ORIGINAL ARTICLE

Evaluation of Anatomical Characteristics of Mandibular Incisive Canal in a Turkish Subpopulation Using Cone Beam Computed Tomography

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ABSTRACT

Objective: *To assess the anatomical characteristics of mandibular incisive canal and to describe the occurrence of anatomical variations according to side, age and gender using cone beam computed tomography (CBCT).*

Methods: *A retrospective study using CBCT images was performed to evaluate mandibular incisive canal in mandible of 100 patients. Both right and left sides were studied (n = 200). Axial, sagittal, cross-sectional and panoramic images were evaluated, and three dimensional images were also reconstructed and evaluated, as necessary. The morphology, course and length of mandibular incisive canals and the inner and outer diameters of the canals were measured.*

Results: *The incisive canal was found in 87% of the scans. The mean endpoint was approximately 10.98 and 10.26 mm anterior to the mental foramen for left and right side, respectively, without a significant difference (*$p > 0.05$*). The mean distance from the lower border of the mandible was 10.7 mm and its course was closer to the buccal border at the starting point while it deviates lingually through the anterior of the mandible. Significant difference was found between gender, side and age groups (*$p < 0.05$*).*

Conclusion: *Awareness of these anatomical variations is important to avoid neurovascular damage during surgical intervention and anaesthetic applications. Cone beam computed tomography is an effective imaging modality in the detection of lingual foramina and canals. Further studies with larger data samples are necessary in comparison and estimation of anatomical results.*

Keywords: Cone beam computed tomography, implant, incisive canal, interforaminal region.

INTRODUCTION

Mandibular interforaminal region (MIR) is generally considered as a safe area during dental surgical procedures, without damage to vital structures (1–7). Surgical operations related to the region are insertion of endosseous implants, bone harvesting from the chin, genioplasty in orthognathic surgery and screwing with or without plating after trauma of the anterior mandible (1–5, 7, 8). Several case reports describe neurosensory disturbances, oedema, haematoma and failure of osseointegration of implants during or after surgical procedures in the MIR (1–10). The important anatomical structures in this anterior mandible are the mental nerve, the incisive canal (IC) and its neurovascular bundle, and the lingual foramen and its contents (1–4, 6, 7, 10–12). However, the precise anatomy of MIR and intramedullary content are controversial (2, 4, 7).

The mandibular incisive canal (MIC) is mostly described as a prolongation of the mandibular canal anterior to the mental foramen, containing a neurovascular bundle. The extension of the mandibular canal mesial to mental foramen is referred to as the IC (1, 2, 6, 7, 11, 12). Radiographic examination is the most important evaluation of significant anatomical sites for the

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pre-operative procedures. Nevertheless, conventional radiographs have several drawbacks, including errors of projection and identification. Conventional radiographic techniques project a three-dimensional (3D) structure onto a 2D structure. The reliability of measurements obtained by panoramic radiography method is low due to distortion and magnification inherent of the technique. Images can vary widely as they depend on both operator and position of the patient. These images commonly fail to show the MIC (2–5, 6, 8, 11, 12).

The use of cone-beam computed tomography (CBCT) was first reported by Mozzo *et al* (13) and has been proposed in the last decade for maxillofacial imaging (2). A CBCT scan uses a different type of acquisition than that used in multi-detector CT (MDCT). Rather than capturing an image as separate slices as in MDCT, CBCT produces a cone-shaped X-ray beam that allows an image to be captured in a single shot. Cone beam CT thus offers the distinct advantage of a lower radiation dose than MDCT and the possibility of importing and exporting individualized, overlap-free reconstructions (14, 15). In CBCT imaging, multiple thin axial slices are obtained through the jaws, and then the data are reformatted with special software packages to produce cross-sectional and panoramic views. Computer software is also available to analyse the CBCT scans and to help in planning implant placement with electronically simulated fixtures (1–9, 11, 12).

Several studies have been published on the detection of IC, anterior loop of mandibular canal, mental foramen and the lingual foramen using conventional MDCT (3, 4, 14). Only few studies were conducted on CBCT imaging (1, 2, 5, 6, 8, 11, 14).

Thus, the objective of this study was to evaluate the presence of the MIC, texture, location and channel positioning related to the cortical bone by means of CBCT, and to investigate the relationship among side (right/left) age and gender.

SUBJECTS AND METHODS

The study protocol was carried out according to the principles of the Helsinki Declaration, including all amendments and revisions. Collected data were only accessible to the researchers. Patients or their legal delegates gave their informed consent prior to radiography. Subjects with evidence of bone disease (especially osteoporosis), relevant drug consumption, skeletal asymmetries or trauma, syndromic patients, patients with congenital disorders, patients with anamnesis of surgical procedures in the interforaminal region, and patients with pathological disorders at mandible were excluded from the study. There was no preference about gender regarding sample choice; however, only Turkish patients were included in the study. Only high-quality scans were included. Images of low quality such as scattering or insufficient accuracy of bony borders were also excluded.

The study population comprises 100 subjects [56 (56%) female, 44 (44%) male] who had undergone CBCT imaging for dental implant surgery, Le Fort I osteotomy, impacted third molar surgery and orthodontic purposes. The mean age of subjects was 42.4 years (age range –21–72 years). The study group was divided into three subgroups according to age and dental status as (a) 39 years and below, (b) 41–60 years and (c) 60 years and above. Dental status of the patients was classified as edentulous, partial edentulous and complete dentate. Edentulous patients were defined as missing of all canine to canine incisor teeth (≤ 6 teeth), while partial edentulousim was classified to be partially missing incisors (≤ 4 teeth) and complete dentate was defined as no missing teeth in the incisor region (Fig. 1).

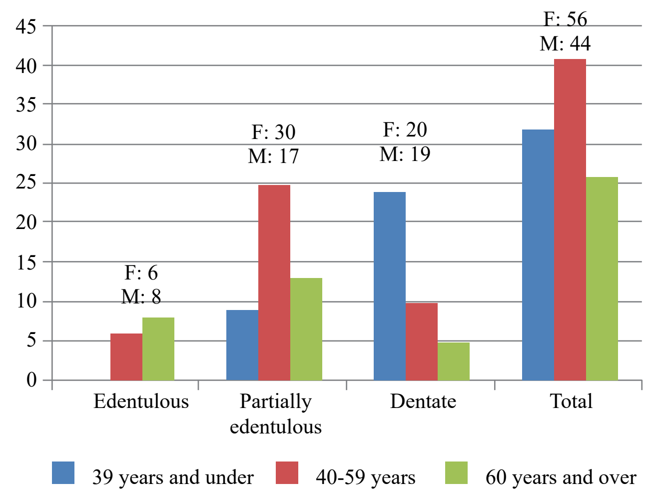

Fig. 1: The distribution of the subjects according to age, gender and dental status. F = female; M = male.

Image acquisition

To visualize the MIC in three dimensions, CBCT scans were retrospectively evaluated. The scans were acquired with an iCaT machine (Imaging Sciences International, Hatfield, PA, USA) with a 40-second scan and a 16 × 22-cm field of view. All CBCT scans were obtained according to the strict standardized scanning protocol. Patients were upright sitting position and checked to ensure that their mouths were closed in a normal, natural occlusive position 0.3-mm-thick axial slices and isotropic voxels. All images were reconstructed on a 21.3-inch flat-panel colour active matrix TFT medical display (Nio Color 3MP, Barco, France) with a resolution at 76 Hz and 0.2115 mm pitch at 10 bits. The examiners were also permitted to use enhancements and orientation tools such as magnification, brightness and contrast to improve visualization of the anatomical landmarks.

Image evaluation

All CBCT images were evaluated retrospectively by a single oral and maxillofacial radiologist. Axial, sagittal, cross-sectional and panoramic images were reconstructed for all mandibles, and 3D reconstructions were used as necessary (Figs. 2 and 3). The course and length of the IC measured on cross-sectional and panoramic reconstructed CBCT images using the CBCT system's own software.

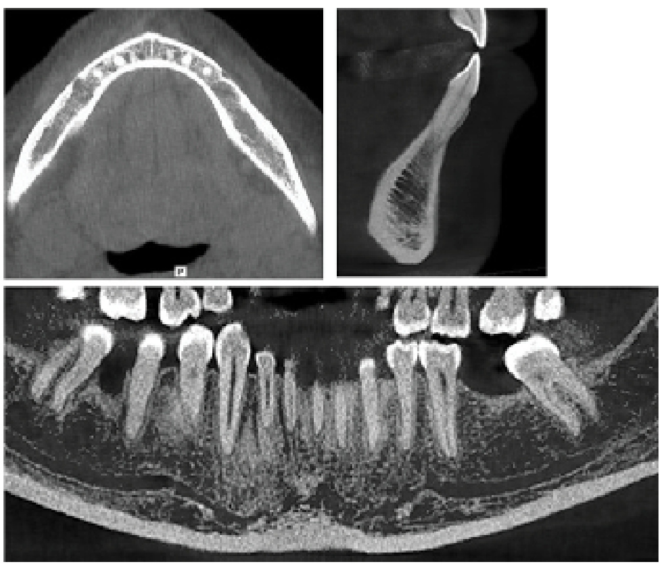

Fig. 2: Axial, sagittal, cross-sectional and panoramic views were reconstructed for all mandibles.

The measurements were performed in three different locations, namely starting, middle and end points following Orhan *et al*'s study (2). The starting point was defined to be 6 mm mesial to the mental foramen because of anterior loop of the mandibular canal which was indicated by previous studies as a mean length ranging from 0.4 to 6.0 mm (8–16). The visible length of the canal measured from the mesial aspect of the mental foramen (starting point) to the most mesial location that was visible (end point). The middle point was defined as the centre point of the starting and end points. The course of the canal was considered by examining all cross-sectional, panoramic and 3D images (if necessary), starting from the separation to end to visualize its direction (Fig. 4). The location of the IC was assessed

Fig. 3: Axial and 3D CBCT images showing the MIC, which were located on the buccal plate of the anterior mandible (red arrows). Blue arrows demonstrate mental foramen.

along its course, and allocated as middle, lower or upper third. The canal was also classified as being to be located buccally or lingually (Fig. 5). The vertical and buccolingual diameters of inner and outer contours were measured from the starting point, middle and the end of the IC. The distance from the lower border of the IC to the lower border of the mandible was also measured on cross-sectional images in all points (Fig. 6).

Statistical analyses

Statistical analyses were carried out using SPSS 17.0.1 (SPSS, Chicago, IL, USA) software program. Pearson Chi-square, Mann–Whitney test and Kruskal–Wallis

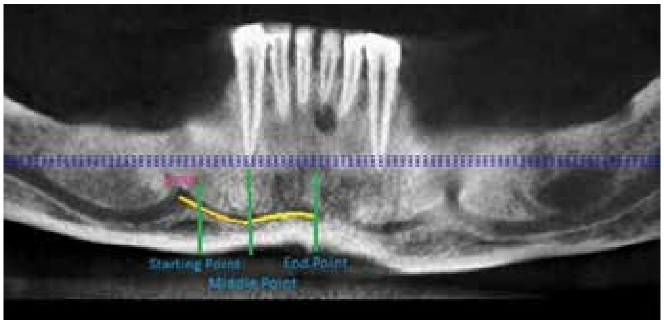

Fig. 4: The visible length of the canal measured from the mesial aspect of the mental foramen (starting point) to the most mesial location that was definitely visible (end point). The middle point was defined as the centre point between the starting points.

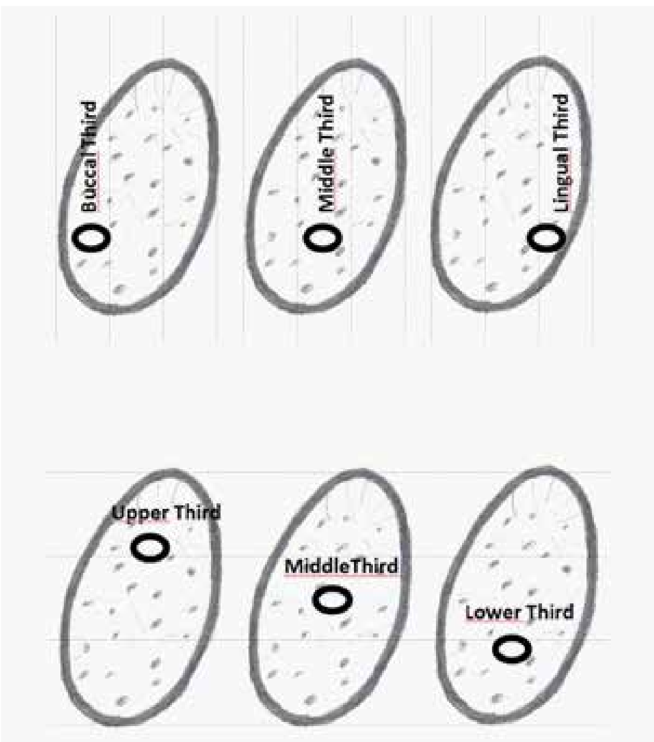

Fig. 5: The location of the MIC was evaluated along its course and divided vertically as the upper, middle or lower third. The MIC was categorized buccolingually as the buccal, middle or lingual third.

tests were used to compare measurements in terms of gender, age groups and left/right side. A p value of less than 0.05 was considered statistically significant.

RESULTS

The IC between the interforaminal region was detected in 87% (174 sides) of the scans. We divided our study group according to age and dental status. Table 1 shows the association among age, gender and the measurements of the IC. The mean length of the IC ranged from 10.26 to 10.98 mm, right and left, respectively, with a mean of 10.62 mm, and that of the distance from the lower border of the IC to the lower border of the mandible ranged from 8.83 to 10.92 mm with statistical significant difference between male and female patients ($p < 0.05$). However, the length of the MIC did not differ among gender and also measurements did not differ significantly by side ($p > 0.05$). Table 1 also shows the results for age groups. There was no significant difference according to age groups ($p > 0.05$). The results indicated that distance from the lower border of the IC to the lower border of the mandible is greater in males than in females in all groups which were all statistically significant ($p < 0.05$).

Fig. 6: The vertical and buccolingual diameters of the inner and outer contours were evaluated from the starting, middle and end points of the MIC. The distance from the lower border of the MIC to the lower border of the mandible was measured on cross-sectional images from the three points.

Table 2 shows the mean buccolingual diameter of the outer and inner contours, which ranged from 1.23 to 1.8 mm for inner contour, and from 1.88 to 2.49 mm for outer contour. The mean vertical diameter of the outer and inner contours ranged from 1.31 to 1.93 mm for inner contour, and from 1.98 to 2.73 mm for outer contour. Measurements differed significantly gender ($p < 0.05$).

Tables 3 and 4 show the measurements according to age groups. The results indicated statistical significant difference among age groups. Both the outer and inner

Table 1: Mean values of MIC measurements according to age group and gender

	Gender	n	Mean	p
Length of IC (right)	Female	56	10.18	0.861
	Male	44	10.36	
	Total	100	10.26	
Length of IC (left)	Female	56	10.86	0.625
	Male	44	11.14	
	Total	100	10.98	
Right starting point/distance from IC to lower border of mandible	Female	56	9.41	0.009
	Male	44	10.58	
	Total	100	9.92	
Left starting point/distance from IC to lower border of mandible	Female	56	9.15	0.034
	Male	44	10.11	
	Total	100	9.57	
Right middle point/distance from IC to lower border of mandible	Female	56	9.31	0.001
	Male	44	11.21	
	Total	100	10.15	
Left middle point/distance from IC to lower border of inner mandible	Female	56	8.83	0.005
	Male	44	10.37	
	Total	100	9.51	
Right end point/distance from IC to lower border of mandible	Female	56	9.74	0.003
	Male	44	11.52	
	Total	100	10.53	
Left end point/distance from IC to lower border of mandible	Female	56	9.07	0.001
	Male	44	10.92	
	Total	100	9.88	
Length of IC (right)	39 years and under	32	10	0.881
	40–59 years	42	10.43	
	60 years and over	26	10.31	
	Total	100	10.26	
Length of IC (left)	39 years and under	32	11.69	0.362
	40–59 years	42	10.57	
	60 years and over	26	10.77	
	Total	100	10.98	
Right starting point of distance from IC to lower border of mandible	39 years and under	32	9.58	0.42
	40–59 years	42	10.13	
	60 years and over	26	10.02	
	Total	100	9.92	
Left starting point of distance from IC to lower border of mandible	39 years and under	32	9.75	0.871
	40–59 years	42	9.59	
	60 years and over	26	9.32	
	Total	100	9.57	
Right middle point of distance from IC to lower border of mandible	39 years and under	32	10.29	0.769
	40–59 years	42	10.19	
	60 years and over	26	9.9	
	Total	100	10.15	
Left middle point of distance from IC to lower border of mandible	39 years and under	32	10.02	0.334
	40–59 years	42	9.35	
	60 years and over	26	9.13	
	Total	100	9.51	
Right end point of distance from IC to lower border of mandible	39 years and under	32	10.47	0.996
	40–59 years	42	10.53	
	60 years and over	26	10.59	
	Total	100	10.53	
Left end point of distance from IC to lower border of mandible	39 years and under	32	10.1	0.806
	40–59 years	42	9.89	
	60 years and over	26	9.6	
	Total	100	9.88	

IC = incisive canal; MIC = mandibular incisive canal; $p < 0.01$

Table 2: Mean values of the diameter of the MIC measurements according to gender

	Gender	n	Mean	*p*
Starting point buccolingual inner diameter (right)	Female	56	1.57	0.03
	Male	44	1.8	
Starting point buccolingual inner diameter (left)	Female	56	1.36	0.184
	Male	44	1.51	
Middle point buccolingual inner diameter (right)	Female	56	1.43	0.017
	Male	44	1.71	
Middle point buccolingual inner diameter (left)	Female	56	1.24	0.552
	Male	44	1.32	
End point buccolingual inner diameter (right)	Female	56	1.51	0.318
	Male	44	1.6	
End point buccolingual inner diameter (left)	Female	56	1.23	0.955
	Male	44	1.2	
Starting point buccolingual outer diameter (right)	Female	56	2.34	0.093
	Male	44	2.6	
Starting point buccolingual outer diameter (left)	Female	56	2.11	0.14
	Male	44	2.36	
Middle point buccolingual outer diameter (right)	Female	56	2.06	0.009
	Male	44	2.49	
Middle point buccolingual outer diameter (left)	Female	56	1.91	0.021
	Male	44	2.25	
End point buccolingual outer diameter (right)	Female	56	2.12	0.103
	Male	44	2.37	
End point buccolingual outer diameter (left)	Female	56	1.88	0.596
	Male	44	1.93	
Starting point vertical inner diameter (right)	Female	56	1.44	0.039
	Male	44	1.65	
Starting point vertical inner diameter (left)	Female	56	1.43	0.109
	Male	44	1.66	
Middle point vertical inner diameter (right)	Female	56	1.31	0.062
	Male	44	1.52	
Middle point vertical inner diameter (left)	Female	56	1.45	0.577
	Male	44	1.52	
End point vertical inner diameter (right)	Female	56	1.32	0.169
	Male	44	1.55	
End point vertical inner diameter (left)	Female	56	1.32	0.964
	Male	44	1.34	
Starting point vertical outer diameter (right)	Female	56	2.15	0.007
	Male	44	2.56	
Starting point vertical outer diameter (left)	Female	56	2.21	0.004
	Male	44	2.73	
Middle point vertical outer diameter (right)	Female	56	2.02	0.003
	Male	44	2.33	
Middle point vertical outer diameter (left)	Female	56	2.27	0.135
	Male	44	2.45	
End point vertical outer diameter (right)	Female	56	1.98	0.135
	Male	44	2.31	
End point vertical outer diameter (left)	Female	56	1.98	0.358
	Male	44	2.13	

IC = incisive canal; MIC = mandibular incisive canal; $p < 0.01$

canal diameters were greater in young ages than in old patients ($p < 0.05$).

Table 5 shows the location of the IC along its course according to side which was allocated as upper, middle or lower third of mandible. The canal was also classified as being located to buccal, middle or lingual third of the mandible. The results indicated that the canal was located more lingually of the mandible at the end point in all patients. The majority of the ICs were located in lower third of the mandible which is followed by middle third. No significant difference was found according to side ($p > 0.05$).

Table 3: Mean values of the inner/outer diameter of the MIC measurements according to age (buccolingually)

		n	Mean	*p*
Starting point buccolingual inner diameter (right)	39 years and below	32	1.93	0.017
	40–59 years	42	1.5	(2-1)
	60 years and above	26	1.62	
Starting point buccolingual inner diameter (left)	39 years and below	32	1.45	0.424
	40–59 years	42	1.48	
	60 years and above	26	1.31	
Middle point buccolingual inner diameter (right)	39 years and below	32	1.7	0.143
	40–59 years	42	1.42	
	60 years and above	26	1.6	
Middle point buccolingual inner diameter (left)	39 years and below	32	1.42	0.081
	40–59 years	42	1.16	
	60 years and above	26	1.29	
End point buccolingual inner diameter (right)	39 years and below	32	1.77	0.021
	40–59 years	42	1.4	(2-1)
	60 years and above	26	1.5	
End point buccolingual inner diameter (left)	39 years and below	32	1.35	0.278
	40–59 years	42	1.16	
	60 years and above	26	1.14	
Starting point buccolingual outer diameter (right)	39 years and below	32	2.77	0.026
	40–59 years	42	2.24	(2-1)
	60 years and older	26	2.4	
Starting point buccolingual outer diameter (left)	39 years and below	32	2.29	0.359
	40–59 years	42	2.26	
	60 years and above	26	2.04	
Middle point buccolingual outer diameter (right)	39 years and below	32	2.35	0.353
	40–59 years	42	2.12	
	60 years and above	26	2.35	
Middle point buccolingual outer diameter (left)	39 years and below	32	2.17	0.424
	40–59 years	42	1.96	
	60 years and above	26	2.09	

IC = incisive canal; MIC = mandibular incisive canal; $p < 0.01$

DISCUSSION

Mandibular interforaminal region is generally taken into consideration as a safe zone in the course of many dental surgical procedures, without important risks to damage vital anatomical structures (1–7, 16–30). It is very significant to have exact knowledge about anatomical textures to perform a surgical procedure in anterior mandible (17–19). Important anatomical landmarks in the MIR involve mental foramina, anterior loop and mandibular IC (2, 3, 6, 8–10, 12, 14, 17–24). Nonetheless,

Table 4: Mean values of the inner/outer diameter of the MIC measurements according to age (vertically)

		n	Mean	*p*
Starting point vertical inner diameter (right)	39 years and below	32	1.75	0.05
	40–59 years	42	1.32	(2-1)
	60 years and above	26	1.61	
Starting point vertical inner diameter (left)	39 years and below	32	1.49	0.483
	40–59 years	42	1.62	
	60 years and above	26	1.45	
Middle point vertical inner diameter (right)	39 years and below	32	1.45	0.028
	40–59 years	42	1.26	(2-1,
	60 years and above	26	1.25	3-1)
Middle point vertical inner diameter (left)	39 years and below	32	1.59	0.157
	40–59 years	42	1.43	
	60 years and above	26	1.41	
End point vertical inner diameter (right)	39 years and below	32	1.55	0.113
	40–59 years	42	1.42	
	60 years and above	26	1.26	
End point vertical inner diameter (left)	39 years and below	32	1.46	0.278
	40–59 years	42	1.22	
	60 years and above	26	1.34	
Starting point vertical outer diameter (right)	39 years and below	32	2.71	0.013
	40–59 years	42	2.05	(2-1)
	60 years and older	26	2.31	
Starting point vertical outer diameter (left)	39 years and below	32	2.37	0.755
	40–59 years	42	2.55	
	60 years and above	26	2.34	
Middle point vertical outer diameter (right)	39 years and below	32	2.35	0.353
	40–59 years	42	2.12	
	60 years and above	26	2.35	
Middle point vertical outer diameter (left)	39 years and below	32	2.24	0.124
	40–59 years	42	2.02	
	60 years and above	26	2.28	

IC = incisive canal; MIC = mandibular incisive canal; $p < 0.01$

the certain anatomy of MIR is still contradictive (2, 3, 4, 7, 18, 25). Some researchers omit presence of true MIC (7).

Any dental surgery in the anterior mandible may bring about temporary or persisting neurosensory disturbances (1, 4–10, 17, 19, 20, 22, 23, 25–30). Abarca *et al* (31) and Kutuk *et al* (32) reported that patients complained of discomfort after implant therapy in the interforaminal area and contributed this problem to direct or indirect injury to the mandibular incisive nerve. Direct trauma to the incisive neurovascular bundle may give rise to sensory disturbances, oedema, haematoma, transient or persistent hypoesthesia, paraesthesia, anaesthesia, disabling dysesthesia in the MIR and the lower lip (2–4, 17, 20, 21, 27, 28, 30, 33, 34). Sensory disturbances leading to direct damage of the MIC has been reported in 17% of cases after implant surgery in the anterior mandible region (7, 20, 25).

Indirect trauma to the IC bundle may incline to haematoma formation in the closed chamber at the branch of the inferior anterior bundle of the mental and incisive nerve (3, 17, 20, 21). The haematoma may cause pressure on the mental nerve resulting in neural damage (1, 4, 21). Pre-operative or post-operative haemorrhage from damage to the sublingual artery or the submental artery has also been taken into consideration during the insertion of implants (7, 17, 23, 31, 32). Rosenquist (35, 36) explained that the large size of the diameter of the MIC may damage the osteointegration of the implant and haemorrhages may occur in the interforaminal region. Life-threatening haemorrhage and haematoma formation in the MIR have been reported (17, 33). Besides, profuse, pulsatile brisk bleeding from dental implant therapy in the anterior mandible is also infrequent (2, 6, 7, 17, 23, 27, 33, 37). Kohavi and Bar-Ziv (38) reported a patient with severe pain and discomfort after implant insertion in the MIR (3, 5–8, 21, 27, 30). Lately, Romanos *et al* (22, 30) reported a case of unexpected pain during placement of an implant in the IC with a large diameter. Although mental foramen was determined during the surgical procedures every time and all implants were inserted at least 3 mm medial to the anterior border of the mental foramen, permanent sensory disturbance in the lower lip was stated in 7% of the cases (3, 4, 17, 21). Researchers reported an altered sensation of the lower lip after implant surgery in the mandible (8, 17). Rosenquist (35) explained that the incisive bundle caused implant failure by migration of soft tissue around the implant, thus preventing osseointegration.

In a study on the use of the chin as a source of autogenous bone, it was reported that 12% of the lower anterior teeth had pulpal canal obliteration and 4% had negative pulpal sensibility when bicortical bone grafts were obtained from the interforaminal region (7, 22, 25, 34, 37). These neurosensory disturbances occurred while respecting the generally recommended safety margins defining the harvest zone as being 5 mm anterior to the mental foramen, 5 mm below the tooth apices, and 5 mm above the lower border of the mandible. However, these safety recommendations are not based on knowledge of the position and course of the MIC (5, 22, 25, 34). Pommer *et al* (37) proposed new safety margins to protect the MIC: at least 8 mm below the tooth apices and a maximum harvest depth of 4 mm.

Another potential result of implant surgery into a neurovascular bundle, which has not been documented in the literature, is occurrence of a traumatic neuroma

Table 5: Vertical and buccolingual location(s) of the MIC according to side

		Group						Chi-square test	
		Right		Left		Total			
		n	%	n	%	n	%	Chi square	*p*
Starting vertical location of IC (right)	Lower third	50	50	57	57	107	53.5	*	0.311
	Middle third	42	42	41	41	83	41.5		
	Upper third	3	3	2	2	5	2.5		
	Buccal third	1	1	0	0	1	0.5		
	Midline middle third	3	3	0	0	3	1.5		
	Midline lower third	1	1	0	0	1	0.5		
	Total	100	100	100	100	200	100		
Middle vertical location of IC (right)	Lower third	53	53	54	54	107	53.5	*	0.71
	Middle third	44	44	45	45	89	44.5		
	Upper third	3	3	1	1	4	2		
	Total	100	100	100	100	200	100		
End vertical location of IC (right)	Lower third	41	41	48	48	89	44.5	*	0.357
	Middle third	56	56	50	50	106	53		
	Upper third	3	3	1	1	4	2		
	Lingual third	0	0	1	1	1	0.5		
	Total	100	100	100	100	200	100		
Starting buccolingual location of IC (left)	Lower third	1	1	0	0	1	0.5	*	0.803
	Middle third	54	54	50	50	104	52		
	Buccal third	21	21	22	22	43	21.5		
	Lingual third	24	24	28	28	52	26		
	Total	100	100	100	100	200	100		
Middle buccolingual location of IC (left)	Middle third	39	39	55	55	94	47	7.062	0.09
	Buccal third	19	19	20	20	39	19.5		
	Lingual third	42	42	25	25	67	33.5		
	Total	100	100	100	100	200	100		
End buccolingual location of IC (left)	Middle third	47	47	49	49	96	48	0.418	0.811
	Buccal third	24	24	26	26	50	25		
	Lingual third	29	29	25	25	54	27		
	Total	100	100	100	100	200	100		

IC = incisive canal; MIC = mandibular incisive canal; * = $p < 0.01$

(amputation neuroma), a benign tumour (27), which may be dolorous (2, 30).

In 1928, Olivier (39) first defined the MIC as a continuation of the inferior alveolar nerve from the posterior mandible. The MIC is a mesial extension of the mandibular canal, containing the incisive nerve and vessels, which irrigate and innervate the lower anterior teeth (1, 2, 6, 7, 11, 12, 17, 18, 20–22, 24, 27–30, 37, 40). The MIC is a bilateral canal that runs medially from mental foramens, between the lingual and vestibular cortical plates (1).

It is very important to have complete information about the MIC before carrying out any dental surgical procedures in the anterior mandible region in order to prevent complications (19).

Pre-operative radiographic examination is an essential diagnostic method to determine these anatomical structures in the intermental area. Conventional 2D images (such as intraoral, panoramic) are troublesome to interpret by reason of the overlapping of complex osseous structure. Therefore, anatomical structures such as the lingual foramen and IC which contain neurovascularization can hardly be defined (3–5, 8, 11, 12, 14, 19, 21, 26–28). In this respect, intraoral and occlusal radiographs generally fail to show the MIC. Whenever the orthodontic wire and/or contrast medium were applied, intraoral and occlusal radiographs illustrated the course of an IC in 80% of the cases. On the other hand, in panoramic radiography, the IC was visualized as a prolongation of the mandibular canal in 50% of the investigated mandibles (5, 17, 35). The non-uniform magnification in panoramic radiography makes this modality unreliable for assessing vertical distances (11, 19, 28). Rouas *et al* (41) stated that panoramic radiography technique is limited to the diagnosis of alterations in the mandibular canal and its extensions. As a result, several studies have reported that panoramic radiographs failed to detect the IC (2, 4, 8, 11, 12, 20, 24, 26–29).

In another method, some authors have explained the effectiveness of high-resolution magnetic resonance imaging for microanatomical studies of the mandibular incisive nerve. Nevertheless, this technique is not in prevalent use in consequence of its limited scanning volume, long waiting time, high cost and limited correctness (5, 11).

Furthermore, cross-sectional imaging techniques (*eg*, conventional spiral tomography or spiral CT) offer a better alternative for the precise visualization of anatomical structures in the oral region aiming at pre-operative planning (3, 8, 12, 24). Jacobs *et al* (2, 3, 8, 11, 12, 21, 22, 26) showed the presence of a well-defined IC in the mental interforaminal region by spiral CT. The IC could be identified in 93% of the spiral CT scans of the lower jaw. Nevertheless, CBCT allows comparatively less radiation and higher resolution than spiral CT (9).

Computed tomography/MDCT may be especially appropriate before carrying out the dental surgical procedures, as the 3D imaging and the high-resolution examination of the entire body of the mandible provide sufficient data for the anatomical structures (2, 5, 8–10, 18, 20, 21, 26). However, CT is still not ideal for the particular diagnostic instrument in dental procedures (14). Computed tomography has been limited to the MIC evaluation because of the high radiation dose (12). Cone beam CT, along with a high validity of linear measurements and the low radiation dose, has lower cost compared to MDCT (2, 5, 8, 11, 20–22, 25, 27).

Liang *et al* (14) explained that CBCT gives another promising application since it makes submillimetre resolution images of high diagnostic quality, with short scanning time and reduced radiation dose up to 15 times lower than multi-slice CT scans.

As De Souza Tolentino *et al* (40) stated, CBCT permits a greater accuracy in the diagnosis of anatomical structures in the jaws compared to panoramic radiography.

This study evaluated the existence of the MIC, composition, location and channel positioning related to the cortical bone and investigated the relationship between the MIC and MIR, and explained the MIC according to dental status, age and sex by CBCT. We have investigated CBCT images of unequal numbers of male and female between 18 and 80 years of age, as in previous studies (1, 2, 6, 8, 11, 21, 22, 25, 34). Uchida *et al* (9) measured the MIC using CBCT in cadavers of 140 hemimandibles (age at death ranging from 48 to 103 years of male and female).

The study group was divided into three subgroups according to dental status as edentulous, partially edentulous and completely dentate. Edentulous patients were determined as missing all canines and incisors (≥ 6 teeth), partially edentulous patients were determined as missing some incisors (≤ 4 teeth) and completely dentate patients were determined as missing no teeth in the incisor area (2).

The MIC can be detected well in cadavers. As Mardinger *et al* (2, 4, 21) explained, a mandibular incisive bundle was anatomically found in all hemimandibles 100% of cadavers. Al- Ani *et al* (2, 5, 25) investigated the MIC by CBCT of 60 patients and the MIC was determined in 100% of the images. Kong *et al* (5) evaluated the MIC with CBCT of 50 subjects. They observed that the MIC was determined in 38.6% of panoramic radiographic images and 100% of CBCT images provided from Han Chinese subjects. In our study, we found that the MIC in 87% of the CBCT of 100 patients was found bilaterally. Other studies by investigators from Greece, the USA, Belgium, Malaysia, Germany, and elsewhere have explained a high ratio of MIC detection in CBCT (5, 8, 11). Several researchers have explained a high prevalence of MIC by means of CBCT. To illustrate, Sokhn *et al* (42) reported that MIC was visible in 97.5% of the cases. Sahman *et al* (27) reported that IC was described in 94.4% in CBCT images. Again, Apostolakis and Brown (22) identified the MIC in 93% of images. Moreover, Yovchev *et al* (1) explained the IC in 92.9% by dental volumetric tomography of the 140 patients, and the MIC was found bilaterally in 68.6% of the cases and unilaterally in 24.2%. Makris *et al* (8) also reported the MIC was visible in 91% of the CBCT images. Orhan *et al* (2) found the MIC in 91% of the cases in CBCT and bilaterally. On the other hand, Parnia *et al* (21) and Pires *et al* (11) observed the canal in 83% by CBCT (5, 6, 21). Pires *et al* (11) also showed that the MIC could be seen in 64% bilaterally and in 19.1% unilaterally.

In this study, the location of the IC was categorized along its course and vertically allocated as the middle, lower or upper third. The canal was also buccolingually classified as the middle, buccal or lingual third (2). The results indicated that the canal was located more lingually of the mandible at the end point in all patients. The majority of the ICs were located in lower third of the mandible which is followed by middle third. No significant difference was found according to side ($p > 0.05$).

The length of the MIC was evaluated macroscopically by some researchers and the anatomical studies on cadavers. De Andrade *et al* (43) in a study of 12 human dissected mandibles demonstrated that the mean length of the IC to the midline was 20.58 mm on the right side and 21.45 mm on the left.

In a similar study, Rosa *et al* (20, 28) evaluated that the MIC had a mean length of 9.11 ± 3.00 mm by CBCT. Again, Apostolakis and Brown (22, 28) showed that a MIC had a mean length of 8.9 mm by CBCT. Also, Makris *et al* (8) and Pires *et al* (11) obtained the mean length of the IC as 15.13 mm and 7 mm (2, 19, 22, 28), whereas Pereira-Maciel *et al* (28) reported the mean length of MIC for the right side 9.64 ± 3.97 mm and for the left side was 9.84 ± 3.82 mm (19). Orhan *et al* (2) studied the mean length of the IC ranged from 10.4 to 14.2 mm the right and left sides of the mandible in 356 patients by CBCT.

In our study, the MIC length was measured separately for the right and left sides in the completely dentate, edentulous and partially edentulous individuals. The mean length of the MIC was 10.26 mm on the right side and 10.98 mm on the left of total cases. Measurements did not differ significantly by side. However, the results indicate that the left side of the MIC length was longer than right side. Moreover, the canal length was not affected by dental status and ageing.

Similarly, as Orhan *et al* (2) did, in our study, measurements were done at the starting, middle and end points of the MIC (8). The starting point was determined as 6 mm mesial to the mental foramen because previous investigations have supported that the anterior loop of the mandibular canal has a mean length of 0.4–6.0 mm. The visible length of the canal was measured from the mesial aspect of the mental foramen (starting point) to the most mesial location that was certainly visible (end point). The middle point was determined as the centre point between the starting and end points.

Some of the researchers observed that the MIC diameter was measured in certain tooth regions using CBCT, and others reported that the diameter was determined from fixed points (1, 2, 5, 9–11, 19–23, 25, 27–30, 37).

Yovchev *et al* (1) found the mean inner vertical diameter of MICs measured at the beginning was 1.44 ± 0.39 mm, while Uchida *et al* (9) reported that the IC diameter ranged from 1.0 to 6.6 mm2. Pires *et al* (11) stated that the range of the IC diameter was from 0.4 × 0.4 mm to 4.6 × 3.2 mm (2). Also, Parnia *et al* (21) stated that the diameter of IC was measured in four points with 2 mm distance from each other, and the MIC diameter was obtained 1.47 ± 0.50 mm. Again, Sahan *et al* (27) obtained that the MIC ranged from 0.6 to 3.9 mm. Each MIC was evaluated as one of four groups according to its diameter.

As in Orhan *et al* (2) study, the diameter widths of the starting, middle and end points of the channel were evaluated. In our study, the buccolingual diameter of the outer contour ranged from 1.88 to 2.49 mm, the buccolingual diameter of the inner contour ranged from 1.23 to 1.8 mm, the vertical diameter of the outer contour ranged from 1.98 to 2.73 mm, and the vertical diameter of the inner contour ranged from 1.31 to 1.93 mm. These measurements are similar to those of former investigations.

The vertical and buccolingual diameters of the inner and outer contours were measured from the starting, middle and end points of the IC. Measurements differed significantly between genders according to starting right of buccolingual inner diameter values ($p < 0.05$). Buccolingual inner diameter right starting value was significantly greater in males than in females. While measurements differed significantly between genders according to middle right of buccolingual inner diameter values ($p < 0.05$), and buccolingual inner diameter middle right value was significantly greater in males than in females, measurements differed significantly between genders according to middle right of buccolingual outer diameter values ($p < 0.05$), and buccolingual outer diameter middle right values were significantly greater in males than in females.

On the one hand, measurements differed significantly between genders according to middle left of buccolingual outer diameter values ($p < 0.05$). Buccolingual outer diameter middle left values were significantly greater in males than in females. On the other hand, measurements differed significantly between genders according to starting of vertical inner diameter right values ($p < 0.05$). Vertical inner diameter right starting values were significantly greater in males than in females. For starting of vertical outer diameter right/left, values were significantly greater in males than in females according to gender ($p < 0.05$); for middle of vertical outer diameter, right values were significantly greater in males than in females in terms of gender ($p < 0.05$).

As for right starting point of buccolingual inner diameter, values were significantly greater in 39 years and under than in 40–59 years according to age groups ($p < 0.05$). In the right starting point of buccolingual outer diameter, values were significantly greater in 39 years and under than in 40–59 years in terms of age groups ($p < 0.05$). In the right end point of buccolingual inner diameter, values were significantly greater in 39 years and under than in 40–59 years according to age groups ($p < 0.05$); middle right of vertical inner diameter values were significantly greater in 60 years and older than in 40–59 years in terms of age groups ($p < 0.05$); right starting of vertical outer diameter values were significantly greater in 39 years and under than in 40–59 years ($p < 0.05$).

Nevertheless, measurements did not differ significantly between genders and dental status ($p > 0.05$), while differing significantly between groups ($p < 0.05$). Left group of buccolingual inner diameter starting, middle and end point values were significantly smaller than the right group values.

Last of all, left group of buccolingual outer diameter starting and end point values were significantly smaller than the right group values ($p < 0.05$).

In this study, no measurement was made from the alveolar crest owing to potential periodontal disease. We evaluated the distance from the lower border of the MIC to the lower border of the mandible on CBCT images at all points because this region is free of bony change and resorption, where we found that the distance from the lower border of the IC to the lower border of the mandible ranged from 8.83 to 10.92 mm.

Similarly, De Andrade *et al* (43) found that the distance of the IC to the lower border of the mandible was 10.36–10.75 mm as compared to 9.4–11.15 mm found in Makris's study (2, 8). Orhan *et al* (2) explained the distance from the lower border of the IC to the lower border of the mandible ranged from 9.1 to 11.9 mm (mean 10.5 mm). The distance from the lower border of the IC to the lower border of the mandible was significantly greater in males than in females, and measurements did not differ significantly according to side.

Parnia *et al* (21) measured that the mean of IC from lower border of the mandible was 8.72 mm. Pereira-Maciel *et al* (28) obtained the mean distance from the canal to the inferior border of the mandible were 7.06 ± 2.95 mm.

Right/left starting point distance from IC to lower border of mandible right/left starting values was significantly greater in males than in females according to gender ($p < 0.05$). Right/left middle point distance from IC to lower border of mandible right/left starting values was significantly greater in males than in females in terms of gender ($p < 0.05$). Finally, left middle and right end point distances from IC to lower border of mandible right starting values were significantly greater in males than in females according to gender ($p < 0.05$).

CONCLUSION

In this study, we retrospectively evaluated the morphology, location, presence and course of the MIC in edentulous, partial edentulous and completely dentate cases by means of CBCT, which is a useful imaging modality while detecting lingual foramina and canals. However, further studies with better data groups are needed to compare and estimate anatomical results.

AUTHORS' NOTE

A Akbulut participated in the study design, data collection interpretation of data, writing manuscript and approval of final version. K Orhan participated in the study design data analyses and approval of final version.

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