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Mandibular Incisive Canal Morphometry: A Cone-Beam Computed Tomography Study in Jordan

Morfometría del Canal Incisivo Mandibular: Un Estudio de Tomografía Computarizada de Haz Cónico en Jordania

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SUMMARY: Mandibular incisive canal (MIC) and related mental foramen (MF) and anterior loop (AL) morphometrics are important landmarks in medical and dental clinical applications. The main aim of this retrospective study to determine the morphometry of the mandibular incisive canal (MIC) in a Jordanian population and to propose a new shape-pattern classification of the MIC. In addition, MF and AL morphometrics were determined. Carestream 3D imaging software was used on 100 Cone-Beam Computed Tomography (CBCT) of a Jordanian population to determine the MF, AL and MIC morphometrics. The detection prevalence of the MIC was 96 %. The right and left MIC showed four distinct line patterns, proposed for the first time in this paper. The line-patterns were angular (L-line), straight (I-line), curved (V-line) and wavy (W-line), with a prevalence of 41 %, 19 %, 25.5 %, and 10.5 %, respectively. MF was detected in all mandibles with a round shape in 58 % of the images. The most common horizontal and vertical positions of the MF were H4 and H3 (73.5 %) and V3 and V2 (95 %), respectively. An accessory MF was detected in 14.5 % of the samples and was more prevalent in males and on the right side. AL was detected in 92.5 % of the samples and exhibited a pattern prevalence of 25.5 %, 40 % and 27 % for types I, II and III, respectively. Results revealed that asymmetry and gender differences between right and left MIC, MF, AL and AMF was seen in patient's mandibles. In conclusion, this is the first study to propose and show that Mandibular incisive canal exhibits four potential line patterns (L, I, V and W lines patterns). Gender and ethnic variations of the mandibular canal landmarks morphometrics of both right and left hemi-mandible are important to be acknowledged in learning anatomy and when planning or performing dental and medical procedures.

KEY WORDS: Mandibular Canal; Mandibular Incisive Canal; Cone-Beam Computed Tomography; Mental Foramen; Mandible.

INTRODUCTION

Mandibular canal (MC), also called the inferior alveolar canal (IAC) since it carries the inferior alveolar nerve (IAN), extends from the mandibular foramen on the medial surface of the mandible and ends on the lateral surface of the mandible at mental foramen (MF) forming the anterior loop (AL). Before exiting the MF, the IAN divides into two branches, mental branches that leave the MF and extend to provide the inferior lip and chin with sensation, while the second branch, called the incisive branch, passes anteriorly within the mandible through the mandibular incisive canal (MIC) to innervate the anterior lower teeth and related gingivae (Nelson, 2014; Iwanaga *et al*., 2020). The morphometrics of the MIC, MF, and AL have critical implications in a wide range of medical and dental procedures that involve the mandible. Acknowledging and addressing the variations in these mandibular landmarks when planning for treatments and interventions involving the mandible will significantly reduce potential complications related to neurovascular involvements, which are major concerns when performing dental implants, facial plastic surgery or facial fractures as highlighted by Caughey *et al*. (2021), Barbosa *et al*. (2021), and Pelé *et al*. (2021). Cone-beam computed tomography (CBCT) is increasingly employed in planning dental and surgical treatments and

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offers a valuable three-dimensional morphometry of the mandible since it is relatively low-dose scanning system that can build a three-dimensional tomography image slices using a conical X-ray beam and reciprocal image detector without superposition as described by Zmyslowska-Polakowska *et al*. (2019), and Pelé *et al*. (2021). Morphometries of the MC and its terminal landmarks have been researched to identify the different patterns and variations observed were classified according to ethnicity, gender, and mandibular asymmetry.

A systemic review by Pelé *et al*. (2021), highlighted the morphology and gender variations in mandible landmarks relative to the second premolar. One study of Prados-Frutos *et al*. (2017), using CBCT on a Spanish population over the age of 65 showed that AL was not detected in nearly 46 % of the examined mandibles and suggested a 0.67 mm safe margin from mental foramen to spare the AL neurovascular components. El Naudory *et al*. (2021), study reported that AL was detected in 40 % of 267 CBCT images from an Egyptian population. Similarly, Barbosa *et al*. (2021), review reported that the AL was detected in only 43 % of the subjects. AL with a Y shape pattern was detected in nearly 60 % of CBCT adults' sample from Saudi Arabia with an age range of 40-60 years by Alyami *et al*. (2021). Mashyakhy *et al*. (2021) retrospective study on a Saudi Arabian population revealed that MF was detected in 88 % of the examined CBCT mandibles (mean age of 28.74 ± 9.56 years) and it was located mostly inferior and close to the second premolar (~87 %) with a round shape (~45 %). Mohammad *et al*. (2016), analysis of two-dimensional panoramic images from a Palestinian population (Age 18 and above) showed that location of the MF lies close or anterior to apex of the second premolar in 79 % of the subjects.

Barbosa *et al*. (2021), recent review by reported that MF is located anterior or in line with the second premolar with an oval or circular shape in 87 % of examined CBCT images. A research study revealed that the most common vertical position of MF in Jordanian samples was below the level of root apices of mandibular premolar teeth and the most common horizontal location was between the first and second premolars with a round shape MF by Al-Khateeb *et al*. (2007). Similarly, Alsoleihat *et al*. (2018), study reported that MF horizontal location in 95 % of the subjects was between the first and second premolars and its size changes with age in both genders differently. On the other hand, Zmyslowska-Polakowska *et al*. (2019), study using a sample from a Polish population reported significant gender differences in the dimensions of the MF but not with age.

Most studies focused on MF and Al and their classifications; however, only a few studies reported the prevalence and morphology of the MIC despite its clinical importance (Caughey *et al*., 2021). For instance, a study reported the absence of MIC in 1 % in Belgian subjects and a gradual decrease in its diameter (Gilis *et al*., 2019). Dissections of the mandible by Mardinger *et al*. (2000), showed the MIC was present in all samples with a variable diameter; however, Parnia *et al*. (2012), reported that radiographically the MIC was visible in only 20 % of the same examined mandibles (MIC was detected in 83 % of CBCT images; whereas analysis of two-dimensional x-ray images by Kong *et al*. (2016), reported an MIC detection percentage of nearly 40. A retrospective study by Alshamrani *et al*. (2021), on Saudi Arabian subjects showed that MIC is detected in 97 % of the examined CBCTs with an average distance of 7.7 mm from the root tips of lower incisors. However, a study on Indian subjects (mean age of 20 - 60 years) by Ayesha *et al*. (2019), using CBCT images revealed that the MIC was not detected in 56 % of the samples. In summary, no studies attempted to report its prevalence or classifying the MIC patterns. This study aimed to determine the prevalence of the MIC among the Jordanian population using CBCT images and attempted to classify the potential patterns of the MIC. Moreover, this study investigated the prevalence of the different types of AL, MF and accessory mental foramen (AMF) as well as their shapes.

MATERIAL AND METHOD

A retrospective epidemiological study was carried out using CBCT images of 100 Jordanian subjects who were referred to imaging medical centers which have the same model of CBCT between 2018 and 2021. The Institutional review board (IRB) of The Hashemite University reviewed and approved the study and the STROBE checklist was followed. Soft copies of anonymized images, coded by serial numbers with age and gender data were obtained. Images were analyzed using the Carestream 3D imaging software Images (New York, USA) for mandibular morphometric landmarks related to MF, AL and MIC measured by experienced technicians after the intra and inter observer errors were assessed before data collection (Table I). The inclusion criteria included were Jordanian subjects with no mandibular deformity. Data collected were categorized based on gender and mandible lateralization (R/L). MIC shapes were first identified for all images and a potential patterns classification were proposed based on the shape of the line assumed by the canal. MIC prevalence and line patterns were then determined for all mandibles bilaterally. The mandibles with deformity that might affect the measurements and observations have been excluded. Prevalence of AL, MIC, and MF was presented using percentage and sexual difference was assessed using the Chi Square test of independence and significance were determined at a P value less than 0.05.

RESULTS

Mandibular Incisive canal (MIC). The sample collected has an age range of 25 – 66 years and a 48:52 males to females' ratio. Images of the MIC revealed different shapes and directions that starts at the mental foramen and extend anteriorly between the apices of the lower incisors. These shapes might be categorized into four potential line patterns based on the shape and direction of the canal it assumes; angular (L-line), straight (I-line), curved (V-line) and wavy (W-line) lines (Fig. 1). MIC prevalence was 96 % and the prevalence of MIC line patterns based on the proposed classification seen in Figure 1 were: 41 %, 19 %, 25.5 %, 10.5 %, for the angular (L-line), straight (I-line), curved (V-line) and wavy (W-line) lines, respectively (Table II). Data showed slight differences in the symmetry between right and left halves of male mandibles while asymmetry was evident in the straight and curved shapes of females between right and left halves. Statistical analysis showed no significant gender differences in the distribution of MIC proposed types on the right or left sides of the mandible. However, statistical analysis showed that there was a significant difference between right and left sides of female's MIC types but not in males.

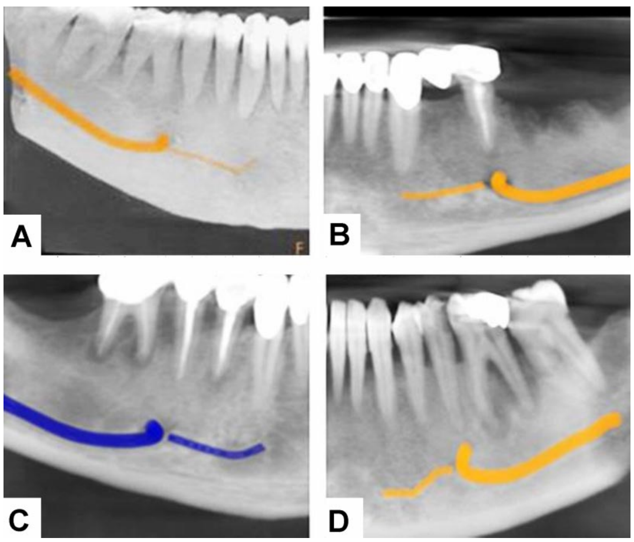

Fig. 1. Proposed patterns of the Mandibuklar incisive canal (MIC): A: Angular(L-line); B: Straight(I-line);C: Curved (V-Line); D: Wavy (W-line).

Mental Foramen and Anterior Loop. Results showed that mental foramina were detected in all examined mandibles bilaterally and assume most commonly a round shape (58 %), while the H-Oval and V-Oval were reported 22 % and 20 % respectively in patient's mandibles (Table I). MF vertical and horizontal location was found very close to apex of the second premolar in most cases, vertically 62.5 % of MFs lie below the level of the apices of the first and second mandibular premolar teeth (V3), 32.5 % of MFs lie at the level of the apices of the first and second mandibular premolar teeth (V2) while only 5 % of MFs lie above the level of the apices of the first and second mandibular premolar teeth (V1). Horizontally 44 % of MFs lie at the level of the second premolar (H4), 28.5 % of MFs lie between the first and second premolar (H3), 22 % of MFs were at the level of the first premolar (H2), 3 % of MFs were between the second premolar and the first molar (H5), 2.5 % of MFs

Table I. Mandibular morphometric criteria.

#	Landmark	Features Studied
1	Mental Foramen (MF)	Prevalence and shape (H-oval, V-oval, and Round) were classified based on Sekerci *et al*. (2013).
2	Mental Foramen (MF)	Vertical position (V1, V2, and V3) and horizontal position (H1, H2, H3, H4, H5, and H6) were classified based on Sekerci *et al*. (2013) work.
3	Mental Foramen (MF)	Distance between MF and midline and the distance between MF and inferior margin margin of mandible and prevalence of accessory mental foramen (AMF).
4	Anterior loop (AL)	Presence and shapes (I, II, and III) were classified based on Solar *et al*. (1994) work.
5	Mandibular Incisive Canal (MIC)	Prevalence and line-patterns were classified based on a proposed classification of four types angular (L-line), straight (I-line), curved (V-line) and wavy (W-line) lines.

Table II. Mandibular incisive canal prevalence and morphology distribution according to sex and bilateral symmetry.

Mandibular incisive canal		Male (n=48)		Female (n=52)		Total (n=100)	%
		R	L	R	L		
Presence	Yes	46	46	50	50	192	96
Classification	Angular (L-line	19	17	24	22	82	41
	Straight (I-line)	6	9	6	17	38	19
	Curved (V- line)	16	14	14	7	51	25.5
	Wavy (W- line)	5	6	6	4	21	10.5

lie between the canine and first premolar (H1) whereas the presence of MFs at the level of the first molar was not seen in any patient's images (Table III). Statistical analysis showed no significant gender differences in the distribution of MF shapes on the right or left sides of the mandible. In addition, statistical analysis showed that there was no significant difference in the shape of MF between right and left sides of males or females.

The mean distance of the right mental foramina (RMF) and left mental foramina (LMF) from the midline and the inferior margin was slightly more in males than females. The mean distance of RMF from the midline was 28.39± 3.91 mm in males and it was 26.69± 3.04 mm in females, and the mean distance of LMFs from the midline was (28.40± 4.51 mm) in males and it was 25.74± 4.50 mm in females (Table II). The mean distance of RMF from the inferior margin of the mandible was found to be 13.28± 2.58 mm and 12.20± 1.90 mm in males and females respectively, while it was found that the mean distance of LMF from the inferior margin of the mandible was 13.51± 2.33 mm in males and 12.18± 1.66 mm in females (Table III).

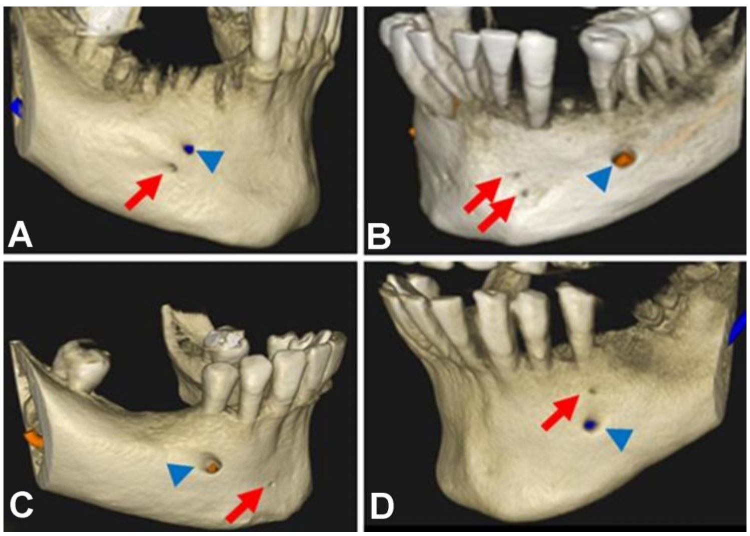

Fig. 2. Diagram show the accessory mental foramen (red arrows) and metal foramen (blue arrow heads).

Right and left accessory MFs (RAMFs and LAMFs) (Fig. 2) were detected in 21 % of all mandibles and it was found that RAMFs (16 %) is more prevalence than LAMFs (13 %). In addition, AMF were present more in males than females (Table III). Observational data showed that there was no symmetry between RAMFs and LAMFs in the shape, position and numbers (Fig. 2).

The anterior loop (AL) prevalence and classes were determined and data extracted showed that AL was not detected in 7.5 % of the CBCT collected images. Different classes of AL shapes were seen and type II was the most prevalent with 43 % while type I and III prevalence's were 28 %, and 29 %, respectively based on Solar *et al*. (1994) work (Table IV). Data showed differences in the symmetry between right and left halves of male

Table III. Mental Foramen prevalence and morphology distribution according to sex and bilateral symmetry.

Mental foramen (MF) Feature		Male (n=48) R	L	Female (n=52) R	L	TOTAL (n=100)	%
Presence	Yes	48	48	52	52	100	100
Horizontal location	H1	2	3	0	0	5	2.5
	H2	13	14	9	8	44	22
	H3	10	10	19	18	57	28.5
	H4	21	19	23	25	88	44
	H5	2	2	1	1	6	3
	H6	0	0	0	0	0	0
Vertical location	V1	4	4	1	1	10	5
	V2	10	11	22	22	65	32.5
	V3	34	33	29	29	125	62.5
Shape	Round	31	34	35	36	136	67.5
	V-Oval	1	1	2	1	5	2.5
	H-Oval	16	13	15	16	60	30
MF distance from mandible midline (M±SD)	mm	28.39±3.91	28.40±4.51	26.69±3.04	25.74±4.50	-	-
MF distance from mandible inferior margin (M±SD)	mm	13.28±2.58	13.51±2.33	12.20±1.90	12.18±1.66	-	-
Presence of right accessory MF (RAMF)	Yes	10		6		16	16
Presence of left accessory MF (LAMF)	Yes	9		4		13	13

Table IV. Anterior Loop prevalence and morphology distribution according to sex and bilateral symmetry.

Anterior loop (AL) Feature		Male (n=48) R	Male (n=48) L	Female (n=52) R	Female (n=52) L	Total (n=100)	%
Presence	Yes	48	46	44	47	185	92.5
Classification	Type 1	19	6	15	11	51	28
	Type 2	18	21	16	25	80	43
	Type 3	11	19	13	11	54	29

mandibles AL types I and III while this asymmetry was seen in type II between right and left halves mandibles of females. Statistical analysis showed no significant gender differences in the distribution of AL types on the right or left sides of the mandible. However, statistical analysis showed that there was a significant difference between right and left sides of male anterior loop types but not in females.

In summary, results revealed asymmetry and gender differences between right and left MIC, MF, AL and AMF was seen in patient's mandibles. Moreover, results showed that MF and MIC if present is always bilaterally, while the presence of AL in some mandibles is unilaterally.

DISCUSSION

This study is the first attempt to classify MIC patterns and images scanning revealed four patterns (Fig. 1). Few articles by Caughey *et al*. (2021), Gilis *et al*. (2019), Mardinger *et al*. (2000) and Alshamrani *et al*. (2021) and Ayesha *et al*. (2019) study MIC and concentrated on its prevalence, diameter and buccal and lingual thickness of bone which support the differences in prevalence seen in our findings based on ethnicity regarding the undetected MIC was attributed to inability of image features to identify the canal or the small diameter of the canal or real absence. Akbulut & Orhan (2021) Turkish study reported a lower prevalence of the MIC and a 10.7 mm vertical distance from lower margin of mandible.

Similarly, in this study AL prevalence and types were similar to Ahmed *et al*. (2021), work and it support variations based ethnicity, gender and bilateral symmetry researched by Prados-Frutos *et al*. (2017), El Naudory *et al*. (2021) and Alyami *et al*. (2021). it was found that the AL was detected in 92.5 % of patient's mandibles and type 2 was the most prevalence type in Jordanian people, there were however, no Jordanian studies regarding the AL to compare with. Contrary to an Iranian study using CBCT images, our study showed that AL type II was the most common which could be attributed to sample or ethnicity. Moreover, in an Iranian study by Shaban *et al*. (2017), the incisive canal was described as a forward continuation of MC and decrease in bone thickness of the buccal plate before and after the MF.

MFs were detected in all mandibles bilaterally and assumed most commonly a round shape (58 %) and most prominent in H4 (44 %) and V3 (62.5 %), which is at the level of the second premolar horizontally and below the level of the apices of the first and second mandibular premolar teeth vertically. Data from a Jordanian studies reported by Al-Khateeb *et al*. (2007), and Alsoleihat *et al*. (2018), that the most prevalence horizontal and vertical location of MFs and its shape were similar to our study. In Caucasian study by Neiva *et al*. (2004), it has been found that the most common location of the MF in relation to teeth was found to be below the apices of mandibular premolars.

Barbosa *et al*. (2021) and Pelé *et al*. (2021), recent reviews revealed that MFs have been studied extensively in different populations and results, similar to AL but to lesser extent, support differences related to gender, ethnicity and bilateral symmetry.

The mean distance of the right mental foramina (RMF) and left mental foramina (LMF) from the midline and the inferior margin were slightly more in males than females which might be explained by the larger size and higher density of male bones than female bones. The mean distance of RMF from the midline was 28.39± 3.91 mm in males and it was 26.69± 3.04 mm in females, and the mean distance of LMFs from the midline was 28.40± 4.51 mm in males and it was 25.74± 4.50 mm in females. These results were almost consistent with the results of Sheikhi & Kheir (2016) study in Iranian population which showed that the mean distances from mental foramen to midline were 25.86 mm (SD ± 0.27) and 25.53 mm (SD ± 0.31) in the right and left sides, respectively. In a Pakistani study by Badshah *et al*. (2016), it was found that the mean distance of RMF and LMF from the Medline were 29.1 ± 2.19 mm and 28.1 ± 2.12 mm respectively which showed slight differences from our study, and in Caucasian study by Neiva *et al*. (2004), work it showed that the distance of MF from the midline is 27.61 ± 2.29 mm. These differences in mandibular features may result from variations in mandible shape, size and metrics in different populations. Also the presence of bilateral asymmetry and gender differences may contribute to these differences.

The mean distance of RMF from the inferior margin of the mandible was found to be 13.28± 2.58 mm and 12.20± 1.90 mm in males and females respectively, while it was found that the mean distance of LMF from the inferior margin of the mandible was 13.51± 2.33 mm in males and 12.18±

1.66 mm in females. Our results were almost consistent with those of an Iranian study by Sheikhi & Kheir (2016) who reported for RMF and LMF from the inferior margin of mandible with significant gender difference. Differences in the mean distance of RMF and LMF from the inferior margin of mandible were seen in different ethnicities with gender differences in favor of males such as the Pakistani population by Badshah *et al*. (2016), which agree with our results. Moreover, findings of Mashyakhy *et al*. (2021), and Al-Mahalawy *et al*. (2017), were comparable with our results regarding the average distance of MF from the inferior margin. However, no Jordanian studies reported the mean distance of MF from the midline or inferior margin of the mandible.

The prevalence of AMFs was 21 % of all mandibles, while Al-Khateeb *et al*. (2007), study showed that the AMFs were seen just in 10 % of northern regional Jordanian population. The difference may be due to the variation in studying method, our study depends on CBCT method which is more accurate than panoramic images, and also this result was higher than the result of Lam *et al*. (2019), study which reported that the prevalence of AMF was found to be 6.4 %. The alteration may be due to the smaller our sample size (100 images) comparability to the sample size of Lam *et al*. (2019), study (4000 images), Even though the result of our study is nearer to the result of Iwanaga *et al*. (2016), study which indicated that the incidence of AMF was 14.3 %. The variation of prevalence of AMF between studies may as a result of Ethnicity, sample size, studying method. Our study indicated that RAMF (16 %) was more prevalence than LAMF (13 %) and both right and left AMF more prevalence in males than females; there was no symmetry between RAMF and LAMF in the shape, position, and numbers. Our findings were similar to Pelé *et al*. (2021) and McKay *et al*. (2018) findings.

CONCLUSION

In conclusion, our research showed that MIC exhibits four different patterns based on the line of its canal (angular (L-line), straight (I-line), curved (V-line) and wavy (W-line) lines); the Angular-line was the most common and variations related to gender and lateralization were evident in the examined samples. Knowledge of the MIC morphometries and its variations is essential in learning clinical dental anatomy as well as in medical and dental clinical settings involving the anterior part of the mandible to avoid injury to nerves and blood vessels.

MF and AL prevalence's and patterns were comparable with variations related to gender and lateralization were evident in the examined samples.

Institutional Review Board Statement. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the Hashemite University IRB N. 4/4/2021/2022 on 23/1/2022.

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RESUMEN: Las relaciones de la morfometría del canal incisivo mandibular (MCI), del foramen mentoniano (FM) y del asa anterior (AA) son hitos importantes en las aplicaciones clínicas médicas y dentales. El objetivo principal de este estudio retrospectivo fue determinar la morfometría del MCI en una población jordana y proponer una nueva clasificación de patrón de forma del MCI. Además, se determinaron la morfometría de FM y AA. Se utilizó el software de imágenes 3D Carestream en 100 tomografías computarizadas de haz cónico (CBCT) de una población jordana para determinar la morfometría de FM, MCI y AA. La prevalencia de detección de MCI fue del 96 %. El MCI derecho e izquierdo mostraron cuatro patrones de líneas distintas, propuestas por primera vez en este artículo. Los patrones de líneas fueron angulares (línea L), rectos (línea I), curvos (línea V) y ondulados (línea W), con una prevalencia del 41 %, 19 %, 25,5 % y 10,5 % respectivamente. Se detectó el FM en todas las mandíbulas y con forma redonda en el 58 % de las imágenes. Las posiciones horizontal y vertical más comunes del FM fueron H4 y H3 (73,5 %) y V3 y V2 (95 %), respectivamente. Se detectó FM accesorio en el 14,5 % de las muestras y fue más prevalente en el sexo masculino y en el lado derecho. AA se detectó en el 92,5 % de las muestras y exhibió un patrón de prevalencia del 25,5 %, 40 % y 27 % para los tipos I, II y III, respectivamente. Los resultados revelaron asimetría y diferencias en el sexo entre MCI, FM, AA derecha e izquierda en las mandíbulas de los pacientes. En conclusión, este es el primer estudio que propone y muestra que el canal incisivo mandibular exhibe cuatro patrones de líneas potenciales (patrones de líneas L, I, V y W). Es importante reconocer las variaciones étnicas y de sexo de la morfometría de los puntos de referencia del canal mandibular de la hemimandíbula derecha e izquierda al estudiar y aprender anatomía y al planificar o realizar procedimientos médicos y dentales.

PALABRAS CLAVE: Canal Mandibular; Canal Incisivo Mandibular; Tomografía Computarizada de Haz Cónico; Foramen mental; Mandíbula.

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