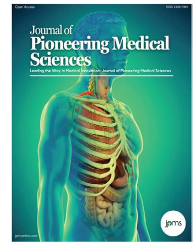

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Cone-Beam Computed Tomographic Evaluation of Mandibular Lingual Canals and Foramina for Safe Implant Placement in Prosthodontics

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Abstract **Background:** The Mandibular Lingual Canals (MLCs) and Mandibular Lingual Foramina (MLFs) are important anatomical structures of the anterior mandible that transmit small neurovascular bundles. Their considerable variation in number, size, course and anatomical position may increase the risk of hemorrhagic and neurosensory complications during dental implant placement and other surgical procedures. Cone-Beam Computed Tomography (CBCT) provides three-dimensional visualization of these structures and allows detailed preoperative assessment. **Objective:** To evaluate the anatomical and morphometric characteristics of mandibular lingual canals and foramina in adults using CBCT and to determine their associations with sex and age. **Methods:** This retrospective cross-sectional study analyzed 72 CBCT scans of adults aged ≥18 years obtained from a private hospital in Sulaymaniyah, Iraq. The sample included 27 males and 45 females and was divided into two age groups: 18-49 years (n = 57) and ≥50 years (n = 15). The number of lingual canals, foramen diameter, canal length, canal direction and distances from the canal to the alveolar crest (L1), adjacent anterior tooth apex (L2), inferior mandibular border (L3) and Labial Cortical Plate (LC/CP) were assessed. Midline canals were classified as supraspinous, interspinous, or infraspinous. Statistical analyses were performed using independent-samples t-test, Mann-Whitney U test, chi-square test, or Fisher's exact test, as appropriate. **Results:** Among the 72 patients, two lingual canals were most common (43, 59.7%), followed by one canal (21, 29.2%) and three canals (8, 11.1%). No significant differences were found in the number of canals according to sex ($p = 0.998$) or age group ($p = 0.849$). Males demonstrated a significantly greater mean canal diameter than females (1.27±0.38 mm vs. 1.08±0.30 mm; $p = 0.018$). No significant sex-related differences were observed for canal length, L1, L2, L3, or LC/CP. The mean L2 distance was significantly greater in participants aged ≥50 years than in those aged 18-49 years (11.99±5.32 mm vs. 9.78±3.05 mm; $p = 0.039$). A total of 131 canals were identified, with oblique canals being the most frequent (45.0%), followed by vertical (32.1%) and horizontal (22.9%) canals. Supraspinous and infraspinous positions each accounted for 40.5%, while interspinous canals accounted for 19.1%. **Conclusion:** Mandibular lingual canals and foramina demonstrate considerable anatomical and morphometric variation in the anterior mandible. Significant sex-related differences were observed in canal diameter, while age was significantly associated with the distance between the canal and the adjacent anterior tooth apex. CBCT assessment should therefore be considered an important component of preoperative planning for implant placement and other surgical procedures involving the anterior mandible to minimize the risk of neurovascular injury and hemorrhagic complications.

Key Words Cone-Beam Computed Tomography, Mandibular Lingual Canal, Mandibular Lingual Foramen, Anterior Mandible, Dental Implant Placement, Morphometric Analysis, Anatomical Variation, Neurovascular Bundle, Preoperative Assessment, Prosthodontics

INTRODUCTION

Mandibular Lingual Canal (MLC) and Mandibular Lingual Foramina (MLF) are major anatomic landmarks of the mandibular alveolar process and these carry smaller neurovascular bundles through the lingual cortex. They can be found either at the midline location or laterally on the mandibular body and there is much variability between individuals in relation to the morphology and distribution, such as number, size, length, course and anatomic locations. The neurovascular structures within MLFs can have connections to branches of the sublingual, submental and mylohyoid neurovascular systems. Even though these MLFs are relatively small in size, the related vessels may have clinical importance during surgeries on the anterior mandible [1-4].

The anterior portion of the mandible is commonly utilized in prosthodontic procedures, particularly dental implant placement, as well as bone grafting, genioplasty, orthognathic surgery, trauma cases and many other surgeries. Injury to the neurovascular bundles that run through the lingual foramina can cause hemorrhaging and other problems after surgery. Having many foramina, large foramina, or deep canals through the mandibular symphysis adds emphasis on the need for accurate pre-surgical evaluation of the structures [1,2,5].

Traditional two-dimensional imaging modalities such as panoramic and periapical radiographs have very little potential to evaluate the complicated three-dimensional anatomy of the anterior mandible due to anatomical superimposition, geometrical distortion and difficulty in defining the path of tiny lingual canals. Cone-Beam Computed Tomography (CBCT) helps in the multi-planar and three-dimensional assessment of the mandibular symphysis and evaluation of lingual foramina along with the associated canals. CBCT can thus be applied to identify the number and size of foramina, length and path of the canal, as well as the relation of these anatomical features with alveolar crest, tooth apex, mandibular border and labial plate of cortex [3,6,7].

Previous CBCT investigations have shown significant anatomical variations in the mandibular lingual canal system. Various descriptions of a single foramen, double foramina, or multiple foramina have been made, while the orientation of the lingual canal is described as being either vertical, horizontal, or oblique. The location of the midline lingual canals has also been examined in regard to the genial spines, as being supraspinous, interspinous, or infraspinous in regard to the genial spines. These variations may be important when considering the implications on surgery due to the different number and location of foramina [3,5,8,9].

Age and gender can also affect the morphometric features and anatomical location of the mandibular lingual canals. Earlier studies have revealed gender differences in the canal length, foraminal diameter and the distance between lingual foramina and adjacent anatomical structures. Changes due to age in the morphology of the alveolar bone and resorption of the alveolar bone can also lead to variations in the association between the lingual canal and alveolar crest. There are, however, some inconsistencies in the literature with respect to the impact of age and gender and further research is needed [3,8,10].

Although CBCT imaging has gained popularity in the evaluation of the anterior mandible in recent times, wide disparity exists among previous research studies concerning the parameters measured and the definition criteria used to categorize the canals under the tongue. Moreover, no data on the precise morphological characteristics of lingual canals in the mandible in the Kurdish population in Iraq exist. It is expected that a thorough study of the number of foramina present, size of individual foramina, length of the canals and their orientation could yield useful information. Thus, this current research was conducted with an aim of assessing the anatomical and morphometric features of the mandibular lingual canals and foramina in adults who were 18 years old and above. The study evaluated the correlation between these features and sex and age groups (18 to 49 years and 50+ years) in addition to the number of the foramina (one, two or multiple), diameter of the foramina, lingual canal length, lingual canal direction (vertical, horizontal or oblique) and the distance from the canal to the alveolar crest (L1), apex of the anterior teeth (L2), inferior border of the mandible (L3) and Labial Cortical Plate (LC/CP). Furthermore, the classification of midline mandibular lingual canals was done based on their position with respect to the genial spines (supraspinous, interspinous, or infraspinous).

METHODS

Study Design and Ethical Considerations

The retrospective cross-sectional study consisted of the assessment of 72 CBCT images retrieved from the radiographic files of a private hospital in Sulaymaniyah, Iraq. No further investigations such as radiographic imaging or clinical investigations were conducted for this study. The CBCT images were analyzed in a retrospective manner after the removal of all patient identifying data and thus there was no access to any identifiable patient data during the entire study period.

Study Population and Sample Selection

Participants for the study consisted of 72 adult subjects, age ≥18 years, whose CBCT images involved the anterior region of the mandible. This sample consisted of 27 males and 45 females. These individuals were divided into two age groups, where Group 1 was 18-49 years old (n = 57) and Group 2 ≥50 years old (n = 15).

Inclusion Criteria

- Subjects above 18 years old
- CBCT images including the mandibular anterior area and the lingual cortex plate
- Sufficiently clear images that would enable evaluation of the lingual canal and foramen
- Adequate imaging of the relevant anatomical structures needed for morphometric analysis

Exclusion Criteria:

- Past history of injury or fractures to the anterior mandible
- History of previous dental implants placed or surgical procedures in the area of interest
- Presence of cystic lesions, tumors, congenital malformations, or any other pathological conditions related to the anterior mandible

- Bone resorption and changes in the anatomy making it impossible to accurately identify the relevant anatomic landmarks
- CBCT radiographs with significant movement, metallic or other artifacts

CBCT Image Acquisition and Analysis

CBCT exams were analyzed with the help of the available software. All images were studied in axial, sagittal, coronal and cross-sectional scans. The parameters like brightness, contrast and magnification were modified wherever required to visualize the lingual foramen and its canal. The measurements were taken in millimeters accurate to 0.1 mm unless stated otherwise due to software limitations.

Identification and Classification of Lingual Foramina

A mandibular lingual canal is described as a radiolucent canal originating from a lingual foramen into the mandible. The number of lingual foramina was counted as either one, two, or multiple (more than two). In cases where there were more than one foramen or canal, each separate foramen with its own canal was analyzed individually. Individual morphometric measurements were also made for each individual canal (Table 1).

Definition of Canal Direction

The direction of every lingual canal was assessed using multiplanar CBCT scans. A canal was considered to be vertical if its main orientation was oriented from superior to inferior in relation to the mandibular body; a canal was considered horizontal if its main orientation was oriented approximately anterior-posteriorly in the mandibular body; and oblique if it had a diagonal orientation. The assessment was based on the main orientation of the canal rather than any short deviation in direction.

Midline Lingual Canal Classification

For canals that were in the mandibular midline, the location of the lingual foramen/canal was described based on the relation of the canal to the genial spines. Supraspinous canals were those whose positions were above the genial spines; interspinous canals were found in the region between the superior and inferior genial spines and infraspinous canals were below the genial spines.

Observer Reliability

To determine the intra-examiner reliability, a random selection of CBCT images was re-examined by the same examiner after a period of approximately two weeks. The Intraclass Correlation Coefficient (ICC) was used for determining the agreement on continuous variables, while Cohen’s Kappa Coefficient was employed for categorical variables such as the number of lingual foramina, canal direction and midline canal position.

Statistical Analysis

Analysis was performed using the IBM SPSS Statistics software package (IBM Corporation, Armonk, NY, USA).

Table 1: Morphometric and Anatomical Parameters

Parameter	Code/Categories	Definition/Measurement
Sex	Male/Female	Recorded from the patient demographic record.
Age group	18-49 years; ≥50 years	Age at the time of CBCT examination.
Number of foramina	Single/Double/Multiple	Total number of identifiable lingual foramina in the evaluated region.
Foramen diameter	mm	Maximum diameter of each identifiable foramen measured at the external opening.
Lingual canal length	mm	Linear distance from the lingual foramen to the most anterior/deepest identifiable point of the associated canal.
Canal direction	Vertical/Horizontal/Oblique	Determined according to the predominant direction of the canal relative to the mandibular body.
L1	mm	Shortest distance from the lingual canal/foramen to the alveolar crest.
L2	mm	Shortest distance from the anterior-most point of the lingual canal to the apex of the nearest anterior tooth.
L3	mm	Shortest distance from the lingual canal/foramen to the inferior border of the mandible.
LC/CP	mm	Shortest horizontal distance from the anterior-most point of the lingual canal to the inner surface of the labial cortical plate.
Midline canal position	Supraspinous/Interspinous/Infraspinous	Classification according to the relationship of the canal/foramen to the genial spines.

Normality tests were performed to assess continuous variables, which were then described by mean±SD or median and IQR as applicable. Categorical variables were described by number (frequency) and percentage (%). Differences in continuous morphometric variables according to sex and age group were evaluated by the independent samples t-test or Mann-Whitney U test, respectively. Association between categorical variables was assessed using the chi-square test or Fisher's exact test, respectively.

Where there were multiple lingual canals for any patient, the morphometric parameters (diameter of the foramen, length of the canal, L1, L2, L3 and LC/CP) were first obtained individually for each canal. However, for the inferential analysis involving comparisons with respect to gender and age groups, the measurements for the morphometric parameters were taken as the mean of all canals for a patient, in order to ensure that each patient had only one observation, thereby maintaining the assumption of independent observations. On the other hand, the directions and midline positions of the canals were analyzed using descriptive statistics at the level of the canal since these factors are canal-specific and multiple canals from a single patient cannot be considered independent.

RESULTS

Patient Characteristics

In total, 72 CBCT scans were used in this study. The study sample was composed of 27 males (37.5%) and 45 females (62.5%).

Table 2: Demographic Characteristics of the Study Population and Distribution of the number of Lingual Canals per Patient (n = 72)

Characteristic	Category	n (%)	p-value
Gender	Male	27 (37.5%)	0.998
	Female	45 (62.5%)	
Age group	Group 1	57 (79.2%)	0.849
	Group 2	15 (20.8%)	
Number of lingual canals	One	21 (29.2%)	
	Two	43 (59.7%)	
	Three	8 (11.1%)	

Table 3: Comparison of Patient-Level Morphometric Measurements according to Gender and Age Group (n = 72). Values are Presented as Mean ± Standard Deviation (SD)

Variable	Male Mean ± SD	Female Mean ± SD	p-value	Age Group 1 Mean ± SD	Age Group 2 Mean ± SD	p-value
Diameter (mm)	1.27±0.38	1.08±0.30	0.018	1.14±0.36	1.20±0.29	0.528
Canal length (mm)	7.92±1.99	8.40±2.05	0.332	8.25±1.93	8.08±2.43	0.773
L1 (mm)	20.23±3.12	18.56±3.84	0.060	19.32±3.24	18.66±5.04	0.534
L2 (mm)	10.57±4.21	10.04±3.40	0.555	9.78±3.05	11.99±5.32	0.039
L3 (mm)	4.25±2.07	4.42±2.50	0.771	4.41±2.33	4.14±2.43	0.690
LC/CP (mm)	3.13±1.31	2.73±1.37	0.223	2.90±1.29	2.81±1.63	0.807

Table 4: Distribution of Canal-Level Anatomical Characteristics (n = 131 canals)

Variable	Category	n	%
Canal direction	Direction 1	42	32.1
	Direction 2	30	22.9
	Direction 3	59	45.0
Midline canal position	Position 1	53	40.5
	Position 2	25	19.1
	Position 3	53	40.5

Based on age distribution, 57 patients (79.2%) belonged to Age Group 1, while 15 patients (20.8%) belonged to Age Group 2.

The number of lingual canals in each patient varied between 1 and 3 canals. The most prevalent occurrence of 2 lingual canals was detected in 43 patients (59.7%), followed by 1 lingual canal in 21 patients (29.2%) and 3 lingual canals in 8 patients (11.1%). There were no statistically significant differences in the number of lingual canals based on gender ($p = 0.998$) and age group ($p = 0.849$) (Table 2).

Patient-Level Morphometric Analysis

In light of the fact that a number of the patients had more than one lingual canal, morphometric data (diameter, canal length, L1, L2, L3 and LC/CP) were computed for each patient. For instance, for patients with more than one canal, the average of all the morphometric data from all canals was computed for each patient.

A comparison of morphometric measurements on patient basis with regards to gender is given in Table 3. In terms of diameter of canal, males have significantly larger (1.27±0.38 mm) canals as compared to females (1.08±0.30 mm) ($p = 0.018$).

Mean length of the canal was 7.92±1.99 mm for males and 8.40±2.05 mm for females, where there was no statistically significant difference ($p = 0.332$). Also, no significant difference based on gender for L1, L2, L3, or LC/CP was found (all $p>0.05$).

Comparison based on age groups revealed mean diameter of the canal 1.14±0.36 mm in Age Group 1 and 1.20±0.29 mm in Age Group 2 ($p = 0.528$). Similarly, there was no statistically significant difference between the two age groups with respect to canal length, L1, L3, or LC/CP (all $p>0.05$). However, L2 was significantly higher in Age Group 2 (11.99±5.32 mm) than Age Group 1 (9.78±3.05 mm) ($p = 0.039$ (Table 3).

Canal-level Anatomical Characteristics

A total of 131 lingual canals were recorded and assessed. Because of canal direction and anatomy being intrinsic to canals and not to patients, these parameters were assessed at the canal level.

The frequency distribution of canal direction and anatomy is shown in Table 4.

Out of 131 lingual canals, the oblique canal direction had the highest frequency (59 canals, 45.0%), followed by the vertical canal direction (42 canals, 32.1%) and horizontal canal direction (30 canals, 22.9%).

In respect to anatomical position, there was an equal distribution of supraspinous and infraspinous positions, each occurring in 53 canals (40.5%) while the interspinous position was found in 25 canals (19.1%).

The inferential analysis of the relationship between canal direction and anatomical position based on gender or age was not undertaken as there is no independence between canals from one individual. Thus, these canal-based measures were presented descriptively to comply with the independence assumption of statistical tests.

DISCISSION

In general, the anterior mandible has been regarded as a relatively safe area where prosthodontic treatments such as dental implants, genioplasty and harvesting of bone grafts could be performed without major problems. The only problem associated with the anterior mandible is that there are several neurovascular bundles located along the course of the lingual canal and passing through the lingual foramen. Thus, a careful study of these structures before surgical intervention is required. CBCT allows for high-resolution 3D images of the complicated anatomy structures to be obtained. This study has analyzed the prevalence and morphometric characteristics, as well as the anatomical distribution of the mandibular lingual canals and foramina in 72 adult patients.

Regarding patient demographics and canal configuration, the presence of multiple lingual canals was extremely common in our study, wherein two canals were the most common (59.7%), followed by single (29.2%) and triple (11.1%) canals. These results differ slightly from those obtained regionally from Middle Eastern countries and internationally by Al-Amery *et al.* [11], who used CBCT to show 60.0% for double canals in males and 43.1% for singles in females. In the same vein, Tagaya *et al.* [12] and Von Arx *et al.* [13] report on a multidimensional multicenter evaluation and morphometric assessment, respectively, where it is revealed that the number of canals is often underestimated in traditional two-dimensional examinations but becomes much more evident through three-dimensional evaluations. However, in our study, there were no statistically significant differences in the number of canals in relation to gender ($p = 0.998$) or age ($p = 0.849$). On the other hand, there were some interesting observations regarding the structural dimensions. For instance, males had a larger canal diameter (1.27±0.38 mm) compared to females (1.08±0.30 mm; $p = 0.018$). The sexual differences in osseous structure and vascular channel width are consistent with a number of global morphological analyses conducted by Timock *et al.* [14] and Liang *et al.* [15], which reveal greater bone structure and well-developed vascular networks within male mandibles based on craniofacial skeletal size.

The results of the patient-based morphometric study revealed that the vertical distance from the canal to the alveolar crest (L1), inferior border (L3) and labial cortical plate distance (LC/CP) had no statistical significance regarding gender and age groups ($p>0.05$ for all). In contrast, the age group difference was found to be statistically significant ($p = 0.039$) for the shortest distance from the canal to the apex of the adjacent anterior tooth (L2), being 9.78±3.05 mm for Age Group 1 (18-49 years old) and 11.99±5.32 mm for Age Group 2 (≥50 years old). This variation can be explained by age-related resorption of alveolar bone, physiological attrition of teeth and eruption of teeth continuously, all these contributing to variations in the vertical positional relationship between the apices of teeth and internal landmarks of mandible, as found by Kawai *et al.* [16] and Şişman *et al.* [17].

With respect to canal level anatomy, a total of 131 lingual canals were analyzed, where the predominant direction was oblique (45.0%) compared with vertical (32.1%) and horizontal (22.9%). This is consistent with the results found by Sheikhi *et al.* [18], in which the majority of canals are directed superiorly and obliquely. In terms of the midline canal anatomical location with regard to the genial spines, supraspinous and infraspinous locations were equally common (40.5% each), whereas interspinous locations constituted 19.1%. With this information, it becomes apparent that if surgery, osteotomy, or even fixture placement takes place at the symphysis, then canals running through multiple vertical planes should be considered. Given the nature of the pathways, which carry terminal branches of sublingual and submental arteries, a distance of at least 2 to 3 mm is required from the foramen to maintain vessel safety. Some of the potential methodological issues that need to be taken into account while analyzing the above results include the fact that the study is a retrospective cross-sectional study using archived CBCT scans from only one regional center and thus the results would depend on the demography of the population in that particular region and might not apply universally to other ethnic groups. Moreover, clinical factors like systemic bone mineral density status and accurate periodontal attachment status could not be gathered from the radiographic records.

CONCLUSION

CBCT analysis shows high prevalence of multiple mandibular lingual canals and various anatomical variations in the anterior mandible region. There is sexual dimorphism in the size of the canals and age-related variations that significantly affect the distance of the canals to the adjacent apices (L2). Given the universal occurrence and various anatomical structures of the lingual canals, it is highly advised to conduct a CBCT evaluation prior to surgical procedures in the anterior mandible to prevent severe hemorrhagic or neurosensory complications.

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