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Age-Related Morphometric Variations of the Mandibular Canal: A Cross-Sectional Analysis using cone beam computed tomography

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ABSTRACT

Background:

The mandibular canal houses the inferior alveolar neurovascular bundle and exhibits morphometric variations that can change with age. These differences are clinically important for various dental procedures, including implant placement, surgical interventions, and the administration of local anesthesia. Cone-Beam Computed Tomography (CBCT) provides enhanced three-dimensional visualisation relative to conventional imaging methods like orthopantomograms (OPG), rendering it an essential instrument for comprehensive morphometric analysis.

Objectives-To evaluate the age-related morphometric variations of the mandibular canal using CBCT imaging.

Materials and Methods:

A combined total of 200 participants, comprising both males as well as females aged between the 18 and 60 years, were enrolled. CBCT scans were employed to assess the diameter and length of the mandibular canal, its positioning in relation to the buccal as well as lingual cortical plates, and the existence of anatomical variations such as bifid or trifid canals. Statistical analysis utilised SPSS software, and evaluations among different ages were executed by ANOVA, with significance established at $p < 0.05$.

Results:

A significant link exists among age as well as the length along with location of the mandibular canal ($p < 0.05$). The occurrence of bifid canals was noted in a subset of the research population, suggesting anatomical diversity that may affect surgical and anaesthetic results.

Conclusion:

Age has a significant impact on the morphometric characteristics of the mandibular canal. These findings highlight the importance of preoperative CBCT evaluation to improve the accuracy and safety of dental and maxillofacial procedures

Keywords: *Cone beam computed tomography, Mandibular canal, Morphometry, IAN*.

1. INTRODUCTION

The mandible, often known as the lower jaw, is the most massive, most solid, and lowest bone of the facial skeleton (viscerocranium). The structure consists of a U-shaped horizontal body that curves anteriorly, accompanied by a pair of vertically ascending rami on each side. The mandibular foramen, situated on the medial surface of the mandibular ramus, serves as the ingress to the mandibular canal, which descends and advances beneath the molar roots, curves gently, and extends towards the mental foramen, featuring several branches that connect with neighboring teeth.[1]

The mandibular canal originates in the mandibular foramen and proceeds in a downward and anterior direction towards the mental foramen. This pathway contains the lower alveolar neurovascular bundle,[2] which includes the inferior alveolar nerve and its accompanying blood vessels. The anterior alveolar nerve (IAN) is a principal sensitive branching of the mandible division of the trigeminal nerve, also known as (cranial nerve V) and is observed as a distinct single bundle within the canal.[3]

During numerous dental and surgical interventions—such as third molar extraction, dental implant insertion, mandibular osteotomies, and bone graft harvesting—there exists a danger of iatrogenic injury to the inferior alveolar nerve, particularly when the canal's position is inadequately evaluated. Such injuries may lead to sensory problems, including either temporary or permanent paraesthesia, anaesthesia, or dysesthesia, frequently impacting the lip, chin, and surrounding soft tissues. These issues generally stem from the excessive extension of surgical instruments, improper implant length, or erroneous administration of local anaesthetics. [4]

Comprehending the three-dimensional trajectory of the mandibular canal is crucial to minimise the risk of nerve injury. Conventional radiographs, such as orthopantomograms (OPGs), exhibit limitations stemming from picture distortion and magnification inaccuracies. Conversely, Cone-Beam Computed Tomography (CBCT) delivers high-resolution, distortion-free, and multiplanar imaging, facilitating enhanced visualisation of intricate anatomical differences, such as bifid and trifid mandibular canals. CBCT imaging reduces artefacts such ghost images and overlapping structures, facilitating precise evaluation of canal shape.[5] A comprehensive morphometric assessment of the mandibular canal is essential prior to any surgical procedure in the posterior mandibular area. Precise localisation mitigates difficulties such as neurosensory injury, haemorrhage, or insufficient anaesthesia.[6] This study seeks to assess the length, location, and occurrence of bifid or trifid variants of the mandibular canal by CBCT imaging, providing essential anatomical knowledge for clinicians to improve safety and accuracy in dental and maxillofacial interventions

2. MATERIALS AND METHODS

Study Design and Ethical Approval

This empirical cross-sectional research was collaboratively done by the Department of Anatomy and the Department of Oral Medicine and Radiology at NIMS University in Jaipur, Rajasthan. The Institutional Ethics Committee obtained ethical clearance for the project. Informed written consent was acquired from all participants following a comprehensive explanation of the study's aims and procedures.

Study Population

During a one-year period, 200 participants, comprising both males and females aged 18 to 60 years, who received CBCT scans for clinical reasons, were incorporated into the study..

Inclusion and Exclusion Criteria

Only people with natural teeth within the designated age range were included. The exclusion criteria were retained deciduous and supernumerary teeth, absent or misaligned first or second mandibular molars, as well as any pathological diseases impacting the mandible, such as cysts, tumours, or fractures. Scans exhibiting low resolution or artefacts that might disrupt anatomical assessment were excluded.

Imaging Protocol

CBCT scans were obtained via the Gendex I-CAT CB 500 equipment. The scan parameters were a field of view (FOV) of 14x 8.5 cm, a pixel size of 90 micrometres, an X-ray pulse length of 30 milliseconds, a tube voltage range of 60–90 kVp, a tube flow of 2–15 mA, and a cumulative exposure time of 10.8 seconds. All pictures were processed and assessed utilising Anatomage InVivo 5 dental software, facilitating comprehensive analysis in multiplanar views—cross-sectional, sagittal, and coronal.

Morphometric Assessment

The length of the mandibular canal was evaluated through the panoramic reconstructive view by locating the line connecting the foramen of the mandible and the mental foramen, calculated at the midpoint between the lower and upper cortications of the canal. The position of the mandibular canal was ascertained in both horizontal as well as vertical plane by measuring the distance from the canal's outermost margin to the lingual cortical plate & crestal bone level to the inferior border of the jaw. Furthermore, anatomical differences, including bifid and trifid mandibular canals, were noted wherever applicable.[7]

Statistical Analysis

All gathered data were collated and analyzed utilizing SPSS version 20.0 (IBM Corp., USA). Descriptive statistics were utilized to summarize the data, and comparison between age groups were conducted using Analysis of Variance (ANOVA). A p-value below 0.05 was deemed indicative of statistically significant.

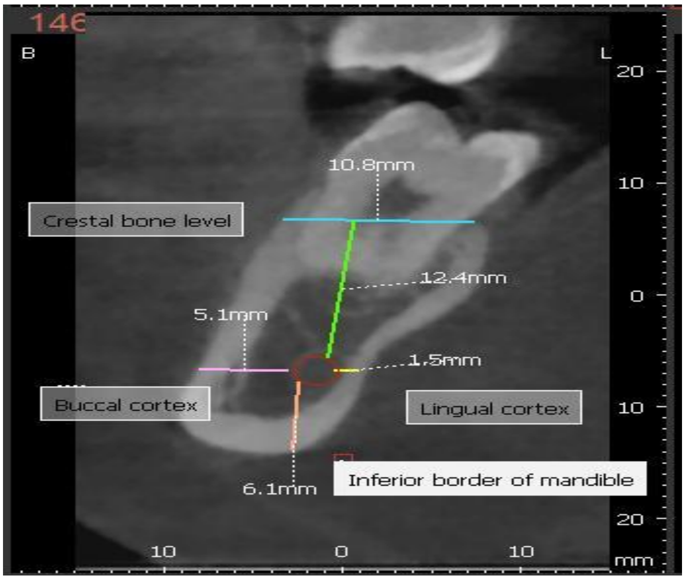


Fig. 1 Measurement of location in vertical & horizontal plane of mandibular canal

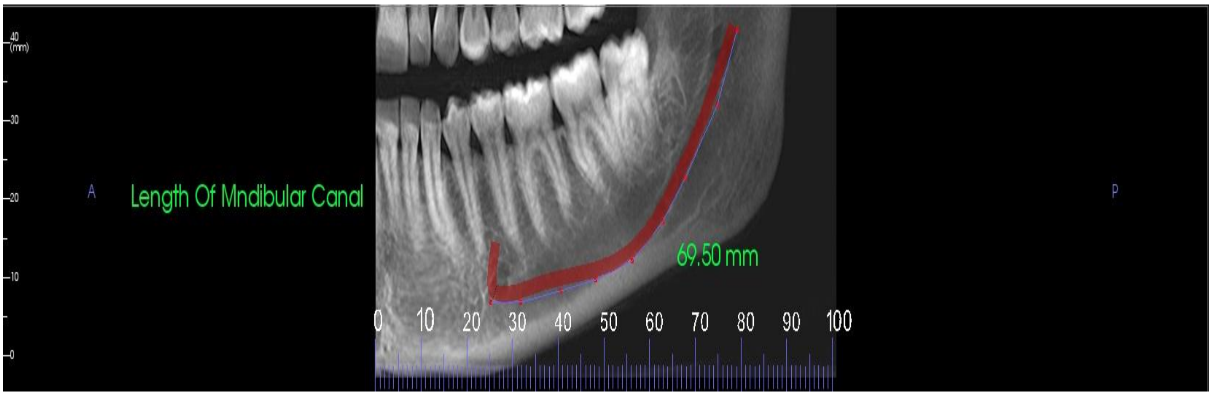
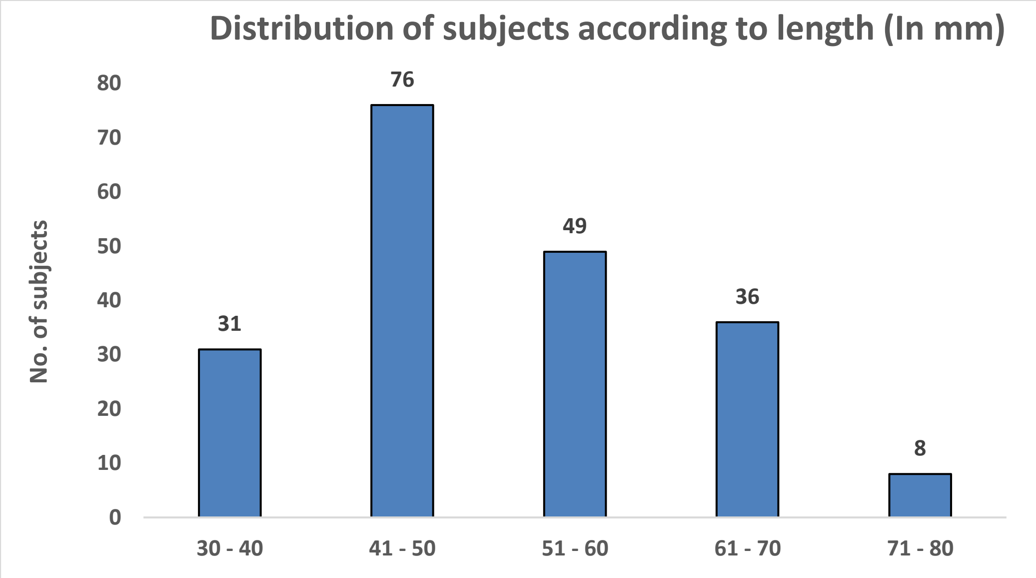


Fig. 2 Measurement of Length of mandibular canal

3. RESULTS

The Predominance of diameters in the range of 1.51 - 2.00 mm highlights a common morphometric feature in the studied population, majority of the subjects, 171 in total, have a mandibular canal diameter ranging from 1.51 to 2.00 mm, making up a significant proportion at 85.5%. A small percentage exhibiting diameters ≤ 1.00 mm emphasizes the importance of meticulous measurement in clinical assessments.

A varied distribution of mandibular canal lengths showcases the diversity in this crucial anatomical parameter. Peaks in the 41 - 50 mm and 51 - 60 mm ranges suggest distinctive patterns in mandibular canal lengths across the sample. The majority of the subjects, 76 in total, have a mandibular canal length ranging from 41 to 50 mm, making up a substantial proportion at 38.0% with a mandibular canal length between 51 and 60 mm accounting for 49 individuals, representing 24.5% of the overall study population.



Variables		Minimum	Maximum	Median (IQR)	Mean ± SD
Age (In yrs.)		20	60	34 (29-40)	35.18 ± 9.36
Diameter (In mm)		1	2.5	-	2.0 ± 0.201
Length (In mm)		32	71	49 (42-54)	49.82 ± 10.44
Location (In mm)	Vertical (V)	11.65	19.56	18.01 (15.85-18.56)	16.91 ± 2.30
	Vertical (IB)	7.45	10.02	8.98 (8.56-9.12)	8.85 ± 0.46
	Horizontal (B)	3.52	5.41	4.54 (4.14-4.75)	4.49 ± 0.43
	Horizontal (L)	3.54	6.01	4.98 (4.18-5.25)	4.78 ± 0.67
Bifid / Trifid (In mm)		1	32	1.5 (1.275-17.5)	9.96 ± 10.35

Table 1: Descriptive statistics of measurement of mandibular canal of all subjecs

Category	Present	Absent	Chi-square test	P – Value
18 – 30	7	58	11.74	0.00835
31 – 40	13	78		
41 – 50	10	22		
51 – 60	5	7		

Table 2: Association of bifid / trifid mandibular canal with age by using chi square test

This indicates that the prevalence of bifid/trifid mandibular canals varies among different age groups. The findings underscore the possible impact of age on the occurrence of bifid/trifid mandibular canals, stressing the necessity of accounting for age as a variable in the anatomical variability of the mandibular canal.

Variables		18 - 30	31 - 40	41 – 50	51 – 60	ANOVA	P – Value	Significance
Diameter (In mm)		1.99 ± 0.176	2.01 ± 0.24	2.02 ± 0.155	2 ± 0	0.213	0.88760	Not significant
Length (In mm)		49.02 ± 10.4	49.79 ± 10.7	50 ± 10.26	53.92 ± 9.69	3.745	0.01199	Significant
Location (In mm)	Vertical (V)	16.59 ± 2.43	16.87 ± 2.22	17.26 ± 2.3	18.05 ± 2.03	3.016	0.03110	
	Vertical (IB)	8.78 ± 0.41	8.85 ± 0.48	8.92 ± 0.49	9.04 ± 0.496	3.497	0.01659	
	Horizontal (B)	4.53 ± 0.446	4.44 ± 0.46	4.47 ± 0.35	4.62 ± 0.29	0.936	0.42443	Not significant
	Horizontal (L)	4.81 ± 0.62	4.65 ± 0.67	4.98 ± 0.67	5.16 ± 0.76	3.500	0.01652	Significant

Table3: Comparing measurement of mandibular canal according to age group by using ANOVA

Overall, the ANOVA results suggest that there are statistically significant differences in mandibular canal length, vertical location (V and IB), horizontal location (L), and the loop of the mandibular canal among different age groups. However, diameter, horizontal location (B), and distance do not exhibit significant differences.

These findings emphasize the influence of age on specific morphometric characteristics of the mandibular canal, providing valuable insights for understanding age-related variations in mandibular anatomy.

4. DISCUSSION

The observed increase in both the **length** and **vertical positioning** of the mandibular canal with age likely reflects the process of **age-related bone remodeling**. Interestingly, there were no statistically significant variations in the **canal diameter** or **buccolingual distances**, suggesting that these particular dimensions are relatively stable across different age groups and are less influenced by the aging process.

The **spatial localization of the mandibular canal (MC)** has long been a focal point in dental and maxillofacial research. Various studies have employed different measurement strategies to explore the anatomical complexity of the canal within the mandible. Notable among these are the works of **Levine et al.**, **Safaee et al.**, and **Hsu et al.**, which have significantly advanced the collective understanding of mandibular canal positioning.[3,8,4]

The results of this study mainly concur with those of Safaee et al., who assessed the distance between the centre of the inferior alveolar nerve (IAN) canal and the outside buccal and lingual cortical plates. Their research emphasised that the mandibular canal's position fluctuates in relation to the mental foramen (MF), noting a consistent directional shift of the canal from lingual to buccal and from posterior to anterior, highlighting the dynamic trajectory of the canal within the mandible.

Our study echoes the prevailing literature, highlighting the bifid mandibular canal as the most prevalent anatomical variant. Our observations align with the reported prevalence range of 10% to 66% on CBCT examinations, as documented in studies by **Fuentes et al. in 2019 and Muinelo-Lorenzo et al. in 2014**.[9,10]This variation predominantly manifests in the posterior mandible or mandibular ramus, in line with the findings of **Fuentes et al., Muinelo-Lorenzo et al., and Rashsuren et al.** [11]

Parameter	Age-Related Trends	Possible Explanations	Clinical Implications	Supporting Literature
Mandibular Canal	Decreases slightly	Bone remodeling	Important for	Kim et al. [2](2019);

Length	with age	and alveolar resorption in elderly	implant planning, especially in older patients	Shankland (2001)[5]
Mandibular Canal Diameter	Tends to reduce in older individuals	Reduced bone density and thinning of cortical boundaries with age	May increase risk of nerve injury during surgery in elderly	Alves et al. (2013);[12]Angelopoulos et al. (2008)[13]
Vertical Position from Alveolar Crest	Increases with age	Due to alveolar ridge resorption	Alters landmarks for surgical procedures (e.g., extractions, implants)	Sanchis et al. (2013)[6]
Horizontal Position from Buccal/Lingual Cortices	Minimal change with age	Canal remains centrally positioned despite cortical changes	Confirms canal's stable medio-lateral position in all age groups	Sato et al. (2017)[14]

5. CONCLUSION

This study provides comprehensive insights into the morphometric characteristics of the mandibular canal, including its diameter, length, and spatial orientation in both vertical and horizontal dimensions, as well as the presence of anatomical variations such as bifid and trifid canals. The results contribute significantly to the existing body of knowledge on mandibular canal anatomy and are consistent with findings from previous research, particularly in highlighting age-related morphological changes. Given the increasing reliance on dental implants and the frequent need for surgical procedures such as third molar disimpactions, the ability to accurately assess the mandibular canal through three-dimensional imaging is crucial. By utilizing CBCT technology, this study offers clinicians a more precise anatomical roadmap, ultimately enhancing surgical planning and minimizing the risk of neurovascular complications in maxillofacial interventions.

Limitations

Limited sample diversity.

No sex-based or dental status differentiation.

In some cbct scans difficulty in visibility

Conflict of Interest- No Conflict of Interest.

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Author Contributions- All contributed in maling abstract,collecting data & making manuscript

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