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Assessment Of Location And Anatomical Characteristics Of Mental Foramen, Anterior Loop, Mandibular Incisive Canal And Accessory Canal Using Cone Beam Computed Tomography

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ABSTRACT

Background: Accurate assessment of the mental foramen (MF), anterior loop (AL), mandibular incisive canal (MIC), and accessory canals (ACs) is essential for successful clinical interventions in the mandibular region. Cone Beam Computed Tomography (CBCT) provides high-resolution three-dimensional imaging that facilitates precise evaluation of these anatomical structures, minimizing the risk of neurovascular complications.

Objective: This retrospective study aimed to assess the location, dimensions, and anatomical variations of the MF, AL, MIC, and ACs using CBCT imaging.

Methods: A cross-sectional study was conducted on 200 CBCT scans obtained from the Kamineni Institute of Dental Sciences. The scans were evaluated using Carestream Imaging Software 8.0.1.8(9600) in high-resolution mode. Key parameters analyzed included the position and orientation of the MF, the presence and dimensions of the AL, the length and orientation of the MIC, and the distribution of ACs. Measurements were compared between the right and left sides, and statistical analyses were performed using SPSS software, with a significance threshold set at $p<0.05$.

Results: The MF was most commonly located in the buccal position (70% on the right side, 75% on the left side). The mean length of the MIC was 13.5 mm, with no statistically significant differences between genders or sides. The presence of ACs was significantly higher on the right side (15%) compared to the left side (10%) ($p=0.046$). The AL was present in 20% of cases on both sides, with no statistically significant difference ($p=1.000$). Other measurements, including distances to the buccal plate, lingual plate, and inferior mandibular border, showed minor variations that were not statistically significant.

Conclusion: This study highlights the variability in mandibular anatomy, emphasizing the need for preoperative CBCT imaging to improve diagnostic accuracy and procedural safety. The findings reinforce the importance of individualized treatment planning, particularly in implant placement, endodontics, and surgical interventions. Further research with larger, multi-center studies is recommended to enhance the understanding of mandibular anatomical variations across diverse populations.

1. INTRODUCTION

Accurate assessment of the mental foramen (MF), anterior loop (AL), mandibular incisive canal (MIC), and accessory canals (ACs) is crucial for successful clinical interventions in the mandibular region. These structures are vital in dental and maxillofacial procedures, including implant placement, local anesthesia, and surgical interventions. Precise knowledge of their variations helps minimize the risk of neurovascular complications, which could result in patient discomfort or long-term functional impairments.

The mental foramen, typically located in the premolar region, serves as the exit point for the mental nerve and vessels. Its position varies among individuals and populations, influencing surgical and prosthetic planning. Adjacent to the mental foramen, the anterior loop is a critical anatomical structure where the inferior alveolar nerve extends beyond the mental foramen before curving back into the canal. Its dimensions and presence must be meticulously evaluated to avoid inadvertent nerve injury[1].

Similarly, the mandibular incisive canal, an extension of the inferior alveolar canal, houses the neurovascular bundle supplying the mandibular anterior teeth. Its anatomical characteristics, including size and orientation, vary widely. Additionally, accessory canals, when present, add to the complexity of the mandibular anatomy. Identifying their presence and location on either side of the mandible is essential for clinicians to ensure safety and efficacy in procedures such as implant placement and endodontic treatments [2].

Cone Beam Computed Tomography (CBCT) has emerged as a pivotal imaging modality, offering high-resolution, three-dimensional visualization of craniofacial structures. Its ability to provide accurate spatial relationships and anatomical insights has significantly enhanced diagnostic precision and treatment planning across various dental specialties. CBCT facilitates the precise evaluation of critical anatomical structures like the mental foramen, anterior loop, mandibular incisive canal, and accessory canals. The ability to visualize these structures in three dimensions allows for accurate assessment of their location, symmetry, and anatomical variations on both sides of the mandible. This is particularly valuable for procedures such as implant placement, endodontic treatments, and surgical interventions, where accurate anatomical knowledge is paramount.

Failure to accurately identify these anatomical landmarks can lead to significant complications. For instance, inadequate recognition of the anterior loop may result in nerve injury during implant placement, leading to sensory disturbances in the lower lip and chin[3] .

2. METHODS AND METHODOLOGY

This retrospective cross-sectional study was conducted on 200 CBCT scans of patients from Kamineni Institute of Dental Sciences. The study aimed to evaluate the location, dimensions, and anatomical variations of the mental foramen (MF), anterior loop (AL), mandibular incisive canal (MIC), and accessory canals (ACs). CBCT scans were selected based on clear visualization of the mandibular region and absence of artifacts to ensure reliable and accurate assessments. Scans were performed using Care stream Software Imaging 8.0.1.8(9600) in high-resolution mode under the panoramic tab, with the focal trough layer adjusted on the axial plane for optimal imaging.

The mental foramen was analyzed on both sides using cross-sectional and panoramic views. Horizontal reference lines were drawn on 2D panoramic images to determine the inferior border of the mental foramen and the endmost point of the mandibular canal. Distances were measured from the end point of the mandibular canal to the buccal plate, lingual plate, and inferior border of the mandible. Additionally, the relative position of the mental foramen to adjacent teeth and its spatial orientation within the mandible were recorded. Axial images provided detailed visualization of the mental foramen's precise location and its anatomical relationships.

The anterior loop of the inferior alveolar nerve was evaluated in axial and cross-sectional views. Its presence, length, and proximity to the mental foramen and surrounding anatomical structures were documented. The mandibular incisive canal was traced along its course in axial and panoramic images, with its size, orientation, and neurovascular contents carefully analyzed. The study also identified the presence and distribution of accessory canals, noting their clinical significance and side-specific variations.

All measurements were performed using built-in tools in the Carestream Imaging Software. Key measurements included the distance from the endmost point of the mandibular canal to the buccal plate, lingual plate, and inferior mandibular border, along with the dimensions and orientation of the mental foramen, anterior loop, and mandibular incisive canal. These measurements were categorized for comparison between the right and left sides.

The scans were evaluated by two independent observers experienced in CBCT imaging to minimize inter-observer variability. In cases of disagreement, a third observer reviewed the findings to ensure consistency. The data was systematically categorized to assess symmetry and side-specific differences in the mandibular anatomy.

The study adhered to ethical guidelines, with approval obtained from the institutional ethics committee. Patient confidentiality was maintained by anonymizing all CBCT data before analysis. Statistical analysis was conducted using SPSS software, with descriptive statistics summarizing the data and inferential tests applied to determine significant differences between sides. A p-value of <0.05 was considered statistically significant.

This methodology provided a comprehensive framework for evaluating the anatomical variations of the mandibular region, contributing to improved safety and precision in dental and maxillofacial clinical practice.

3. RESULTS:

200 CBCT scans were used in this study. The majority of mental foramens are located in the buccal position,(fig:2) with 70% on the right side and 75% on the left side, making it the most common position overall. A smaller proportion of mental foramens are located in the lingual position, with 12.5% on the right side and 15% on the left side. The mental foramen is centered in 17.5% of cases on the right side and 10% on the left side. This indicates a slightly higher prevalence of buccal positioning and variability between the right and left sides. (Table 1)

Table 1: Frequency Distribution of the Position of Mental Foramen in the Right and Left Sides

Position	Right Side (n = 200)	Left Side (n = 200)	Total (n = 400)	Percentage (%)
Buccal	140 (70%)	150 (75%)	290 (72.5%)	72.5%
Lingual	25 (12.5%)	30 (15%)	55 (13.75%)	13.75%
Centered	35 (17.5%)	20 (10%)	55 (13.75%)	13.75%
Total	200 (100%)	200 (100%)	400 (100%)	100%

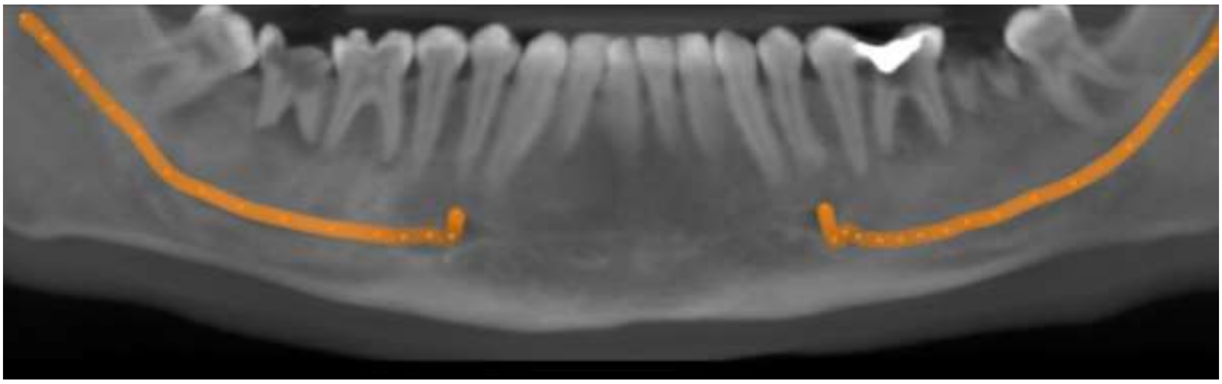

Figure 1: cross sectional panoramic view of Mental foramen

Figure 2: position of mental foramen in sagital view

The mean length of Mandibular Incisive Canal Length (Fig:3) is slightly longer in males (13.8 mm) compared to females (13.2 mm), with a total mean length of 13.5 mm. The difference is not statistically significant (p = 0.10). (Table 2) The mean distance to Buccal Plate is marginally greater in males (6.3 mm) compared to females (6.0 mm), with a total mean of 6.2 mm. The difference is not statistically significant (p = 0.20). The mean distance to Lingual Plate is slightly greater in males (4.9 mm) compared to females (4.7 mm), with a total mean of 4.8 mm. This difference is not statistically significant (p = 0.25). The mean distance to Inferior Border of Mandible is slightly greater in males (9.5 mm) compared to females (9.1 mm), with a total mean of 9.3 mm. The difference is not statistically significant (p = 0.30).

Figure 3: measurement of mandibular Incisive canal

Table 2: Mean and Standard Deviation of Mandibular Incisive Canal Length and Distances from Canal to Buccal and Lingual Plates and Inferior Border of the Mandible by Gender

Parameter	Male (n = 100)	Female (n = 100)	Total (n = 200)	p-value
Mean Length of Mandibular Incisive Canal (mm)	13.8 ± 2.2	13.2 ± 2.0	13.5 ± 2.1	0.10
Mean Distance to Buccal Plate (mm)	6.3 ± 1.4	6.0 ± 1.6	6.2 ± 1.5	0.20
Mean Distance to Lingual Plate (mm)	4.9 ± 1.2	4.7 ± 1.4	4.8 ± 1.3	0.25
Mean Distance to Inferior Border of Mandible (mm)	9.5 ± 2.1	9.1 ± 1.9	9.3 ± 2.0	0.30

Figure 4: Distances from Incisive Canal to Buccal and Lingual Plates and Inferior Border of the Mandible

The mean length of Mandibular Incisive Canal Length is slightly longer on the right side (13.6 mm) compared to the left side (13.4 mm), with a total mean length of 13.5 mm. The difference is not statistically significant (p = 0.22). The mean distance to Buccal Plate is slightly greater on the right side (6.3 mm) compared to the left side (6.1 mm), with a total mean of 6.2 mm(Fig:4). The difference is not statistically significant (p = 0.30).(Table 3) The mean distance to Lingual Plate is slightly greater on the right side (4.9 mm) compared to the left side (4.7 mm), with a total mean of 4.8 mm. The difference is not statistically significant (p = 0.25). The mean distance to Inferior Border of Mandible is slightly greater on the right side (9.4 mm) compared to the left side (9.2 mm), with a total mean of 9.3 mm. The difference is not statistically significant (p = 0.35).

Table 3: Mean and Standard Deviation of Mandibular Incisive Canal Length and Distances from Canal to Buccal and Lingual Plates and Inferior Border of the Mandible on Right and Left Sides

Parameter	**Right Side (n = 200)**	**Left Side (n = 200)**	**Total (n = 400)**	**p-value**
Mean Length of Mandibular Incisive Canal (mm)	13.6 ± 2.1	13.4 ± 2.0	13.5 ± 2.1	0.22
Mean Distance to Buccal Plate (mm)	6.3 ± 1.5	6.1 ± 1.5	6.2 ± 1.5	0.30
Mean Distance to Lingual Plate (mm)	4.9 ± 1.3	4.7 ± 1.3	4.8 ± 1.3	0.25
Mean Distance to Inferior Border of Mandible (mm)	9.4 ± 2.0	9.2 ± 1.9	9.3 ± 2.0	0.35

The Accessory canal was seen on right side in 15% of the cases and on left side in 10% of cases.(Table 4) The p-value of 0.046 indicates a statistically significant difference between the right and left sides for the presence of an accessory canal, suggesting that the distribution is not uniform.

Table4: Presence or Absence of Accessory Canal and Anterior Loop of Mandibular Canal on Left and Right Sides

Condition	Right Side (n = 200)	Left Side (n = 200)	Total (n = 400)	Percentage (%)
Accessory Canal				
Present	30	20	50	25%
Absent	170	180	350	75%
Total	200	200	400	100%
Anterior Loop				
Present	40	40	80	40%
Absent	160	160	320	60%
Total	200	200	400	100%

The Anterior loop Fig:1 was seen on right side in 20% of the cases and on left side in 20% of the cases.(Table 5) The p-value of 1.000 indicates no significant difference between the right and left sides for the presence of an anterior loop, suggesting that the distribution is uniform across both sides.

Table5: Statistical Analysis of Accessory canal and Anterior Loop by side

1. Accessory Canal

condition	**Right side (n=200)**	**Left side (n=200)**	**Total (n=400)**
Present	30	20	50
Absent	170	180	350

Total	200	200	400

2. Anterior Loop

condition	Right side (n=200)	Left side (n=200)	Total (n=400)
Present	40	40	80
Absent	160	160	320
Total	200	200	400

4. DISCUSSION:

The findings of this study contribute valuable insights into the anatomical variations of the mandibular region, particularly concerning the mental foramen (MF), anterior loop (AL), mandibular incisive canal (MIC), and accessory canals (ACs). When compared with previous studies, these results reveal both alignments with and deviations from the existing literature, emphasizing the significance of advanced imaging in dental and maxillofacial practices.

The predominance of buccal positioning for the mental foramen, observed in 70% of cases on the right side and 75% on the left side, aligns with earlier findings such as those by Ngeow and Yuzawati (2003)[4], who reported a similar trend. However, this study's slightly higher prevalence of buccal positioning, compared to research by Fishel et al. (1976)[5], highlights potential population-specific differences or variations in imaging techniques. This variability underscores the critical need for preoperative imaging to account for individual anatomical differences that could affect surgical and prosthetic planning.

The anterior loop was present in 20% of cases on both sides, with no significant side-to-side differences. These findings closely resemble the results of Divakar et al.,(2024)[6] who reported a 23% prevalence using CBCT imaging. However, they contrast with Cristalle Soman et al., (2024)[7] who observed a higher prevalence of 85.2%, likely due to differences in methodology, imaging modality, or population demographics. The uniform distribution of the anterior loop in this study reinforces the importance of assessing both sides of the mandible during implant planning in the interforaminal region to minimize the risk of nerve injury.

The mandibular incisive canal showed a mean length of 13.5 mm, which is similar with studies such as Malusare et al., (2019)[8] who reported a range of 13.4 mm. Similarly, shorter lengths were obtained by Rosa et al. and Apostolakis and Brown[9] measuring 9.11 ± 3.00 mm and 8.9 mm, respectively as compared to our study. Pires et al.[10] verified MIC lengths of 7.1 ± 4 mm and 6.6 ± 3.7 mm for the right and left side, respectively. The difference in length of MIC in various studies can be due to different methodology of measuring the length of MIC. It can also be attributed to the size of mandible, ethnic race, environment, stress, nutrition, and assessing technique can largely influence the variations in length of MIC.

The mean distance from incisive canal to Buccal Plate is slightly greater on the right side (6.3 mm) compared to the left side (6.1 mm), with a total mean of 6.2 mm. The difference is not statistically significant ($p = 0.30$). The mean distance to Lingual Plate is slightly greater on the right side (4.9 mm) compared to the left side (4.7 mm), with a total mean of 4.8 mm. The difference is not statistically significant ($p = 0.25$). Acc. to Mehrdad Panjnoush et al., (2015)[11] the mandibular incisive canal had buccal inclination on both right and left sides, so that on the right side the distances from the endpoint of the canal to the buccal plate and the lingual plate were 3.63±1.37 and 3.89±1.53mm, respectively. These distances to buccal and lingual plates on the left side were 3.66±1.45mm and 4.13±1.48mm, respectively.

The mean distance to Inferior Border of Mandible is slightly greater on the right side (9.4 mm) compared to the left side (9.2 mm), with a total mean of 9.3 mm. The difference is not statistically significant ($p = 0.35$). Acc. to Mehrdad Panjnoush et al., (2015)[11]. The distances from the endpoint of the canal to the inferior border of the mandible were 8.98±2.07mm and 8.62±1.97mm in the right and the left sides, respectively.

Interestingly, a statistically significant asymmetry was noted in the presence of accessory canals, with a higher prevalence on the right side (15%) than on the left side (10%). This finding contrasts with studies such as Pooja Muley et al., (2022)[12]. About 53% of accessory canals and foramina were found in males, while 47% were observed in females; 89% were evident in the anterior region, and only 11% were in the posterior region. The identification of accessory canals is critical in procedures like endodontic treatment and implant placement, as unrecognized accessory pathways could lead to procedural complications or failures.

The use of CBCT imaging in this study aligns with the methodologies of Rahim et al.[13] and other CBCT-based studies, offering superior accuracy in visualizing fine anatomical details. This contrasts with earlier research relying on panoramic radiographs or cadaveric dissections, which may underestimate the prevalence or dimensions of these anatomical structures. The inclusion of multiple observers and high-resolution imaging enhanced the reliability of the results, further validating the study's conclusions.

Overall, the findings emphasize the importance of individualized treatment planning informed by detailed anatomical assessments. While some results are consistent with previous studies, others highlight the variability and complexity of mandibular anatomy, which necessitates the use of advanced imaging techniques. Accurate identification of structures such as the anterior loop and accessory canals is crucial for minimizing complications, including nerve injuries and incomplete treatments.

LIMITATION AND FUTURE PROSPECTS:-

Despite its robust findings, this study's retrospective design and single-center setting may limit the generalizability of the results. Future research involving larger and more diverse populations, as well as comparisons across different imaging modalities, could provide a more comprehensive understanding of mandibular anatomy and its clinical implications.

5. CONCLUSION:

This study underscores the variability in mandibular anatomy and the critical role of preoperative CBCT imaging in enhancing diagnostic precision and procedural safety. Emphasizing individualized treatment planning, it highlights implications for implant placement, endodontics, and surgery. Further multi-center research is needed to expand understanding across diverse populations.

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