

Assessment of Implant-Related Anatomical Landmarks in the Mandibular Interforaminal Region in an Iranian Population Using Cone-Beam Computed Tomography

Abstract

Background: This study was aimed to assess the implant-related anatomical landmarks in the mandibular interforaminal region in an Iranian population using cone-beam computed tomography (CBCT). **Methods:** In this retrospective cross-sectional study, 378 CBCT images of the mandible were evaluated for the presence of the incisive canal, anterior loop of the inferior alveolar nerve (IAN), mandibular canal, mental foramen, and incisive canal. The effect of age and gender of patients on the abovementioned variables was also evaluated. Data were analyzed using independent *t*-test, analysis of variance, and Chi-square test. **Results:** The anterior loop and the incisive canal were present in 36.24% and 97.62% of the cases, respectively. The mean length of the anterior loop and the incisive canal was 2.70 ± 1.20 mm and 12 ± 3.29 mm in the right, and 2.86 ± 1.24 mm and 12.21 ± 3.38 mm in the left side, respectively. The mean diameter of the mental foramen and incisive canal was 4.25 ± 1.08 mm and 1.89 ± 0.46 mm in the right, and 4.21 ± 1.02 mm and 1.94 ± 0.45 mm in the left side, respectively. The descending path was the most common path of the incisive canal. The distance from the incisive canal to the buccal plate and inferior border of the mandible was significantly shorter in females ($P < 0.001$). **Conclusion:** Considering the high variability and clinical significance of the incisive canal and anterior loop of the IAN, and their high prevalence, it is recommended to assess the presence/absence of these structures in the interforaminal region of the mandible on CBCT scans before surgical procedures in this region.

Keywords: Anatomical landmarks, cone-beam computed tomography, inferior alveolar nerve, mandible

Introduction

The anterior mandibular region, known as the interforaminal region, is often considered a safe zone with no serious complication after implant surgery, osteotomy, genioplasty, orthognathic surgery, and posttrauma surgical procedures in this region.^[1-3] The reason is the absence of important sensory and motor nerves or large blood vessels in this region.^[3] However, due to the anatomical variations, knowledge about the anatomy of the structures in the anterior mandibular region is imperative before surgical procedures in this region.

There are three important anatomical structures in the anterior mandibular region namely the incisive canal, the mental foramen, and the anterior loop of the inferior alveolar nerve (IAN).^[4] The incisive canal is the anterior extension of the mandibular

canal toward the mental foramen, which contains the incisive neurovascular bundle. It often extends bilaterally from the mental foramen toward the lateral incisors.^[1] The incisive nerve innervates the incisors, canines, and first premolar teeth.^[5] The percentage of visibility, length, and diameter of the incisive canal on three-dimensional (3D) scans are reportedly 83%–97.5%, 6.11–17.84 mm and 0.82–2.14 mm, respectively.^[1,4,6,7]

The mental foramen is an important funnel-shaped anatomical landmark in the buccal plate of the anterior mandibular region. It is often used as a reference to determine the boundaries of the IAN in surgical procedures such as osteotomy and implant placement.^[8,9] The mental foramen may be round or oval, and its location may vary from the canine to the first molar site of the mandible.^[10] Its diameter is reportedly 2.85–4.15 mm on 3D scans.^[8,11]

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The anterior loop of the IAN is an anatomical variation in the path of the mandibular canal.^[7,8] The percentage of visibility (7%–90%) and length (0.89–7.99 mm) of the loop widely vary in the literature.^[1,4-6,9,12-14] These anatomical structures can be used to determine the proper site of implant placement, genioplasty, and mandibular fracture surgery to prevent neurosensory disturbances.^[15]

After tooth extraction and alveolar bone resorption, the mental foramen approximates the alveolar crest. In more acute conditions, the mandibular canal and mental foramen may even appear on the surface of the alveolar ridge crest.^[10] In case of not paying attention to anatomical variations of these structures, adverse consequences may occur including pain, discomfort, traumatic neuromas, failure in implant osseointegration, postoperative anesthesia, paresthesia and dysesthesia, which may be temporary or permanent, bleeding and ecchymosis due to direct injury to the nerve or its indirect traumatization due to compression caused by edema, hematoma, infection, or tension.^[8]

Despite the wide availability and easy use of periapical and panoramic radiographic modalities, they are not suitable for the identification of the anterior loop of the IAN since they suffer from distortion and magnification and cannot reconstruct images in buccolingual dimension. Thus, the anterior loop is often mistaken for a large incisive canal.^[4,8] Cone-beam computed tomography (CBCT) has been recently employed for this purpose,^[2,4,7-9,12,15] which is highly accurate for precise presurgical assessment of the region.^[13]

Despite the available literature on the prevalence and anatomy of the anterior loop of the IAN, it has not been adequately emphasized in textbooks, and most dental clinicians are not well acquainted with this anatomical variation. This lack of knowledge may lead to serious intraoperative and postoperative complications.

A few studies are available on the anterior loop of the IAN with widely controversial results.^[6,15,16] Thus, this study aimed to assess the implant-related anatomical landmarks in the mandibular interforaminal region using CBCT in an Iranian subpopulation residing in the west of Iran to provide reference data regarding the surgically safe zone in the anterior mandibular (interforaminal) region for dental clinicians.

Methods

This retrospective cross-sectional study evaluated the CBCT scans retrieved from the archives of an oral and maxillofacial radiology clinic in Kermanshah city. The study was approved by the ethics committee of Kermanshah University of Medical Sciences (ir.kums.ac. 1394.357).

The minimum sample size was calculated to be 378 (189 in each group) according to a study by Chen *et al.*,^[8] assuming the standard deviation of the length of the anterior loop of

the IAN to be 1.81 and 1.72 mm, and the mean values of 0.87 and 1.46 in males and females, respectively, alpha = 0.05, and power of 90%.

A total of 400 CBCT scans of the mandible requested for diagnostic purposes such as implant placement, orthognathic surgery, surgical extraction of impacted third molars or other impacted teeth, trauma, bone pathologies, root fracture, or complex endodontic treatment were retrieved and collected using convenience sampling. Written informed consent was obtained from patients before using their CBCT scans in this study.

The inclusion criteria were bilateral visualization of the mandible, high-quality of images (enabling the determination of root canal boundaries and no blurring due to patient movement while scanning), and optimal bone density (enabling the detection of the mandibular canal and outlining its boundaries).

The exclusion criteria were the presence of extensive artifacts, especially in the interforaminal region (due to the presence of metal dental restorations), pathology affecting the position of mental foramen or the anterior loop of the IAN, presence of an extensive bony lesion/defect in the interforaminal region, and severe resorption of the alveolar ridge (alveolar ridge crest reaching the mandibular canal). The flowchart of the selection process is shown in Figure 1.

Twenty-two images did not meet the eligibility criteria and were excluded. A total of 378 bilateral images of the mandible were selected by convenience sampling and

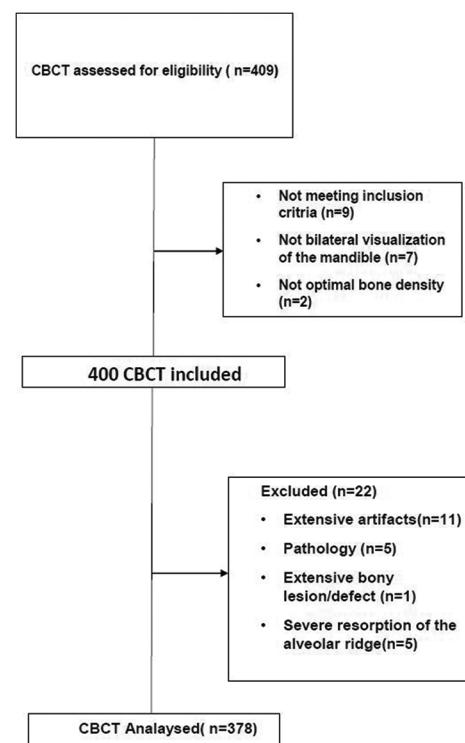


Figure 1: The flowchart of selection process

evaluated. All CBCT scans had been obtained between 2015 and 2018 using NewTom VGi CBCT scanner (QR SRL Co., Verona, Italy) with the following exposure settings: 0.150 mm voxel size (axial pitch), 110 kVp, 10.88 mA, 5.4 s exposure time, and 12×8 -inch field of view.^[2] The NNT Viewer 6.1.0 software (NewTom; QR SRL Co., Verona, Italy) was used to reconstruct the images in sagittal, coronal and axial planes, reconstruct Panorex images, and perform the measurements.^[2,17]

The age and gender of patients were recorded. Panorex images with 8-mm thickness were obtained. Next, the mental foramen at each side was evaluated on axial, coronal, and sagittal planes to find the anterior loop of the IAN. The software enabled the observation of all three planes at the same time on a multiplanar reconstruction (MPR) slice with 0.15-mm thickness to enhance the speed and accuracy of observation of images. In cases where the incisive canal and the anterior loop of the IAN were detected, the following measurements were also made on Panorex images reconstructed from the CBCT scans:

- The position of the IAN (single or double)
- The path of the mandibular canal at the mental foramen
- Presence of the incisive canal
- Path of the incisive canal
- Horizontal distance between the mesial surfaces of the mental foramina in the right and left sides
- Length of the anterior loop of the IAN
- Presence of retromolar canal.

The axial sections were reconstructed when the mental foramina and the buccal and lingual borders of the mandible were visible. After reconstructing the panoramic curve, cross-sectional images perpendicular to the mandibular dental arch with 0.5-mm thickness and 1 mm steps were reconstructed to measure the diameter and height of the mandibular canal (vertical distance from the inferior border of the canal to the inferior border of the mandible), diameter and vertical position of the mental foramen (distance from the superior border of the mental foramen to the alveolar crest and distance from the inferior border of the mental foramen to the inferior border of the mandible), diameter and distance from the incisive canal to the buccal and lingual mandibular borders, alveolar crest, and inferior border of the mandible.

On the Panorex images reconstructed from the CBCT scans, the mandibular canal path toward the mental foramen orifice was classified into three patterns of linear, vertical, and anterior loop according to the classification by Al-Mahalawy *et al.*^[9] [Figure 2]. In the case of detection of the loop, a line (line A) was drawn from the most anterior point of the loop margin, where the incisive canal originated, perpendicular to the inferior margin of the mandible. Another line (line B) was drawn from the anterior border of the mental foramen perpendicular to the inferior border of the mandible. The shortest direct linear distance between

the lines A and B was drawn and measured as the length of the anterior loop of the IAN [Figure 3]. The internal angle of the loop created by the superior border of the canal was considered as the angle of the loop [Figure 4].

After observing the incisive canal on the images, its path was classified into three groups of ascending, descending and linear, relative to the inferior margin of the mandible according to the classification by Rosa *et al.*^[7] [Figure 5].

Next, the incisive canal length was calculated by subtracting the number of the cross-sectional view of the posterior border of the canal (canal origin) from the number of the last cross-sectional view visualizing the

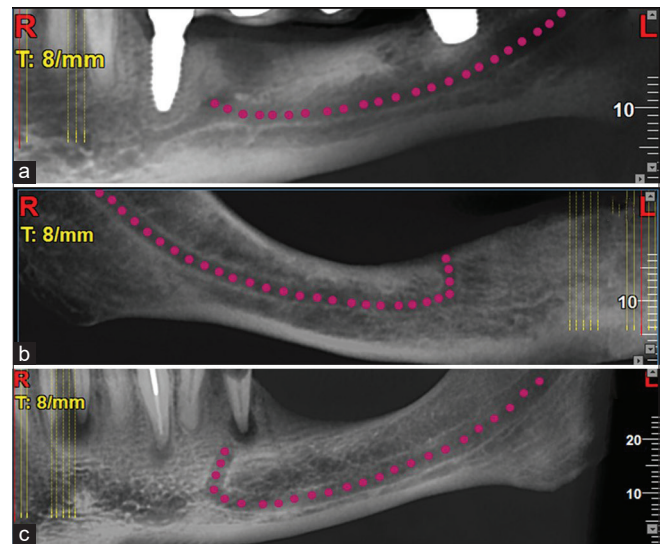


Figure 2: Mandibular canal path towards the mental foramen: (a) Linear path, (b) vertical path, (c) anterior loop

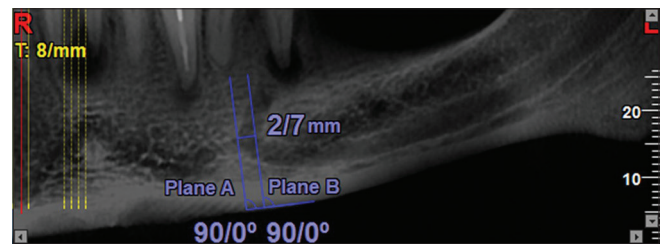


Figure 3: Schematic view of measurement of the length of the anterior loop of the inferior alveolar nerve on a panoramic image. Line A was drawn from the most anterior point of the loop perpendicular to the inferior margin of the mandible. Line B was drawn from the anterior border of the mental foramen perpendicular to the inferior border of the mandible. The shortest distance between the lines A and B was measured as the length of the anterior loop

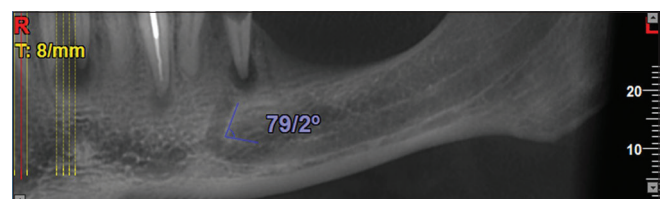


Figure 4: Schematic view of measurement of the angle of the anterior loop of the inferior alveolar nerve on panoramic images

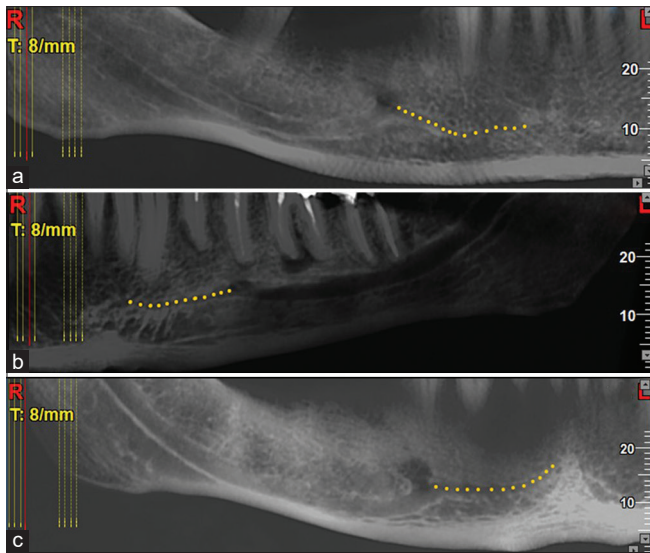


Figure 5: Schematic view of the incisive canal path relative to the inferior margin: (a) Descending, (b) linear, (c) ascending

cortical opaque border of the canal. The horizontal position of the mental foramen was determined by measuring the distance between the mesial borders at the two sides on Panorex images reconstructed from the CBCT scans.

In the MPR mode, the number of mental foramina and presence of accessory mental foramen were evaluated on reconstructed coronal and sagittal images at both sides.

On Panorex images reconstructed from the CBCT scans, bifid canals branched from the mandibular canal posterior to third molars or originating from a foramen other than the mandibular foramen, and the bifid retromolar or mandibular canals extending towards the third molars were also classified as double mandibular canals [Figure 6]. The patients were also divided into three age groups of 14–41 years, 42–52 years, and ≥ 53 years.

All observations were made by a dental student under the supervision of two oral and maxillofacial radiologists. To assess the intra-examiner reliability for the presence of canal, type of canal, and other measurements, the images were inspected again by the same dental student 2 weeks after the first observation and the results of the two observations were compared by calculating the intraclass correlation coefficient (ICC). All observations were made in a semi-dark room on a 14-inch laptop monitor with 300 dpi resolution, maximum brightness, and high-angle (X44H; Asus, Taiwan).

To assess the inter-examiner reliability, records of 30 patients were measured by both the instructor and dental student and the ICC was calculated.

The data were analyzed using independent *t*-test, analysis of variance (ANOVA), and Chi-square test via STATA version 14.2 software (Stata Corp., College, TX, USA) at 0.05 level of significance.

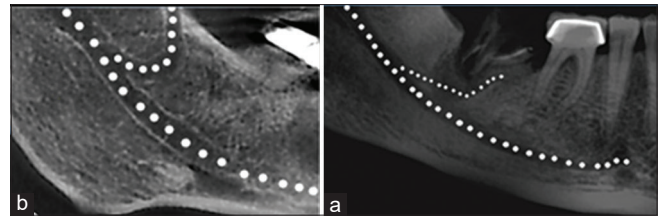


Figure 6: Schematic view of double retromolar canal (a) and double mandibular canal (b)

Results

The minimum ICC was 0.931, which was excellent according to Cicchetti's classification.^[18]

A total of 378 CBCT scans were evaluated; of which 193 (51.06%) belonged to females and 185 (48.94%) belonged to males. The mean age of patients was 47.08 ± 12.6 years (range 14–75 years). The mean age was 48.10 ± 12.24 years in females and 45.99 ± 12.89 years in males.

In terms of dental status, 8.2% were dentate, 2.65% were completely edentulous, and 89.15% were partially edentulous.

The prevalence of anterior loop was 36.24% and it was in the right side in 32.01% and in the left side in 26.46%. A significant correlation was noted between the presence of anterior loop and gender ($P = 0.001$, Chi-square test), such that the anterior loop was seen in 44.32% of males and 28.50% of females.

The mandibular canal was noted on all images. The diameter of the mandibular canal was 3.44 ± 0.69 mm in the right and 3.41 ± 0.63 mm in the left side. The height of the mandibular canal was 7.28 ± 1.60 mm in the right and 7.33 ± 1.35 mm in the left side. Of the mandibular canal patterns, the linear pattern had the highest prevalence (56.08%) followed by the vertical pattern (35.19%), and the anterior loop (36.24%).

A total of 756 sides were evaluated; out of which, the anterior loop was noted in 221 sides (29.23%); it was in the right side in 121 (32.01%) and in the left side in 100 (26.46%) sides.

The anterior loop was present bilaterally in 84 cases (22.22%).

There was no significant difference in the length of the anterior loop between the right and left sides ($P = 0.32$, *t*-test). On the right side, the length of the anterior loop in males was significantly greater than that in females ($P = 0.01$, *t*-test). There was no significant difference in the length of the anterior loop on the left side between males and females ($P = 0.129$, *t*-test).

The length of the anterior loop was not significantly different among different age groups (14–41, 42–52, and ≥ 53 years) in the right ($P = 0.066$, ANOVA) or left ($P = 0.96$, ANOVA) sides.

The length of the anterior loop was not significantly different among dentate, completely edentulous, and partially edentulous patients in the right ($P = 0.11$, ANOVA) or left ($P = 0.26$, ANOVA) sides.

The angle of the anterior loop was not significantly different between males and females in the right ($P = 0.69$, t -test) or left ($P = 0.29$, t -test) side.

The correlation between the angle of the loop in the right side and age was significant ($P < 0.005$, ANOVA) such that the angle of the anterior loop in the right side in ≥ 53 year old was 5.8° higher than that in 14–41 year-old ($P < 0.05$, Tukey’s test) and 7.4° higher than that in 42–52-year-old ($P < 0.005$, Tukey’s test). No significant difference was noted between the two groups of 14–41 and 42–52 year-old in this respect ($P = 1.00$, Tukey’s test).

The correlation between the angle of the loop in the left side and age was significant ($P < 0.005$, ANOVA) such that the angle of the loop in the left side in 14–41-year-old was 5.1° ($P < 0.05$, Tukey’s test) and in ≥ 53 -year-old was 8.4° higher than that in 42–52-year-old ($P < 0.05$, Tukey’s test). No significant difference was noted between the two groups of 14 and 41 and ≥ 53 -year-old in this regard ($P = 0.741$, Tukey’s test).

The mean mesial distance of the mental foramina (mean horizontal position of mental foramen) was 48.04 ± 5.25 mm (range 24.8–65.5 mm). According to the independent t -test, the mean mesial distance of the mental foramina in the right and left sides in patients with an anterior loop was 1.29 mm greater than that in patients without an anterior loop ($P = 0.021$, t -test). The horizontal position of the mental foramen was not significantly different among different age groups ($P = 0.311$, ANOVA).

The vertical position of the mental foramen (distance from the mental foramen to the alveolar crest) in both sides was significantly different between patients with and without a loop such that in the right ($P < 0.0005$, t -test) and left ($P < 0.01$, t -test) sides, this distance was averagely 1 mm greater in patients with a loop than in those without a loop [Table 1]. The difference in the vertical position of mental foramen was significant in the right side among different age groups ($P < 0.00001$, ANOVA). The distance from the superior wall of the mental foramen to the alveolar crest was significantly greater in 14–41-year-old compared

with other groups ($P < 0.005$, Tukey’s test), but the difference between 42 and 52-year-old and those ≥ 53 years was not significant ($P = 0.089$, Tukey’s test). This difference was also significant in the left side ($P < 0.00001$, ANOVA) and this distance in 14–41-year-old was significantly greater than that in other age groups ($P = 0.01$, Tukey’s test). This distance was significantly greater in 42–52-year-old than those ≥ 53 years ($P < 0.05$, Tukey’s test).

The prevalence of oval mental foramina (74.34%) was higher than the prevalence of round mental foramina (25.66%). Accessory mental foramen was noted in the right side in 1.59% and in the left side in 1.06% of the mandibles.

The distance from the mental foramen to the inferior border of the mandible in males was significantly greater than that in females ($P < 0.00001$, t -test) when measured two-dimensionally. The mental foramen height in males was higher than that in females in both sides when measured three-dimensionally [$P < 0.00001$, t -test, Table 2].

The mean diameter of the mental foramen was 4.22 ± 1.01 mm in the right and 4.16 ± 0.96 mm in the left side.

The incisive canal was present in 97.62% of the cases in the right side and 97.62% of the cases in the left side. The path of the incisive canal was descending in the majority of the cases (68.02% in the right and 75.07% in the left side). Table 3 shows the frequency of the incisive canal paths in the right and left sides. The length of the incisive canal was 12.35 ± 3.29 mm in the right and 12.21 ± 3.38 mm in the left side.

The number of the incisive canals with >2 mm diameter was 68 in the left and 92 in the right side. The distance from the incisive canal to the buccal plate was 2.08 ± 0.94 mm in the right and 2.15 ± 1.02 mm in the left side. The difference in this regard was not significant between the right and left sides ($P = 0.322$, t -test). This distance was not significantly different among different age groups in the right ($P = 0.839$, ANOVA) or left ($P = 0.902$, ANOVA) sides.

The distance from the incisive canal to the buccal plate in males was significantly higher than that in females in the right ($P < 0.007$, t -test) and left ($P = 0.000$, t -test) sides. The distance from the incisive canal to the lingual plate was 4.18 ± 1.52 mm in the right and 4.14 ± 1.54 mm in the left side.

Table 1: Mean vertical position of mental foramen in patients with/without an anterior loop in the right and left sides

Group	Frequency (right)	Mean vertical position	SD	Frequency (left)	Mean vertical position	SD
Absence of loop	241	11.52	3.14	241	11.57	3.33
Presence of loop	137	12.67	2.79	137	12.50	3.05
Total difference	378	11.94–1.1508	3.06	378	11.91	3.26
					0.9354	
<i>P</i>		0.0004			0.0073	

SD: Standard deviation

In both sides, the incisive canal was closer to the buccal plate compared with the lingual plate in both sides ($P < 0.00001$, t -test).

The mean distance from the incisive canal to the inferior border of the mandible was 9.68 ± 1.95 mm in the right and 9.37 ± 1.65 mm in the left side. The distance in the left side was significantly shorter than that in the right side ($P = 0.019$, t -test). This distance was not significantly different among different age groups in the right ($P = 0.228$, ANOVA) or left ($P = 0.201$, ANOVA) sides. However, in both sides, this distance was longer in males than females [$P < 0.00001$, t -test, Table 4]. In both sides, the incisive canal was significantly closer to the inferior border of the mandible than the alveolar crest ($P < 0.00001$, t -test).

The effect of the absence of teeth on the anterior loop length was also evaluated. Anterior loop length was not significantly different among the three groups of edentulous, partially edentulous, and dentate patients in the right ($P = 0.114$) or left ($P = 0.265$) side. The effect of the absence of teeth on the vertical position of the mental foramen (distance between the ridge crest and mental foramen) was also evaluated [Table 5]. A significant difference was noted in the vertical position of the mental

foramen in the right side between the three groups of patients ($P < 0.001$) such that this variable in completely edentulous patients was lower than that in partially edentulous patients. This variable was not significantly different between partially edentulous and dentate groups ($P > 0.05$). A significant difference was noted in the vertical position of the mental foramen in the left side between the three groups of patients ($P < 0.001$) such that this variable in fully edentulous patients was significantly lower than that in partially edentulous and dentate patients. Furthermore, it was significantly lower in partially edentulous patients than dentate patients ($P < 0.05$).

Discussion

This study assessed the presence of implant-related anatomical landmarks (anterior loop of the IAN, incisive canal, and mental foramen) in the mandibular interforaminal region in an Iranian subpopulation residing in the west of Iran using CBCT. The results showed that the anterior loop and the incisive canal were present in 36.24% and 97.62% of the cases, respectively. The linear pattern was the most common pattern of the canal (56.08%) followed by the vertical pattern (35.19%). Al-Mahalawy *et al.*,^[9] and Iyengar *et al.*,^[19] also reported that the linear pattern was the most common pattern with 79% and 46.2% prevalence rates, respectively.

Previous studies on the prevalence of the anterior loop of the IAN have reported variable prevalence rates from 7% to 94%.^[1,4-6,8,9,15,16,20-22] Such differences may be due to the study population, the inclusion and exclusion criteria, and different methodologies. However, these differences cannot be solely attributed to racial differences since studies on the same populations have also reported controversial results.^[1,5,20,23] Such differences indicate that the methodology has a significant effect on the results. For instance, studies on dry human mandibles reported higher percentage rates for the prevalence of the anterior loop.^[24-26]

Furthermore, the type of radiographic modality can affect the results. Previous studies showed that the prevalence of the anterior loop on CBCT images was much higher than that on panoramic images and suggested that the panoramic images were not suitable for visualization of the anterior loop since they have high rate of false-positive and false-negative results.^[27-30]

Table 2: Mean height of the mental foramen in the right and left sides in males and females measured three-dimensionally

Group	Frequency		SD	Mean height		SD
	Right	Left		Right	left	
Female	193	12.09	1.52	193	12.36	1.42
Male	185	13.78	1.60	185	13.67	1.54
Total difference	378	12.91	1.77	378	13.00	1.61
		-1.693			-1.307	
<i>P</i>		0.0000			0.0000	

SD: Standard deviation

Table 3: Frequency of incisive canal paths in the right and left sides

	Frequency (%)	
	Right	Left
Descending	251 (68.02)	277 (75.07)
Linear path	103 (27.91)	89 (24.12)
Ascending	15 (4.07)	3 (0.81)
Total	369 (100)	369 (100)

Table 4: Distance from the incisive canal to the inferior border of the mandible in the right and left sides in males and females

Group	Right			Left		
	Frequency	Mean distance	SD	Frequency	Mean distance	SD
Females	188	8.99	1.46	188	8.97	1.46
Males	181	10.4	2.14	181	9.78	1.74
Total difference	369	9.68-1.406	1.95	369	9.37-0.804	1.65
<i>P</i>		0.0000			0.0000	

SD: Standard deviation

Table 5: Vertical position of mental foramen in completely edentulous, partially edentulous, and dentate patients

Vertical position of mental foramen	Right side		Left side	
	Count	Mean±SD	Count	Mean±SD
Completely edentulous	10	6.45 ^a ±4.12	10	7.00 ^{aa} ±3.02
Partially edentulous	337	11.96 ^b ±2.90	337	11.86 ^b ±3.12
Dentate	31	13.50 ^b ±2.57	31	14.10 ^c ±3.01
<i>P</i> [†]	<0.001		<0.001	

[†]One-way ANOVA followed by Tukey's test were used.

Means with the same superscripted letters are not significantly different (*P*>0.05). SD: Standard deviation

Search of the literature by the authors yielded four studies on the prevalence of the anterior loop in Iran. Panjnoush *et al.*,^[4] and Parnia *et al.*^[6] evaluated 200 CBCT scans and reported the prevalence of the anterior loop to be 59.5% and 84.4%, respectively, which were both higher than the rate reported in our study (36.24%). Such differences can be due to different methodologies and sample size. Moreover, they only evaluated the presence of anterior loop on cross-sectional images and did not consider other canal patterns. Thus, they also included the “b” pattern as the anterior loop. Kheir and Sheikhi^[15] evaluated 180 CBCT scans in Isfahan and reported the lowest prevalence rate for the anterior loop (32.8%) among the studies conducted in Iran, which may be due to the small sample size and exclusion of patients under 18 years of age. However, no age restriction was set in our study.

In our study, the anterior loop was significantly more common in males, which was in line with the findings of previous studies^[4,31,32] and was in contrast to the observation of do Carmo Oliveira *et al.*,^[3] who reported a higher prevalence of the anterior loop in females. They attributed this finding to the degree of cortical positioning of bones in females. However, the difference in this regard between males and females was not significant in other studies.^[15,16,20,23,33,34]

The difference in the mean distance of the anterior loop from the incisive canal was not significant between the right and left sides in our study, which was in line with some previous studies.^[7,15,23,26,31,35] However, Apostolakis and Brown^[12] showed the higher mean length of the anterior loop in the right side. In our study, males had a longer anterior loop in the right side than females but the difference in the left side was not significant. Some studies have reported a higher length of the anterior loop in males^[7,12,23,26,31] while no significant difference has been reported between males and females in some other studies.^[15,16,33-35] The main advantage of our study over others is the assessment of the difference in length of the anterior loop between males and females separately in the right and left sides. Uchida *et al.*^[26] reported that gender and height affected the length of the anterior loop, and males and taller individuals often had a longer

anterior loop. However, Benninger *et al.*^[36] attributed the anatomical variations of the anterior loop to race, which was different from the results of Wong and Patil^[35] who showed that race, gender, and side of the mandible had no significant correlation with the length of the anterior loop. In our study, the length of the anterior loop was not significantly different in patients with complete or partial edentulism, which was in line with the results of Uchida *et al.*,^[26] Apostolakis and Brown,^[12] and Rosa *et al.*^[7] The difference in length of the anterior loop was not significant among different age groups either, which was in agreement with previous studies.^[12,15,16,23,26,33,34]

The presence of an anterior loop with a mean length of 2.78 mm in our study population can help surgeons to consider a 5 mm safety margin from the most anterior part of the mental foramen (for the possible presence of loop) before implant placement if they do not have access to CBCT scans of the patient or if the scans have poor quality. Furthermore, surgeons should be more cautious about implant placement in men especially in the right side of the mandible.

The angle of the loop is influenced by the position and angle of the mental foramen relative to the buccal bone surface.^[37] This angle in this study was different from the values reported by Chen *et al.*^[8] They showed that the angle of the loop was correlated with age and gender, and females and younger individuals had a larger angle than males and older people. Different from their results, older individuals had a larger angle than younger individuals in our study, and we found no significant correlation between the angle of the loop and gender.

The mean horizontal position of the mental foramen in the mesiodistal dimension (mean distance between the mesial surfaces of the two mental foramina) was 48.04 mm in our study. Afkhami *et al.*^[38] reported this value to be 55.44 mm on panoramic radiographs. Averagely, this distance in patients with loop was 1.29 mm greater than that in patients without a loop. Chen *et al.*^[8] stated that the anterior loop is more commonly seen when the mental foramen is located under the second premolar compared with situations where it is located under the first premolar or between the first and second premolars. The vertical position of the mental foramen (distance from the superior wall of the mental foramen to the alveolar crest) in our study was lower than that in studies by Al-Mahalawy *et al.*,^[9] and Haktanir *et al.*^[39] It should be noted that Al-Mahalawy *et al.*^[9] excluded patients with edentulism at the interforaminal region, which may explain the higher value obtained in their study compared with ours since we included dentate, completely edentulous, and partially edentulous patients. In this study, by an increase in age, the distance from the superior wall of the mental foramen to the alveolar crest decreased, which is due to alveolar bone loss in old ages.

In our study, the oval shape of the mental foramen was more prevalent, which was in agreement with the results of Mbajjorgu *et al.*,^[40] and Gershenson *et al.*^[41] Accessory mental foramen had 1.59% and 1.06% prevalence in the right and left sides, respectively. This value ranges from 1.4% to 12.8% in the literature.^[20,10]

Chen *et al.*^[8] used CBCT and Mimic software to measure the diameter and height of the mental foramen twodimensionally and threedimensionally. They found no significant difference between two-dimensional and 3D measurements, which was in line with our findings. Al-Mahalawy *et al.*,^[9] and Kalender *et al.*^[42] reported the height of the mental foramen to be 13.8 and 12.4 mm, respectively, which was close to our findings in this respect. In this study, similar to that of Al-Mahalawy *et al.*,^[9] a significant difference was noted between males and females regarding the height of the mental foramen such that the height of the mental foramen in males was higher than that in females, probably due to larger dimensions of the mandible in males.

Clinical findings regarding the position of the mental foramen can greatly help prevent traumatization of the mental nerve during osteotomy, genioplasty, and apical curettage at the site of mandibular premolars, surgical tooth extraction, fixation of mandibular fractures, orthognathic surgery, and periodontal surgery. Furthermore, the information in this respect can help in the more accurate technique of anesthesia administration and prevent nerve traumatization during implant placement.^[33]

In our study, the descending path in the right (68.02%) and left (75.07%) sides was the most common path of the incisive canal, which was in agreement with the results of Panjnoush *et al.*,^[4] and Rosa *et al.*^[7] In our study, 25% of the patients had an incisive canal with >2 mm diameter. Failure in implant osseointegration is a potential complication that occurs due to the perforation of an incisive canal with >2 mm diameter due to the migration of the soft tissue along the implant.^[43]

In our study, the distance from the incisive canal to the buccal plate was not significantly different in the right and left sides. However, Panjnoush *et al.*^[4] found a weak but significant correlation between age and distance of the canal from the buccal plate. This distance in males was significantly greater than that in females in our study, which is due to larger dimensions of the mandible in males. The distance from the incisive canal to the inferior border of the mandible in the left side was significantly smaller than that in the right side in our study; however, since this difference was smaller than 0.5 mm, it was not clinically important. This finding supported the results of Panjnoush *et al.*^[4]

In our study similar to that of Panjnoush *et al.*,^[4] and Kong *et al.*,^[2] the incisive canal at both sides was closer to the buccal plate rather than the lingual plate and was closer to

the inferior border of the mandible rather than the alveolar crest. This highlights the fact that in implant placement in the anterior mandible, implant should be placed slightly inclined towards the lingual border to prevent nerve traumatization.

In this study, single mandibular canal was more prevalent than double type (87.57% vs. 12.43%), which was in line with the results of de Oliveira-Santos *et al.*,^[34] (81% vs. 19%). The prevalence of the retromolar canal was 15.08% in our study. This value ranges from 1%^[44] to over 75%^[45] in the literature. Such controversy can be attributed to different study populations. This rate was 12.8% in a study conducted in Hamadan, Iran.^[46]

This study was conducted in one large oral and maxillofacial radiology clinic in Kermanshah city. Further multicenter studies in different parts of the country and other geographical locations are recommended to better elucidate the anatomical variations of these structures in the Iranian population and increase the generalizability of the results.

Conclusion

Considering the high variability and clinical significance of the incisive canal and anterior loop of the IAN, and their high prevalence, it is recommended to assess the presence/absence of these structures in the interforaminal region of the mandible on CBCT scans before implant placement and surgical procedures in this region.

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Conflicts of interest

There are no conflicts of interest.

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