-thirds to three-quarters of its length (approximately 20–24 mm) to reach the ML. The needle should be inserted at an angle from the contralateral premolar toward the pterygomandibular raphe at the injection site. The spacing between the needle and the cartridge measures 5 mm. To prevent contact between the syringe and the contralateral premolar, the needle should be positioned 1–2 mm higher than the OP at the premolar region. If the needle is inserted parallel at this level, it will reach the ML approximately 6–7 mm from the OP. Our findings indicate a 70 % success rate for the needle reaching the ML under these conditions. Conversely, if the needle is positioned 8 mm from the OP, the success rate decreases to 55 %; at 9 mm, it decreases to 45 %; and at 10 mm, the success rate considerably decreases to 35 %, with increased proximity to the subsigmoid area. If the needle is positioned ≥10 mm above the OP, this implies that the needle is closer to the subsigmoid area, increasing the risk of puncturing blood vessels. Therefore, aspiration during the IANB procedure is crucial to prevent the administration of anesthetic directly into the bloodstream, which may lead to complications such as cardiac distress or acute cardiovascular events. The needle should be inserted with precision, and the recommended trajectory and depth should be maintained. Continual aspiration should be performed to confirm that no blood is drawn before injecting the anesthetic. Force should be minimized during needle insertion to reduce trauma to surrounding tissues and to prevent complications such as hematoma formation or vascular injury.

In conclusion, experienced clinicians are adept at identifying anatomical landmarks and performing accurate needle placement, thereby achieving a high success rate. In contrast, inexperienced practitioners may encounter difficulty locating the ML and MF, which can increase the likelihood of failure or reduced anesthetic efficacy. The effectiveness and safety of the IANB are closely associated with a precise understanding of the relative positions of the MF, ML, and OP. Utilizing CBCT images to evaluate anatomical landmarks enhances procedural accuracy and reduces the risk of complications. In our study, we found that male participants had significantly greater ML–OP and MF–OP distances compared to female participants. Furthermore, individuals with skeletal Class II exhibited significantly smaller ML–OP and MF–OP distances than those with Class I or Class III. Based on our observations, we recommend that the needle be inserted parallel to the OP and positioned approximately 6–7 mm above the OP. It should be advanced to a depth of about two-thirds to three-quarters of its total length to effectively reach the ML. With this orientation and depth, the technique yields a 70 % success rate in accurately targeting the ML.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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