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ORIGINAL ARTICLE

Evaluation of inferior alveolar canal course using cone-beam computed tomography

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Abstract

Background and Objective: Radiographic interpretation of inferior alveolar canal (IAC) and other anatomical structures of the mandible are very important, since the injury to these structures during surgical procedures may pose complications. The present study evaluates the course of the IAC and its variations both in the vertical and buccolingual dimension and to analyze the related anatomical structures of the mandible, using cone-beam computed tomography (CBCT).

Methodology: Three-dimensional scans of the 80 dry human mandibles were obtained using CBCT. The images were evaluated for the course of the IAC, in vertical and buccolingual dimensions. The images were analyzed for the presence of bifid mandibular canal and anterior mandibular structures such as median lingual foramen and canals, lateral lingual canals, for the visibility of incisive canals, and incidental findings.

Results: Course of the IAC was observed as progressive descent in 36.9%, straight projection in 33.1%, and catenary like configuration in 30%. The evaluation of the buccolingual dimension showed three types of the canal as sharp turn pattern in 59.4%, curved soft exit in 35%, and straight exit in 5.6%. Bifid canals were found in 57.5% and median lingual foramen was noted in 96.3%. Median lingual canal, lateral lingual canal, and incisive canal were found in 87.5%, 20.6%, and 96.3%, respectively. Bilateral accessory mental foramen was found in one sample.

Conclusion: The study revealed the interpretation of multiple mandibular anatomic structures, their variations and a range of measurement data using CBCT. This knowledge helps the clinician for precise treatment planning for implant placement and to avoid possible implications during any surgical procedures.

Introduction

"Nothing is more fundamental to treating patients than knowing anatomy." The head-and-neck regions are anatomically complex areas of the body. This considerable anatomical and functional complexity makes radiographic interpretation of this region a challenging task.[1] Conventionally, maxillofacial radiological studies, regardless of the imaging technique, provided only a two-dimensional view of complicated three-dimensional (3D) structures and have limitations such as magnification, distortion, superimposition, and misrepresentation of structures. However, with the recent technological advancement, radiological imaging has moved toward 3D and interactive imaging applications.[2]

Introduction of 3D imaging modalities such as computed tomography (CT) and cone-beam CT (CBCT) has revolutionized our ability to virtually dissect maxillofacial structures. A major concern related to dental CT is the high radiation dose. CBCT technique provides a relatively high isotropic spatial resolution of osseous structures with a reduced radiation dose compared with CT scans. Introduction CBCT has made it possible for the clinician to more accurately evaluate the anatomy of the dental structures.[3]

Inferior alveolar canal (IAC) is a critical anatomical structure which poses great variation in its course and configuration.[4] The IAC houses the inferior alveolar nerve (IAN), the inferior alveolar artery, and inferior alveolar vein. The knowledge of the exact course of the IAC, its neurovascular bundle and its anatomical variations are of great importance during surgical procedures such as third molar surgery, implant placement, osteotomy, and orthognathic surgery to avoid a high risk of injury. Injury to these structures may result in complications, such as altered sensation, numbness, pain, and damage of related blood vessels, which may trigger excessive bleeding.[5]

Hence, sound anatomic knowledge plays a significant role in understanding physiologic and pathologic variations for radiographic interpretation which helps diagnosis and treatment planning. Very few studies are done to understand the anatomy of the IAC and its variations using CBCT. Taking all these factors into consideration, the present study was undertaken using CBCT and dry human mandibles to comply with the radiation protection principle. The study aimed to understand the course of the IAC and its variations both in the vertical and buccolingual dimension and also to analyze the related anatomical structures of the mandible.

Methodology

Eighty unbroken, intact, dry adult human mandibles, and 160 IACs were included in the study. An ethical clearance to conduct the study was obtained from the institutional ethical committee. Before imaging, each dry human mandible was visually examined by direct inspection. Each mandible was mounted and was subjected to CBCT scans using Planmeca Promax 3D Max, CBCT unit. The imaging data were acquired at 66 kV and 2 mA. The scan time was within a range of 8.649–8.655 s and voxel size was 400 μm. Each multiplanar data measuring 400 × 400 pixels at 16 bits were stored in Digital Imaging and Communications in Medicine format. All the images were then analyzed in implant mode using Planmeca Romexis software. All interpretations and assessments were done in appropriate best visualized sections.

The course of the IAC was traced first in a sagittal view and then confirmed by the coronal view. Further, the course of the IAC in the sagittal view was classified into three groups according to the classification given by Ozturk *et al.*[6] [Table 1a]. To study the buccolingual dimension, IAC was first traced in a sagittal view and then confirmed by coronal as well as the axial view. In the axial view, emerging patterns of the IAC were observed and classified into three groups Ozturk *et al.*[6] [Table 1b]. Bifid canals were evaluated in the sagittal view and then confirmed in the coronal view. Various patterns of bifid mandibular canals were categorized according to Naitoh *et al.*[7] [Table 1c]. The median lingual foramen was recorded in the sagittal view and confirmed in the coronal view. Median and lateral lingual canals were recorded in the coronal view and confirmed in the axial view. The incisive canals were traced in the sagittal view and confirmed in the coronal as well as the axial view.

Linear measurements were made in the coronal section, with 0.4 mm sections, at three reference points, from the posterior aspect of the mental foramen.[8] The reference point was placed at a distance of 1 cm, 2 cm, and 3 cm, which coincided with the first, second, and third molar teeth region, respectively. All the values were recorded in millimeters. The measurements performed in each section include,

i. Measurement A, i.e., distance between the buccal most point of the IAC and the perpendicular point on the buccal margin
ii. Measurement B, i.e., the distance between the lingual most point of the IAC and the perpendicular point on the lingual margin of the mandible
iii. Measurement C, i.e., total width of the IAC
iv. Measurement D, i.e., total mandibular width, at the longest axis of IAC in the buccolingual direction.

Statistical analysis

All frequencies and the percentages were calculated, and statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS, V 10.5) package. One-way analyses of variance were used to test the difference between groups.

Table 1: Classification of the inferior alveolar canal and bifid canals

(a) Course of the inferior alveolar canal in the sagittal view		
Type I	Straight projection	The last part of the mandibular canal runs almost at the same level with the mental foramen
Type II	Catenary like configuration	Curled as hanging between two points
Type III	Progressive descent from posterior to anterior	Mandibular canal travels downward then levels off around molar region and ascends to reach the mental foramen at the premolar region
(b) Emerging patterns of the inferior alveolar canal in axial view		
Type I	Sharp turn	Canal with sharp exit sub-classified into, Type Ia: With almost 90° angle Type Ib: Sharp turn with wide angle
Type II	Curved exit from foramen	The canal starting to make a curve one tooth ahead of its exit
Type III	Straight exit	Almost follows a straight line axially from buccal to lingual as the canal travels anteriorly
(c) Bifid canals were evaluated and categorized in the sagittal view as		
Type I	Retromolar canal	
Type II	Dental type of canal	Subclassified as: IIa – Dental canal to the first molar IIb – Dental canal to the second molar IIc – Dental canal to the third molar
Type III	Forward canal	Subclassified as: IIIa – Forward canal with confluence IIIb – Forward canal without confluence
Type IV	Buccolingual canal	Subclassified as: Iva – Buccal canal IVb – Lingual canal

Table 2: Course of the IAC in the sagittal view

Course of IAC	Straight projection (%)	Catenary like configuration (%)	Progressive descent from posterior to anterior (%)	Total (%)
Right	22 (27.5)	25 (31.3)	33 (41.3)	80 (100)
Left	31 (38.8)	23 (28.8)	26 (32.5)	80 (100)
Total	53 (33.1)	48 (30)	59 (36.9)	160 (100)

IAC: Inferior alveolar canal

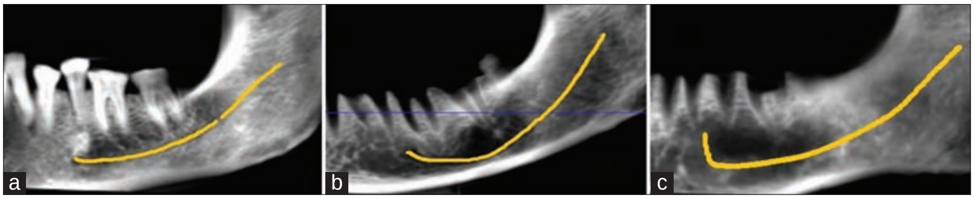

Figure 1: Course of the inferior alveolar nerve canal in sagittal view (a) Type I – straight projection, (b) Type II – catenary like configuration, (c) Type III – progressive descent from posterior to anterior

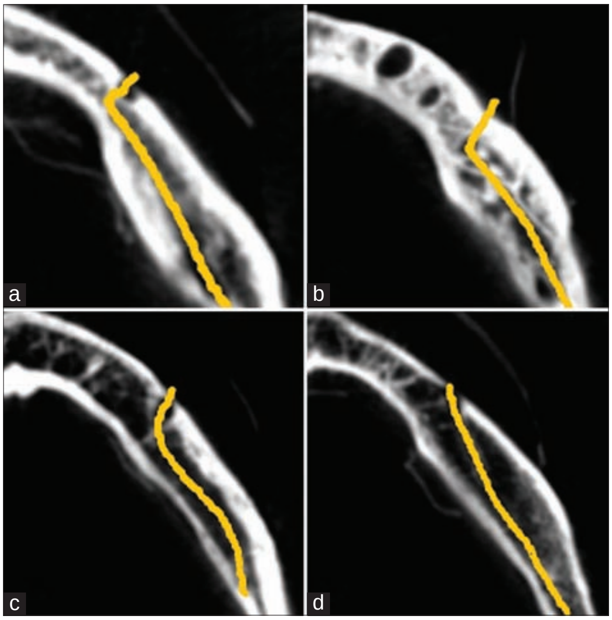

Figure 2: Course of the inferior alveolar canal in the axial view (a) Type Ia – sharp turn with almost 90° angle, (b) Type Ib – sharp turn with wide angle, (C) Type II – curved exit, (D) Type III – straight exit

When comparing more than two means, an ANOVA *F*-test was used. In the case of lower *F* value, it indicates that there is no significant difference between the groups. The level of statistical significance was set as $P < 0.05$.

Results

In the sagittal view we observed, Type I-straight projection in 33.1, Type II-catenary like configuration in 30%, and Type III-progressive descent from posterior to anterior in 36.9% [Table 2 and Figure 1]. In the axial view, we found that Type Ia-sharp turn with almost 90° angles was noted in 53.1%, Type Ib- sharp turn with wide angle was noted in 6.3%, Type II-curved soft exit in 35%, and Type III- straight exit in 5.6% [Table 3 and Figure 2].

The most frequently found that bifid mandibular canal was Type III, i.e., forward canal in 63.4% [Table 4 and Figure 3].

Among 80 samples, 96.3% (n = 77) demonstrated median lingual foramen. Single median lingual foramen was noted in the 71.3% (n = 57) and the double median lingual foramen was seen in the 25% (n = 20). Median lingual canals were seen 70 samples, among them 31.4% (n = 22) were above the genial tubercle, 5.7% (n = 4) in below the genial tubercle, in 55.7% (n = 39) both above and below, the genial tubercle was noted and the center canal was in 7.1% [Figure 4].

Table 3: Course of the IAC in the axial view

Course of IAC	With almost 90° angle (%)	A sharp turn with wide angle (%)	Curved existence from foramen (%)	Straight exit (%)	Total (%)
Right	38 (47.5)	9 (11.3)	30 (37.5)	3 (3.8)	80 (100)
Left	47 (58.8)	1 (1.3)	26 (32.5)	6 (7.5)	80 (100)
Total	85 (53.1)	10 (6.3)	56 (35.0)	9 (5.6)	160 (100)

IAC: Inferior alveolar canal

The lateral lingual canal was found in 20.6% of the samples. The study showed 96.3% of the incisive canal with good visibility (n = 154). Accessory mental foramen (AMF) was recorded in the axial view and confirmed in the coronal view as well as 3D reconstruction. The presence of AMF was noted bilaterally in the one sample [Figure 5].

The measurements performed in each section were as follows [Table 5]:

i) Measurement A was 4.96 ± 1.14 mm (mean ± standard deviation [SD]), 5.65 ± 1.22 mm (mean± SD), and 4.44 ± 1.31 mm (mean ± SD) at the first, second, and third molar teeth region, respectively. On comparison of the mean values these measurements there was a significant difference ($P < 0.01$) [Table 5]

ii) Measurement B was 2.78 ± 1.10 mm (mean ± SD), 2.64 ±1.10mm (mean ± SD), and 2.35 ± 1.05 mm (mean ± SD) at the first, second, and third molar teeth region, respectively. On comparison of these values, there was a significant difference ($P = 0.02$) [Table 5]

iii) Measurement C was 2.12 ± 0.44 mm (mean ± SD), 2.09 ± 0.43 mm (mean ± SD), and 2.21 ± 0.51 mm (mean± SD) at the first, second, and third molar teeth region, respectively. On comparison of these values, there was a significant difference ($P = 0.038$) [Table 5]

iv) Measurement D was 10.14 ± 1.44 mm (mean ± SD), 10.60 ± 1.55 mm (mean ± SD), and 9.34 ± 1.81 mm (mean ± SD) at the first, second, and third molar teeth region, respectively. On the comparison of these values, there was a significant difference ($P < 0.001$).

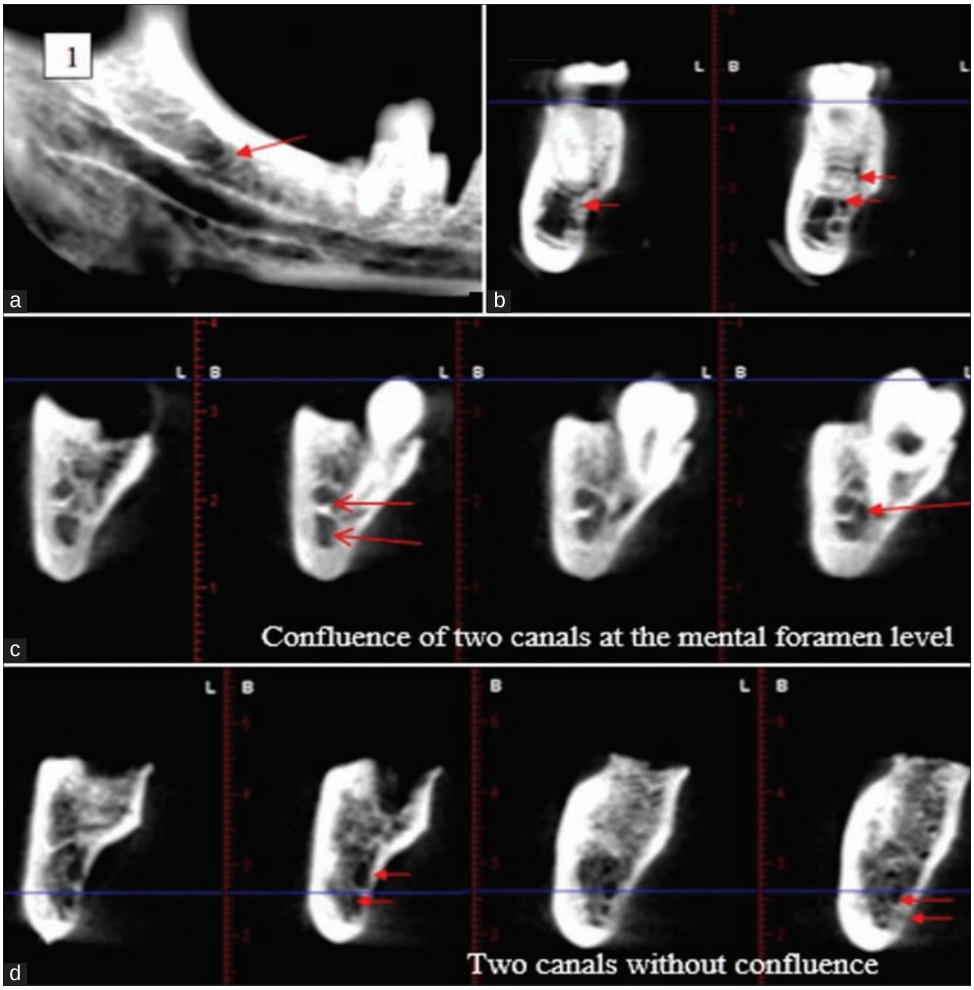

Figure 3: Types of the bifid mandibular canal (a) retromolar canal in sagittal view, (b) dental canal traversing first molar tooth, (c) forward canal with confluence, (d) frward canal without confluence in coronal view

Table 4: Types of the bifid mandibular canals

Retromolar (%)	Dental type (%)			Forward (%)		Buccolingual (%)		Total (%)
	1st molar	2nd molar	3rd molar	With confluence	Without confluence	Buccal	Lingual	
15	6	6	3	45	9	0	1	85
17.6	7	7	3.5	52.9	10.5	0	1.3	100.0

Discussion

In this radiological study, we evaluated the course of the IAC using CBCT. In the sagittal view, the most common canal pattern found was progressive descent from the posterior to the anterior (Type III). In this pattern, mental foramen is found to be at a higher level than the canal and said to have a moderate risk for implant placement. We found 30% of catenary projection (Type II), this pattern provides more space for implant placement, especially in the first molar region compared with the premolar region and is considered more safe for the implant placement.[6] Catenary projection is ideal for implant placement with the maximum available space for the implant. About 33% IAC in our study had straight projection (Type I); this pattern is related to the classic description where the nerve travels down in the body of the mandible and gives mental nerve when it reaches the level of the mental foramen. This type of canal provides the least space and considered to have high risk in implant placement.[6,9]

The buccolingual location of the IAC becomes important when the vertical dimension of the crest is hampered due to bone resorption. There are very less studies that have described the IAC in the buccolingual dimension. We found sharp turn with almost 90° angle both in the right and left sides in 53.1% and sharp turn with a wide angle in 6.3%. Sharp turn pattern

Table 5: Mean comparison of linear measurement in the coronal section at first, second and third molar teeth region millimeters

Site	*n*	Mean±SD	Min.	Max.	*F* value	*P* value
Buccal cortical plate and IAC						
1st molar	160	4.965±1.1458	2.4	7.6	39.027	<0.001
2nd molar	160	5.657±1.2223	2.8	8.8		
3rd molar	160	4.448±1.3107	2.0	8.8		
Lingual cortical plate and IAC						
1st molar	160	2.789±1.1082	0.4	5.6	6.452	0.002
2nd molar	160	2.649±1.1416	0.2	6.6		
3rd molar	160	2.355±1.0550	0.0	5.6		
Total width of the IAC						
1st molar	160	2.112±0.4411	1.2	3.6	3.288	0.038
2nd molar	160	2.091±0.4314	1.0	4.4		
3rd molar	160	2.216±0.5179	0.0	3.6		
Total buccolingual width of the mandible at the IAC						
1st molar	160	10.148±1.4469	6.8	14.0	25.095	<0.001
2nd molar	160	10.602±1.5551	6.4	15.4		
3rd molar	160	9.341±1.8148	4.8	14.0		

SD: Standard deviation, IAC: Inferior alveolar canal

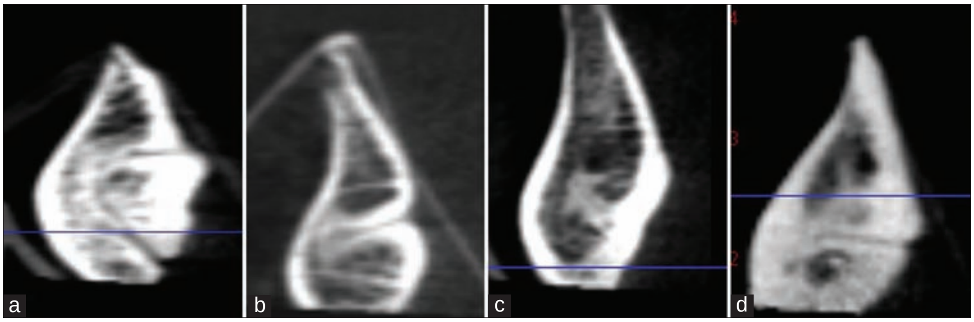

Figure 4: Types of the median lingual Canal (a) Median lingual canal both above and below the genial tubercle, (b) median lingual canal above the genial tubercle, (c) median lingual canal below the genial tubercle, (d) central canal

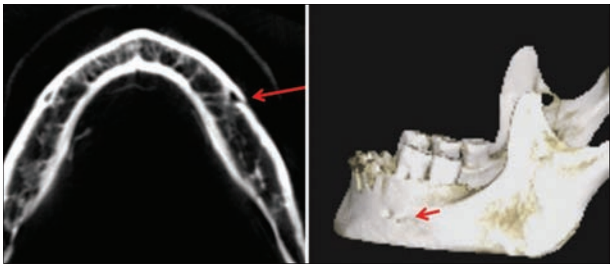

Figure 5: Accessory mental foramen and the three-dimensional reconstructed image

was the predominant type and is the safe pattern for the implant placement.[6] This pattern was followed by the curved soft exit in 35% and straight exit in 5.6%. Our finding was in near agreement with the Ozturk *et al.* study, where they had a majority of sharp turn patterns (53.1%), however, other two types differed. The awareness of the emerging patterns is important while planning the treatment where canals such as curved soft exit or straight exit may pose risk to the implant placement.[6]

In our study, four specific linear measurements were made at the first, second, and third molar teeth region. The measurements revealed the greatest distance between the IAC and the buccal bone at the second molar level, followed by the first molar and the third molar, respectively. The values of the measurement B, the shortest distance was between the IAC and the lingual bone are, at the third molar level, followed by the second molar and the first molar, respectively. The values for measurement C, i.e., the diameter value of the IAC are in agreement with the previous studies.[10,11] The values of the measurement D, on comparison of the mean values of all four measurements at the first, second, and third molar, there was significant difference ($P < 0.05$) suggestive of difference in the approximation of canal buccolingually, difference in canal width and buccolingual mandibular width at three molar teeth region. The range of linear dimension of IAC, bone thickness, distance between the buccal, lingual cortex, and IAN canal helps in accurate pre-operative assessment and planning before the surgical procedures.[11]

Bifid mandibular canals originate at the mandibular foramen and contain a neurovascular bundle.[10] From an embryological perspective, during embryonic development, there might be three inferior dental nerves innervating three groups of mandibular teeth. In our study, bifid canals were found in 41.25% among 160 sides examined, and branching of the canals varied from one to four in number. Detection of the bifid canal is important because of its clinical implications such as inadequate anesthesia, traumatic neuroma, paresthesia, and bleeding could arise because of failure to recognize the presence of this variation.[12]

The most common bifid canal in our study was forward canal, which ran along the course of the main canal and the majority of them inserted into main canal, may have an increased risk of injury. In the forward canal, 59.2% of them were above the main canal; hence, the failure in recognition of this type of canal is more prone to injury. Ridge resorption in such cases where the mandibular canal duplicates may result in impingement on the neurovascular bundle.[13] Predominantly, we had a forward canal with confluence 52.9% either at the mental foramen or ahead of the mental foramen, which may result in inadequate anesthesia. We found 17.6% of the retromolar canal. This type of canal may be particularly at risk of damage during surgery for an impacted third molar due to its location near the third molar.[13]

The presence of a bifid or duplicated mandibular canal must be considered at the time of the surgical procedure, such as dental extractions, reduction of fractures, placement, or removal of implants, including root canal treatment, orthognathic or reconstructive mandibular surgery, and lower third molar surgery. In these cases, there is the possibility of injuring the IAN.[14] Hence, the location and configuration of bifid mandibular canal variations are important in surgical procedures.

Anatomical structures of the anterior mandible

Surgical procedures performed in the anterior mandible are generally considered safe having little chance to cause damage to neurovascular structures or bleeding complications.[15] However, the region includes some important anatomic structures, such as the median lingual foramen, median lingual canal, lateral lingual canal, and the incisive canal. Very few studies have been done to describe these anatomical structures. The anterior region of the mandible from the lingual side is a very vascular area.[16] It is supplied by the sublingual branch of the lingual artery which anastomoses with the submental artery a branch of the facial artery, and the incisive arteries, branches of the inferior alveolar artery. Occasionally, the arterial structures can be accompanied by very small nerves, most likely part of the arterial vasomotor supply.[17]

In our study, among 80 samples, 96.3% demonstrated a median lingual foramen. Single median lingual foramen was noted in the 71.3% and the double median lingual foramen was seen in the 25%.

The number of median lingual foramen varied from one to two in our study. We observed double lingual foramen in 25% percentages of the sample, which was similar to the The major content of this lingual foramen is said to be penetrated by branches from the sublingual artery, submental artery, or branches resulting from the anastomosis between these vessels and lingual nerve.[17] The diameter of the lingual vascular channel is said to be proportional to the diameter of the entering artery increasing the risk of hemorrhage in the floor of the mouth when injured.[18]

In our study, median lingual canals were noted in the 87.5% of the samples. Single median lingual was noted in 61.3%, and two canals were noted in the 26.3%. The presence of lingual vascular foramina and canals in the interforaminal anterior region of the mandible may increase the risk of surgical complications during implant placement, bone grafting procedures, and osteodistraction. Oral and maxillofacial radiologists should recognize this anatomical variant and include a description in their interpretative report to inform the referring clinician of the potential for surgical complications.[19]

The incisive canal is a prolongation of the IAC anterior to the mental foramen, containing a neurovascular bundle. Our study showed 96.3% of the incisive canal with good visibility. Incisive canal has important clinical implications in relation to surgical procedures. An incisive canal with a large diameter could play an important role in successful osseointegration and prevention of post-operative sensory disturbances. Hence, additional attention should be given pre-operative assessment before any surgical procedure in this region.[20]

AMF is as small buccal foramina with continuity to the IAC and presumed to be the result of branching of the mental nerve before its exit from the mental foramen.[21] In our study, we noted the presence of bilaterally symmetrical AMF in one sample.

Clinical applications of CBCT are rapidly being applied to the dental practice. CBCT allows images to be displayed in different sections and a variety of formats, thus eases the interpretation and helps in the identification of minor anatomical structures. Interpretation of CBCT data demands a thorough understanding of the spatial relations of the bony anatomic elements and extended pathologic knowledge of various maxillofacial structures. IAC in the mandible is an important structure which is vulnerable to injury. The canal often shows variations in the course and the anatomy. Hence, it is critical to determine the location and configuration of the IAC and other related vital structures. In general, the anterior mandible is considered safe for the surgical procedures, but important anatomical structures of the anterior mandible such as median lingual foramen, medial lingual canal, lateral lingual canal, and incisive canal may also result in unavoidable complications and should be interpreted as well.

Conclusion

Clinical applications of CBCT are rapidly being applied to the dental practice. CBCT allows images to be displayed in different sections and a variety of formats, thus eases the interpretation and helps in the identification of minor anatomical structures.

Interpretation of CBCT data demands a thorough understanding of the spatial relations of the bony anatomic elements and extended pathologic knowledge of various maxillofacial structures. IAC in the mandible is an important structure which is vulnerable to injury. The canal often shows variations in the course and the anatomy. Hence, it is critical to determine the location and configuration of the IAC and other related vital structures. In general, the anterior mandible is considered safe for the surgical procedures, but important anatomical structures of the anterior mandible such as median lingual foramen, medial lingual canal, lateral lingual canal, and incisive canal may also result in unavoidable complications and should be interpreted as well.

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