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Mandibular foramen location: a CBCT study to improve the success rate of inferior alveolar nerve block

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ABSTRACT | *Objective*: This study proposed to locate the mandibular foramen position by using cone beam computed tomography (CBCT) imaging, based on landmarks used at inferior alveolar nerve block (IANB) technique in order to increase the success rate of this procedure. *Materials and methods*: 58 mandibular foramina of 29 adult patients were evaluated. Linear and angular CBCT measurements were defined for the mandibular foramen based on the IANB technique. The measurements were performed by two radiologists. Data analyses consisted of verifying the normality, obtaining the mean value of all patients and comparing the data obtained between male and female patients. *Results*: Student's t and Mann-Whitney's *U* tests were used to calculate the mean mandibular foramen position. The three mean position measurements of the mandibular foramen were 13.5 mm above the occlusal plan (15.5 mm for male and 11.7 mm for female patients), 14.6 mm below the mandibular notch (14.9 mm for male and 13.7 mm for female patients) and 14.2 mm from the anterior border of mandibular ramus (14.6 mm for male and 13.8 mm for female patients). The angle formed by the molar lines and contralateral premolar lines was 25.8° and the angle formed by the molar lines and contralateral second premolar/molar lines was 31.5°. *Conclusion*: CBCT images were a useful method to provide the measurements of the mandibular foramen position based on landmarks used by the IANB technique. We encourage the use of these measurements as reference to increase the clinical success when performing the IANB technique.

DESCRIPTORS | Cone-Beam Computed Tomography; Mandibular Nerve; Anesthesia; Dental.

RESUMO | **Localização do forame mandibular: um estudo de TCFC para melhorar o índice de sucesso da anestesia do nervo alveolar inferior** • *Objetivo*: Este estudo propôs a localização da posição do forame mandibular através da tomografia computadorizada de feixe cônico (TCFC) baseada em pontos de referência utilizados na técnica do bloqueio do nervo alveolar inferior (BNAI) para aumentar a taxa de sucesso desse procedimento. *Materiais e métodos*: 58 forames mandibulares de 29 pacientes adultos foram avaliados. Medições lineares e angulares de TCFC foram definidas para o forame mandibular baseadas na técnica do BNAI. As medições foram realizadas por dois radiologistas. A análise dos dados consistiu em verificar a normalidade, obtendo o valor médio de todos os pacientes e comparando os dados obtidos entre pacientes do sexo masculino e feminino. *Resultados*: Os testes t de Student e *U* de Mann-Whitney foram usados para calcular a posição média do forame mandibular. As três medições de posição média do forame mandibular foram 13,5 mm acima do plano oclusal (15,5 mm para pacientes do sexo masculino e 11,7 mm para pacientes do sexo feminino), 14,6 mm abaixo da incisura mandibular (14,9 mm para pacientes do sexo masculino e 13,8 mm para pacientes do sexo feminino) e 14,2 mm da borda anterior do ramo mandibular (14,6 mm para o sexo masculino e 13,7 mm para o sexo feminino). O ângulo formado pelas linhas molares e pré-molares contralaterais foi de 25,8º e o ângulo formado pelas linhas molares e pelo segundo pré-molar/molar contralateral foi de 31,5º. *Conclusão*: as imagens de TCFC foram um método útil para fornecer as medições da posição do forame mandibular com base nos pontos de referência usados pela técnica do BNAI. Encorajamos o uso dessas medidas como referência para aumentar o sucesso clínico ao realizar a técnica do BNAI.

DESCRITORES | Tomografia Computadorizada por Raio-X; Nervo Mandibular; Anestesia Dentária.

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INTRODUCTION

Inferior alveolar nerve block (IANB) anesthesia is the most frequently elected technique in dental practice to induce anesthesia in mandibular teeth, mainly in endodontic,[1,2] restorative and surgical[3] procedures. IANB involves the deposition of local anesthetic solution into the pterygomandibular space, consequently soaking the inferior alveolar nerve just before it enters the mandibular foramen (MF).[4] Failure to inject local anesthetic solution directly into the pterygomandibular space – thus failing to reach the inferior alveolar nerve – will result in improper anesthesia.[5]

There are many explanations for inefficiency in IANB technique: pharmacological factors,[6] physiological aspects,[6,7] psychological causes[6] and incorrect IANB technique led by the operator or by a patient's anatomic variations[8] (bifid alveolar nerve, bone density,[9] accessory innervations of the lingual nerve, mylohyoid nerve and cervical plexus[6] and, especially, anatomic variations in mandibular foramen position due to age, absence of teeth or other individual characteristics).[10]

The accurate position of the MF is critical for obtaining a proper IANB.[11] It may be three-dimensionally positioned in relation to other anatomic structures at the maxillofacial complex[10] and should be easy to locate to allow operators to correctly position the needle during the IANB procedure.[12]

There are three main techniques for the inferior alveolar nerve anesthesia: inferior alveolar nerve block (IANB), Gow-Gates's block and Akinosi-Vazirani's block. In all three methods, the professional takes advantage of anatomical structures as reference for inserting the needle in the correct place before starting the anesthetic injection.[10,12,13] Some authors have suggested positioning a long needle slightly above the occlusal plane by the retromolar trigone region; however, they did not recommend a specific position for puncturing the mucosa.[14]

Cavalcanti et al.[15] and Yang et al.[16] established accurate and precise mandibular canal measurements by using computed tomography multiplanar reconstructions. The adoption of cone-beam computed tomography (CBCT) is widespread in dentistry,[17,18] and several software programs can be employed for measuring anatomic landmarks at the maxillofacial complex.[19,20]

Based on these studies, CBCT images were designated to perform measurements to determine the average position of the mandibular foramen using the anatomic landmarks of IANB technique as reference, seeking to successfully guide the dentist to execute the IANB technique.

MATERIALS AND METHODS

From our institution's CBCT database, the radiological records of 29 adult patients (14 males and 15 females) were selected. The sample consisted of 28 male and 30 female mandibular foramina from both left and right sides. A power test was conducted on an Internet-based website (http://powerandsamplesize.com) and it resulted in a powerful sample (power: 0.98). The patients' mean age was 32 years-old; male patients' age ranged between15 and 53 years old, and female patients' age ranged from 15 to 61 years old.

The inclusion criteria were partially or totally dentulous patients, who had all the following teeth: mandibular incisors, second premolars and either the first or the second molars. Exclusion criteria comprised patients younger than 15 years old and presence of maxillary or mandibular pathoses.

Imaging acquisitions were obtained by using a CBCT scanner (iCAT, Imaging Sciences International, Hatfield, PA, USA). This study protocol was established as 13 cm high by 16 cm diameter field of view (FOV), and 0.25 mm voxel size. This FOV allowed the mandible to be observed as a whole, including the condyle and coronoid process.

DICOM (Digital Imaging Communications in Medicine) files were uploaded to Imaging Studio Software version 3.007 (Annesolutions, São Paulo, SP, Brazil). First, an operator adjusted occlusal and medial plans to standardize the initial mandible position (occlusal plan parallel to the horizontal plan, and medial plan aligned to the anterior nasal spine, following the mental spine towards the midline between the condyles and perpendicular to occlusal plan). Subsequently, two previously trained and calibrated dental radiologists analyzed the images using multiplanar reconstruction images (MPR) to perform three different types of measurements: linear – two points at the same plane, angular – three points at the same plane, and three-dimensional measurement – two points in different planes –, as shown in Figure 1.

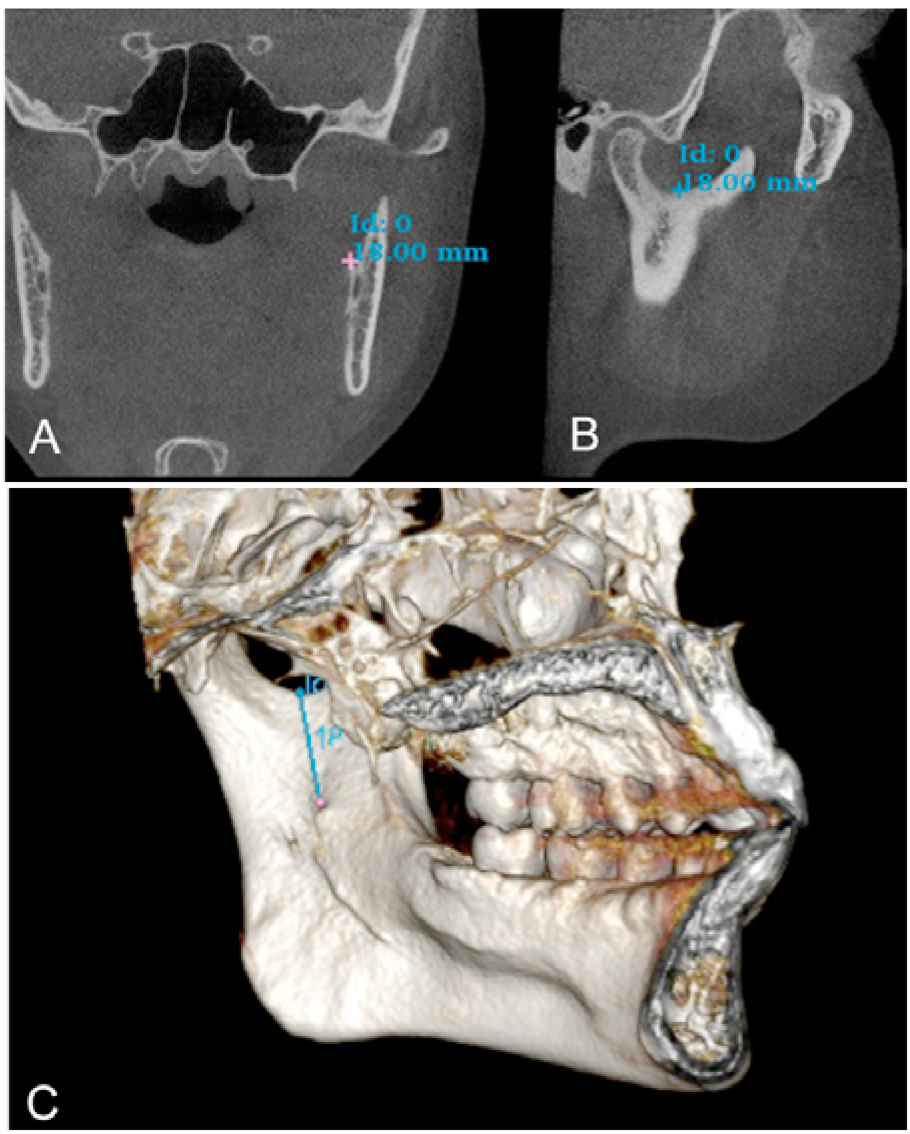

FIGURE 1 | Mandibular notch to mandibular foramen (MN-MF) 3D measurement (18 mm) on MPR images. (A) Coronal view, MF point – pink cross; (B) Sagittal view, MN point – blue cross; and (C) MN-MF measurement represented at 3D reconstructed image (MF – pink point, and MN – blue point).

Based on three mandibular nerve anesthesia techniques, six points, five lines and two angles were selected,[5,12,13] as shown in Table 1. All the anatomical landmarks were determined on MPR images, and the points and measurements were performed based on them (Figure 2). Mandibular foramen (MF) distances from the occlusal plan and the mandibular notch were determined based on a plan that was parallel to the occlusal plan and intersected with the MF (Figure 3). The examiners used the linear measurement tool to identify the anatomical structure landmark. Each landmark was identified on the MPR images and was confirmed with the assistance of multiplanar guides.[15,16] The CBCT volume was analyzed again, and the subsequent point was identified using the references described on Table 1. Finally, the software automatically calculated the smallest distance between the two anatomical landmarks.

Table 1 | Description of plans, points and measurements

	Abbreviation	Name	Description
Plans	OP	Occlusal plan	Occlusal plan that touches the molar cusps and incisal borders (Axial view)
	MFP	Mandibular Foramen plan	Parallel plan to OP that contains MF point (Axial view)
Points	MF	Mandibular Foramen	Lingula of the mandible superior border (Coronal view)
	MN	Mandibular Notch	Most inferior point at the mandibular notch. (Sagittal view)
	4C	Contralateral Premolars	Contact point between the first and the second premolars at the opposite lingula of the mandible side (Axial view)
	5C	Contralateral Second Premolar and Molar	Contact point between the second premolar and the first molar at the opposite lingula of the mandible side (Axial view)
	6	Premolars and Molars	Contact point between the second premolar and the first molar at the same lingula of the mandible side (Axial view)
	AB	Anterior border of mandibular ramus	Most anterior point at the mandibular ramus, located at the MFP (Sagittal view)
	PB	Posterior border of mandibular ramus	Most posterior point from the mandibular ramus, located at the MFP (Sagittal view)
Lines	OP- MF	Occlusal plane to Mandibular Foramen	Distance between OP and MFP, measured in a line perpendicular to these two planes.
	AB – MF	Anterior border to Mandibular Foramen	Distance between the anterior border of the mandibular ramus and Mandibular Foramen, measured at MFP
	AB – PB	Anterior border to posterior border	Distance between the anterior and the posterior borders of the mandibular ramus, measured at MFP
	MN – MF	Mandibular Notch to Mandibular Foramen	Distance between Mandibular Notch and Mandibular Foramen. 3D measurement (MP point located at the sagittal view and MF point at coronal view)
	4C – MF	Contralateral Premolars to Mandibular Foramen	Distance between contralateral premolars and Mandibular Foramen, measured at OP. MF point was projected to OP by a perpendicular line
Angles	4C – MF – 6	Contralateral Premolars – Mandibular Foramen – Molars	Angle formed by the molar lines and contralateral premolar lines. MF point was projected to OP by a perpendicular line.
	5C – MF – 6	Contralateral Second Premolar and Molar – Mandibular Foramen – Molars	Angle formed by the molar lines and contralateral Second Premolar/Molar lines. MF point was projected to OP by a perpendicular line

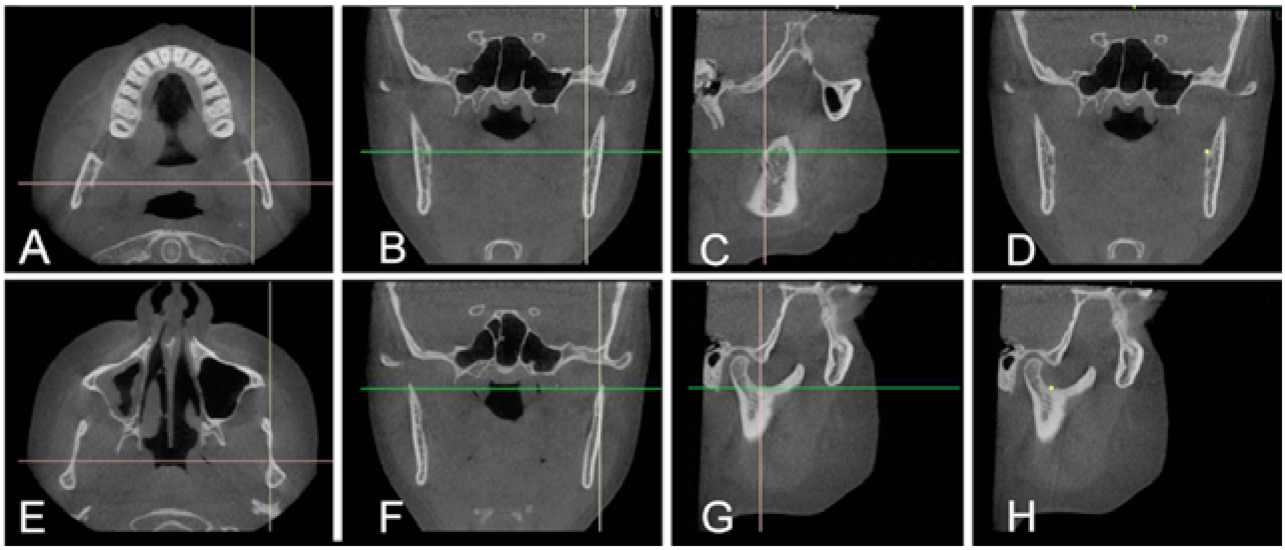

FIGURE 2 | Mandibular Foramen (MF) and Mandibular Notch (MN) points on MPR images. (A, E) Axial view; (B, F) Coronal view; (C, G) Sagittal view; (D) Coronal view, MF point inserted – yellow point; and (H) Sagittal view, MN point inserted – yellow point.

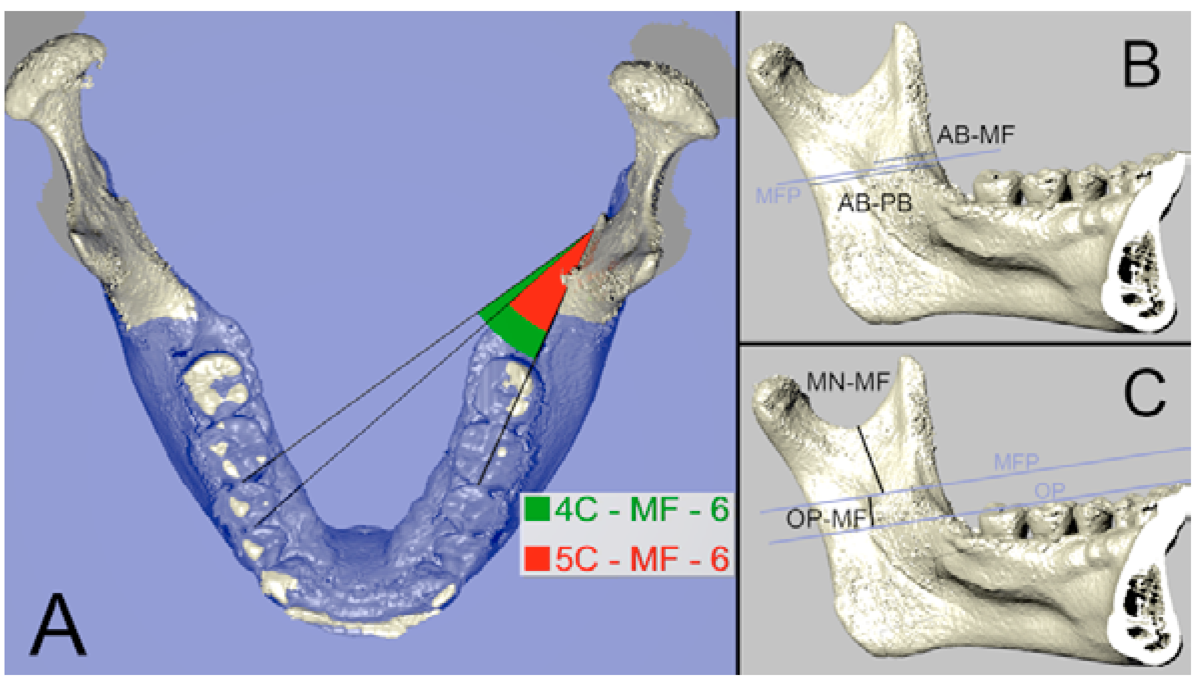

FIGURE 3 | Measurements illustrations. (A) Angular measurements performed at the occlusal plan (purple plan); (B) Linear measurements AB-MF and AB-PB performed at the mandibular foramen plan (MFP represented by a purple line); and (C) linear measurement OP-MF (distance between OP and MFP, measured in a line perpendicular to these two planes)

The lingula of the mandible superior edge/border was selected to identify the mandibular foramen point (MF) because the IANB technique recommends that the needle must be pointed towards the inferior alveolar nerve and anterior to the mandibular foramen gap.[13] The mandibular notch (MN) point was determined at the sagittal plane and the observer had to pinpoint its most inferior portion.

Data analyses consisted of obtaining the mean value of all patients and comparing the means between male and female patients. According to the Lilliefors test, only two measurements conformed to normality and for those, the parametric Student's t test (4C – MF and 4C – MF – 6) were used. The performances of the remaining measurements (OP – MF, AB – MF, AB – PB, MN – MF and 5C – MF – 6) were evaluated by adopting the nonparametric Mann-Whitney's U test. The measurements of inter examiner reliability were assessed by employing the interclass correlation coefficient (ICC), with a 95% confidence interval.

RESULTS

The mean distance between the occlusal plane and the mandibular foramen for all patients was 13.5 mm. This mean increased to 15.5 mm for male patients, and decreased to 11.7 mm for female patients, as described in Table 2. A statistically significant difference between male and female patients' means was found.

Table 2 | Mean values of the mandibular foramen measurements

	All Patient		Male Average		Female Average		p value
	N=58		N=28		N=30		
	Mean	SD	Mean	SD	Mean	SD	
OP - MF	13.5	5.0	15.5	3.7	11.7	4.6	<0.0001* (MW)
AB - MF	14.2	2.4	14.6	2.9	13.7	1.8	0.31 (MW)
4 - MF	75.4	3.1	77.0	3.8	74.7	2.5	0.0008* (t)
AB - PB	28.6	2.8	28.2	3.3	28.5	2.4	0.52 (MW)
MN - MF	14.6	4.3	14.9	5.4	13.8	3.0	0.96 (MW)
4C - MF - 6	25.8	2.7	25.1	2.6	26.0	2.9	0.060 (t)
5C - MF - 6	31.5	2.7	30.6	2.7	31.8	2.9	0.030* (MW)

SD: Standard Deviation; MW: Mann-Whitney's U test; t: Student's t test; *: Statistic significance at 5%

Based on AB-MF and AB-PB measurements results, we determined that the mandibular foramen is located slightly closer to the anterior ramus than to the posterior ramus, and at a mean distance of 14.2 mm below the mandibular notch.

The distance from the mandibular foramen to the mandibular notch (MN – MF) did not present a statistically significant difference between male (median: 14.9 mm) and female (median: 13.8 mm) patients. The mean linear distance between the contralateral premolars and the mandibular foramen (4C – MF) for all patients was 75.4 mm. We found a significant difference between genders; male patients' mean was higher (77.0 mm) when compared to the female patients' mean (74.7 mm).

Another important measurement is the angle formed by the molars on the anesthesia side, the mandibular foramen and the contralateral premolars (4C – MF – 6). This is the recommended syringe position during the nerve block procedure.[16] The mean value for this angle was 25.8°. The other angle (5C – MF – 6), which was also related to the syringe position – but using the contralateral second premolar and subsequent molar as reference –, was wider in female patients, 31.8°, than in male patients, 30.6° (p value 0.030).

The ICC ranged between 0.8776 and 0.9793, demonstrating an almost perfect agreement between examiners (Table 3). The highest and the lowest deviations were found for AB – MF and 4C – MF – 6, respectively.

Table 3 | Interclass correlation coefficient (ICC) for each measurement made by examiners1 and 2

	ICC	(95% CI)
OP – MF	0.9434	(0.9024 to 0.9675)
AB – MF	0.9793	(0.9638 to 0.9882)
4 – MF	0.9461	(0.9070 to 0.9691)
AB – PB	0.9581	(0.9273 to 0.9760)
MN – MF	0.9736	(0.9539 to 0.9849)
4C – MF – 6	0.8776	(0.7939 to 0.9286)
5C – MF – 6	0.8828	(0.8023 to 0.9318)

DISCUSSION

Some anatomic variations that may induce IANB failure include a robust mandible, bulky musculature or excess of adipose tissue. Furthermore, the mandibular foramen position is one of the most variable in the body since it depends on mandible growth and shape, as well as on the ascending ramus size, height and width.[15] Our database, presented a wide variety of mandibular shapes and foramen positions.

Cvetko[21] related the case of a mandibular foramen at a higher position. She proposed the use of Akinosi-Vazirani's block technique variation, in which the needle is angled towards the maxillary occlusal plane, in a position closer to the mandibular notch. The mandibular notch is an important landmark since the anesthetic solution should not be injected above it, because the liquid could soak into other important structures and cause complications for the patient.[22,23] Our results indicate that the mean distance between the mandibular foramen and the mandibular notch is 14.6 mm. This measurement suggests that the operator should not position the needle any higher than 1.0 cm above the mandibular foramen to maintain a safe distance from the mandibular notch.

Two measurements adopted in this research were the distance between the anterior border of the mandibular ramus and the mandibular foramen (AB-MF), and the distance between the anterior and the posterior borders of the mandibular ramus (AB-PB). These distances may be used as reference for the length of the needle to be introduced into the soft tissue. Monnazzi et al.[24] performed different types of mandibular foramen measurements in dry mandibles with a caliper. In their study, the jaw base was determined as the horizontal plan reference. We found similar measurements even though we established different landmarks.

According to Kang et al.,[10] the distance between the occlusal plane and the mandibular foramen was 3.8 mm on adult patients when using the mandibular foramen on both sides of the mandible as reference. In our study, we used the MF as a reference point to perform this measurement due to the technique used (the needle had to deposit the local anesthetic solution above the mandibular foramen, before the inferior alveolar nerve entered the mandibular canal). The mean distance in our study was 13.5 mm.

Findik et al.[25] performed mandibular foramen measurements in CBCT based on surgical procedures needs. Only the AB-MF measurement was similar to our study, with close results (Findik et al.: 15.6 mm and our study: 14.2 mm), although their proposition was different than ours. Findik et al.[25] and Kang et al.[10] used the center of the mandibular foramen as the landmark in their studies and they obtained different results than ours. We believe that this happened because we used the mandibular lingula superior border as the mandibular foramen reference. Furthermore, the patients' ages in Kang et al.[10] study ranged between 8 and 25 years-old, whereas in our study the ages ranged from 15 to 61 years-old.

Based on the measurements obtained in our study and in Thangavelu et al.,[26] the dentist may use a long needle to perform IANB. However, the dentist may not necessarily introduce the entire length of such needle (3.5 cm) since our study found a 1.4 cm distance from the mandibular foramen to the anterior border of the mandibular ramus. According to Malamed,[13] this distance ranges between 2.0 and 2.4 cm; however, his distance is based on soft tissue puncture, whereas our measurement is solely based on bone anatomical landmarks. The intraoral insertion point should be approximately 1.4 cm above the occlusal plane and the barrel of the syringe should be positioned over the contralateral mandibular premolars at a mean angle of 25°.

In this study, CBCT images were elected solely by reasons of image quality and precision to obtain measurements.[16] Thus, the CBCT images selected for this study were previously acquired for diagnostic purposes. Based on the ALARA ("as low as reasonably achievable") principle, we do not endorse the request of a CBCT scan for patients in whom the IANB failed. In other words, is unquestionably not allowed to perform a CBCT exam to determine the patient's mandibular foramen position.

In conclusion, CBCT images were a useful method to provide the measurements of the position of the mandibular foramen based on landmarks used on the IANB technique. We encourage the use of these measurements as references to increase the clinical success when performing the IANB technique.

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