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CBCT BASED ASSESSMENT OF MANDIBULAR ODONTOMETRIC AND MENTAL FORAMEN PARAMETERS FOR GENDER IDENTIFICATION IN INDIAN ADULTS

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ABSTRACT

Background: Forensic odontology is essential for human identification, particularly in mass disasters, criminal investigations, and cases involving decomposed or skeletonized remains when conventional methods such as fingerprints or DNA are unavailable. Accurate gender determination remains a critical component of this discipline, particularly in fragmented skeletal remains. This study aims to evaluate the diagnostic efficacy of two CBCT-based approaches mandibular odontometric measurements (linear and angular) and mental foramen positional morphometrics for gender prediction in an Indian adult population. We hypothesize that both odontometric and mental foramen parameters may exhibit sexual dimorphism and serve as potential indicators for gender determination.

Objective:

Primary Objectives

1. To assess and compare the diagnostic performance (sensitivity, specificity, accuracy, area under the ROC curve) of mandibular odontometric measurements on axial CBCT sections.
2. To assess and compare the diagnostic performance of mental foramen positional parameters (SLM, ILM) on CBCT images.

Secondary Objectives

1. To evaluate the individual predictive value of each odontometric variable.
2. To evaluate the individual predictive value of each MF parameter.
3. To explore whether a combined model incorporating both odontometric and MF variables improves overall gender-prediction accuracy.

Methods: A retrospective cross-sectional study was conducted on individuals undergoing full mouth field-of-view (FOV) CBCT scans for other dental procedures. The odontometric and mental parameter were measured.

Results: Mental foramen parameters showed significant sexual dimorphism ($p < 0.001$–0.009), while only intermolar width was significant among odontometric variables ($p = 0.031$), suggesting MF measurements are more reliable for sex determination.

Conclusion: Mental foramen positional parameters are significantly more reliable for gender determination than mandibular odontometric measurements. The vertical position of the mental foramen, as measured by SLM and ILM, exhibits robust sexual dimorphism and should be prioritized in CBCT-based forensic protocols. These findings support the routine incorporation of mental foramen morphometric analysis into forensic radiographic identification procedures.

KEYWORDS: sex determination, cone-beam computed tomography, mandibular odontometric, mental foramen, forensic odontology

INTRODUCTION

Forensic odontology is a branch of dentistry that use dental and skeletal characteristics for legal identification, analyzing bone morphologic features to determine gender differences among groups. [1] Gender determination is of paramount importance in forensic investigations, as correctly identifying gender immediately reduces the pool of potential matches for missing persons by half and provides the necessary foundation for subsequent estimations of age and stature [2]. The pelvis and skull are considered the most dimorphic skeletal elements, with the pelvis offering up to 95% accuracy. [3] However, in forensic contexts involving mass disasters or fragmented remains, the complete pelvis or cranium is often unavailable. In such scenarios, the mandible emerges as an invaluable resource.

The mandible is a paired bone that develops within the mandibular arch with embedded teeth and forms the articulation of the jaw with the cranium.[4] Because of its dense cortical bone, the mandible resists post-mortem degradation better than most other skeletal elements, making it a durable target for forensic gender estimation [5]. The mental foramen is placed bilaterally on the buccal cortical plates of the mandible and commonly lies near the apices of mandibular premolars. [6] Among the many landmarks found in the human skull, the mental foramen stands out for its consistent position on the mandible, a reliability that makes it genuinely useful when interpreting anatomical structures in both oral pathology and forensic work [7].

Historically, morphometric analysis of the mandible relied on direct osteometry of dry bones or two-dimensional radiographic imaging, such as panoramic radiographs and lateral cephalograms. However, these techniques have inherent limitations, including projection distortion, magnification errors, and sensitivity to patient positioning, which can compromise the accuracy and reproducibility of measurements [8].

The advent of Cone-Beam Computed Tomography (CBCT) has revolutionized craniofacial analysis by providing high-resolution, undistorted, three-dimensional images with a 1:1 object-to-image ratio, effectively eliminating the geometric inaccuracies of its predecessors [9]. With a lower radiation dose compared to conventional medical CT, CBCT has become the modality of choice for precise, reliable, and reproducible morphometric analysis in both clinical and forensic settings [10].

The primary metric approaches are commonly employed for gender estimation from the mandible using CBCT. Odontometric, the quantitative measurement of teeth and dental arches, is a well-established method based on the general pattern of sexual dimorphism in dentition where males typically exhibit larger teeth and consequently wider dental arches than females [11]. However, odontometric parameters can be affected by dental pathology, tooth loss, restorative work, orthodontic treatment, or attrition, limiting their applicability in certain forensic contexts [12]. In contrast, the mental foramen is a stable anatomical landmark whose vertical position relative to the mandibular base show's consistent sexual dimorphism across diverse populations [13].

Despite these promising findings, there is a shortage of direct comparative studies evaluating the relative efficacy of these two approaches in Indian populations. Given the population specific nature of skeletal and dental characteristics, validating these methods in diverse populations is crucial for their reliable application in forensic casework [15].

The present study was therefore designed to evaluate and contrast the diagnostic performance of mandibular odontometric and Mental Foramen morphometric analyses for gender determination using CBCT in a North-Indian adult cohort.

MATERIALS AND METHODS

Study Design and Setting

A retrospective cross-sectional study was conducted at the Department of Oral Medicine and Radiology, D.Y. Patil School of Dentistry, Navi Mumbai. The study was conducted over a period of six months, following approval from institutional ethical committee.

Participants

A total of 39 CBCT scans (20 males, 19 females) were included in the study. The sample size was calculated prior using the formula:

$n = (\sigma_1^2 + \sigma_2^2)(z_{1-\alpha/2} + z_{1-\beta})^2 / \Delta^2$

Where σ_1 and σ_2 denote the standard deviations of the two groups, Δ the anticipated mean difference, $z_{1-\alpha/2} = 1.96$ for a 95% confidence interval, and $z_{1-\beta} = 0.84$ for 80% power. Substituting pilot data yielded a required sample of 19 subjects per group.

Inclusion Criteria

- Adults aged 18-60 years
- Complete permanent mandibular dentition
- High-diagnostic-quality CBCT scan (voxel size 0.2-0.6 mm)

Exclusion Criteria

- Mandibular fractures, pathologic lesions, or developmental anomalies such Missing teeth, extensive restorations, prostheses, orthodontic appliances, or edentulous arches
- Scans with motion artifacts or severe beam-hardening that obscured the MF or dental landmarks
- Severe developmental anomalies, large osseous pathologies, or extensive malocclusion

Data Sources and Imaging Protocol

CBCT scans were acquired using the Carestream CS 9600 dental imaging system.

Odontometric Measurements

On axial section where the crowns of the all the mandibular teeth were clearly visible, the following linear and angular distances were recorded bilaterally:

Measurement is shown in figure no.1

Linear Measurements:

- It measures the mandibular dental arch from the CBCT axial section. The width was divided into three sections, CC, BB, and MM, which correspond to the line drawn from the most vestibular parts of the left and right canines, second premolars, and second molars.
- **Cuspid-Cuspid Width (CCW):** Distance between the most vestibular part of the right and left mandibular canines
- **Bicuspid-Bicuspid Width (BBW):** Distance between the most vestibular part of the right and left mandibular first premolars
- **Molar-Molar Width (MMW):** Distance between the most vestibular part of the right and left mandibular 2nd molar

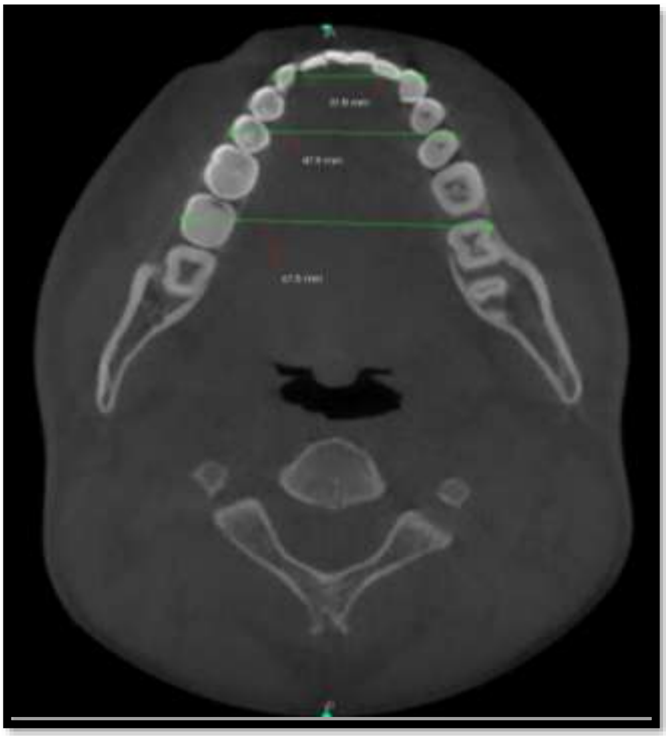


FIGURE NO.1: LINEAR MEASUREMENT

Angular Measurements:

- The median line is drawn touching the vestibular area of the occlusal radiographic projections of the mandibular central incisors. The intersection of these points denoted as "X" point. From this point, another line was drawn toward the most vestibular portion of the canine tooth denoted as "C" point. The angle formed by these two points and "R" point, named as **CXR**.
- Following the same methodology, a line from "X" point to the most vestibular portion of the second pre-molar denoted as "Bi" point and second molar as "M" point were drawn and named as angular measure "XBi"and "XM," respectively. The angle obtained by these two points ("XBi" and "XM") and "S" and "T" points called as "**BiXS**" and "**MXT**" respectively.

Measurement shown in figure no.2

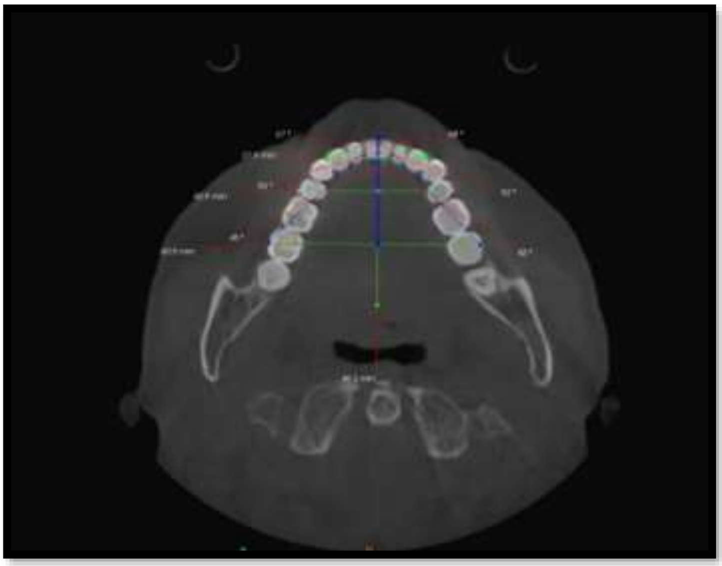


FIGURE NO.2: ANGULAR MEASUREMENT

Mental Foramen Measurements

The mental foramen was identified in the sagittal section and precise vertical measurements were generated. Three vertical distances were measured on each side:

At the lower border of the mandible and the superior border of the MF, two tangents were drawn. Additionally, a line was drawn perpendicularly between the tangents of the mandibular outer cortex's lower boundary and the superior border of MF. The measurement of this perpendicular line was taken between the lower border of the mandible **(SLM)** and the superior border of MF.

Additionally, a tangent was drawn at the inferior border of MF in order to measure the distance between the lower border of MF and the lower border of the mandible **(ILM).** From the tangent at the inferior boundary of MF to the tangent at the lower border of the mandibular outer cortex, a perpendicular line was formed. This measurement was noted as ILM.

A tangent was also drawn at the mandible's inner cortex in order to quantify the mandibular cortical width **(LM**). A perpendicular line was then drawn between the tangents at the mandibular lower border's inner and outer cortexes.

- **SLM (Superior-to-Mandibular-Base distance):** Perpendicular distance from the superior MF border to the inferior border of the mandibular body
- **ILM (Inferior-to-Mandibular-Base distance):** Perpendicular distance from the inferior MF border to the same mandibular base line
- **Thickness of Lower Border of Cortex(T):** The thickness of the compact cortical bone at the inferior border of the mandible
- Measurements were performed bilaterally and recorded.

FIG. NO 3: SUPERIOR AND INFERIOR BORDER OF MF DISTANCE TO LOWER BORDER OF MANDIBLE

FIG. NO 4: THICKNESS OF LOWER BORDER OF CORTEX

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics version 22. Descriptive statistics were presented for all variables. Normality of each continuous variable was evaluated with the Shapiro-Wilk test ($p > 0.05$ = normal distribution). Statistical significance was set at $p \leq 0.05$ for all tests.

RESULTS

Normality Assessment

Data normality was evaluated using the Shapiro-Wilk test. Most linear and angular variables showed p-values greater than 0.05 in both male and female subjects, confirming normal distribution. These variables were therefore analyzed using the independent t-test. However, a few mental foramen-related parameters demonstrated deviation from normality: right cortical thickness in males ($p = 0.003$), right cortical thickness in females ($p = 0.026$), left SLM in males ($p = 0.001$), and left ILM in males ($p = 0.010$). For these variables, group comparisons were carried out using the non-parametric Mann-Whitney U test.

Age Distribution

The mean age of male subjects was 30.05 ± 8.62 years, whereas female subjects showed a slightly higher mean age of 33.37 ± 14.64 years. The age difference of -3.32 years was not statistically significant ($p = 0.391$; $t = -0.868$), confirming that both groups were age-comparable.

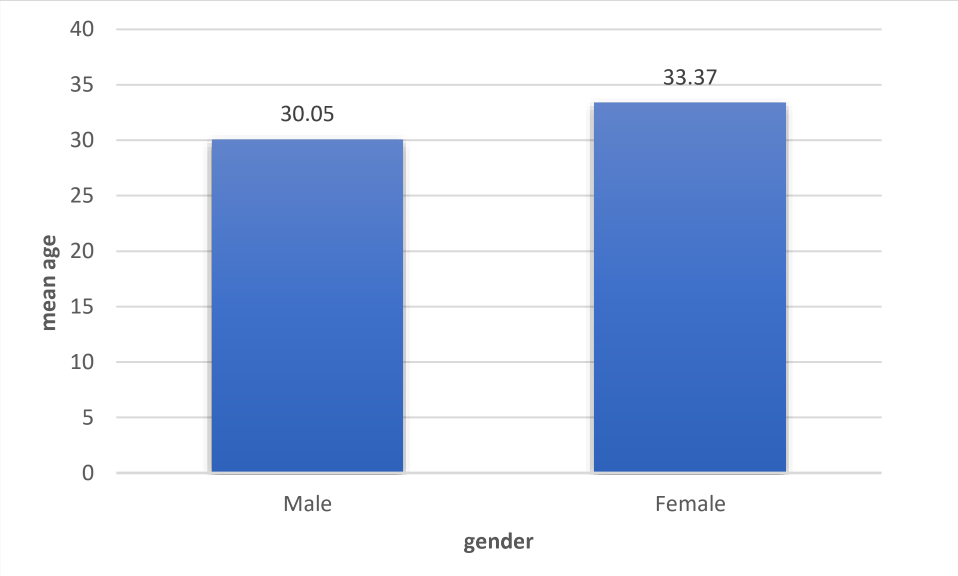
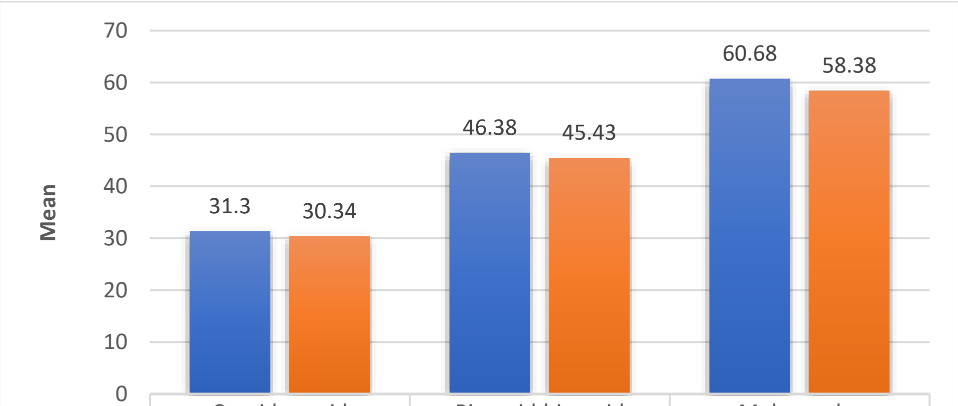


FIG NO.5: AGE DISTRIBUTION

Comparison of Odontometric Linear Measurements

Analysis of inter-arch linear dimensions revealed that male subjects exhibited consistently larger measurements compared to female subjects. The mean cuspid-cuspid width was higher in males by 0.96 mm, although this difference was not statistically significant ($p = 0.080$). Similarly, the bicuspid-bicuspid width showed a non-significant difference of 0.95 mm between the genders ($p = 0.141$). However, a statistically significant difference was found in the molar-molar width, wherein males demonstrated a 2.30 mm greater dimension than females ($t = 2.249$, $p = 0.031$). These findings suggest that gender-related variations are more pronounced in the posterior dental arch region.



	Cuspid-cuspid	Bicuspid-bicuspid	Molar-molar
Male	31.3	46.38	60.68
Female	30.34	45.43	58.38

Male Female

FIG NO.6: Comparison of linear measurements between male and female subjects

Comparison of Odontometric Angular Measurements

Angular measurements assessed on both the right and left sides of the mandible did not reveal any statistically significant differences between male and female subjects. On the right side, slight increases in CXR, BiXS, and MXT angles were noted in males; however, none of these differences reached statistical significance ($p > 0.05$). Similarly, on the left side, although females demonstrated marginally higher mean MXT values, the differences in CXR, BiXS, and MXT angles remained non-significant ($p > 0.05$). These results indicate that angular morphology of the mandible is generally comparable between genders.

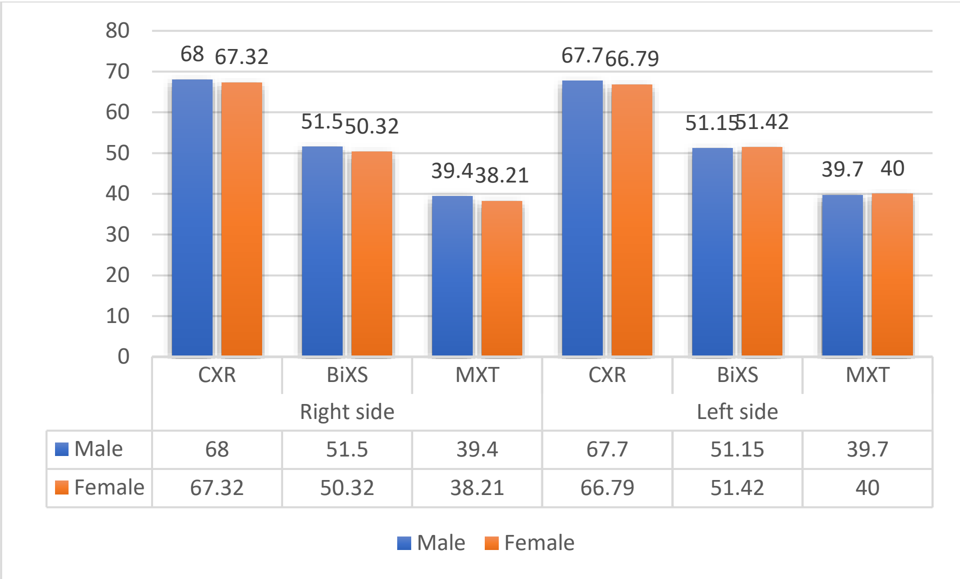


Fig. No. 6: Comparison of angular measurements between male and female subjects

Comparison of Mental Foramen Measurements

Significant gender-based variations were observed in the mental foramen-related parameters on both sides. Male subjects demonstrated significantly greater superior and inferior landmark distances from the mental foramen compared to female subjects. On the right side, both the SLM and ILM measurements were significantly higher in males by 2.02 mm ($p = 0.001$) and 1.49 mm ($p = 0.009$), respectively. A similar pattern was seen on the left side, where males recorded significantly greater SLM and ILM distances by 2.12 mm ($p = 0.001$) and 1.73 mm ($p = <0.001$), respectively. In contrast, the thickness of the lower cortical border showed no significant difference between males and females on either side ($p > 0.05$).

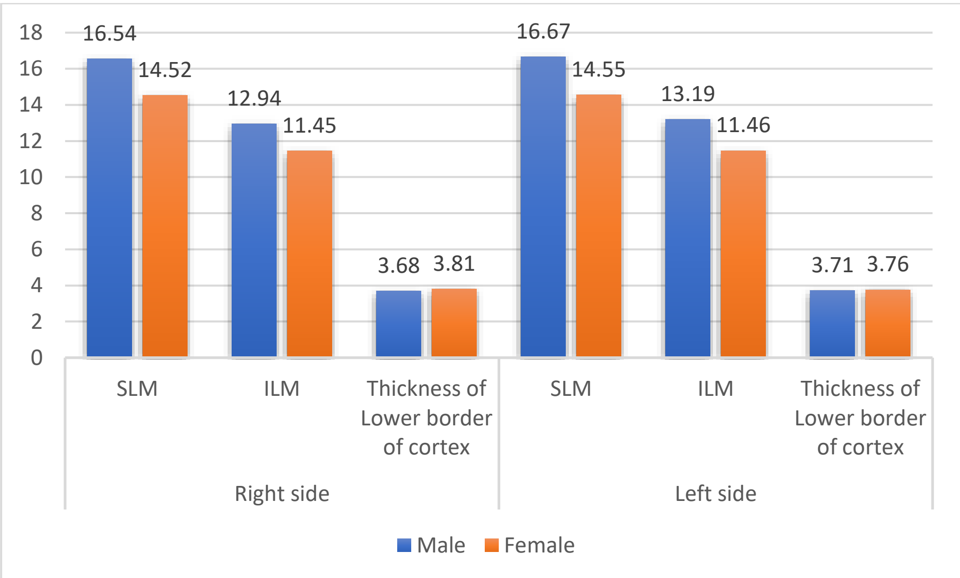


Fig no.7: Comparison of mental foramen measurements between male and female subjects

DISCUSSION

This retrospective CBCT investigation confirms that mental foramen morphometry is a significantly more reliable indicator of sexual dimorphism than conventional mandibular odontometric measurements in a North-Indian adult cohort. While odontometric variables followed the expected pattern of larger dimensions in males, only the inter-molar width reached statistical significance ($p = 0.031$). In stark contrast, all Mental Foramen parameters (right and left SLM and ILM) displayed highly significant differences ($p \leq 0.009$), with males showing consistently greater mean values.

The mean SLM values observed in our study (males: 16.54 mm right, 16.67 mm left; females: 14.52 mm right, 14.55 mm left) are remarkably consistent with those reported by Singh et al. [5] in a North-Indian population (males: 16.03 mm right, 15.83 mm left; females: 15.35 mm right, 14.49 mm left). Similarly, our ILM values (males: 12.94 mm right, 13.19 mm left; females: 11.45 mm right, 11.46 mm left) align with their findings (males: 13.04 mm right, 12.74 mm left; females: 12.05 mm right, 11.87 mm left). This consistency across studies confirms the robustness of MF positional sexual dimorphism in North-Indian populations. However, our study found no significant gender difference in cortical thickness, suggesting that MF position dimorphism is primarily due to overall mandibular size rather than cortical thickness alone.

Comparison with Prior Studies

The superior diagnostic performance of MF measurements observed in this study is consistent with several recent CBCT-based reports. Singh et al. [5] demonstrated that MF vertical position exhibits marked sexual dimorphism in a North-Indian population, achieving sensitivity and specificity values exceeding 80% for both SLM and ILM parameters. Chandra et al. [13] reported significant differences in SLM and ILM between males and females in a North-Indian sample, with highly significant p-values (<0.001).

Grewal et al. [16] conducted a panoramic radiographic study on 100 subjects (50 males, 50 females) and found significantly higher SLM and ILM values in males compared to females. Their findings corroborate our results, though their values are slightly lower, likely due to magnification inherent in panoramic radiography compared to the undistorted 1:1 ratio of CBCT. This underscores the superiority of CBCT for precise morphometric analysis.

In contrast, studies focusing on odontometric parameters have yielded more heterogeneous results. Hashim and Al-Ghamdi [17] studied tooth width and arch dimensions in 120 orthodontic study casts and found that males exhibited significantly larger tooth dimensions and arch widths than females, with inter-molar width showing one of the strongest gender differences. However, their reported accuracies remained below 80%, reflecting limited predictive capacity. Similarly, Grewal et al. [18] evaluated maxillary odontometric parameters and found a modest overall accuracy of 71% for odontometric sex determination.

The systematic review by Capitaneanu et al. [19] reported that odontometric measurements on casts achieved accuracies ranging from 34.5% to 100%, with considerable heterogeneity across populations.

Clinical and Forensic Implications

From a forensic standpoint, rapid, non-invasive, and highly accurate gender estimation is indispensable when skeletal remains are incomplete or when DNA analysis is impractical due to degradation, cost, or time constraints. The MF can be visualized on routine maxillofacial CBCT scans that are often already available in dental, medico-legal, or disaster-victim identification contexts, enabling opportunistic use of existing imaging without additional radiation exposure [20].

The high sensitivity and specificity observed for MF parameters in this study suggest that MF measurements could serve as a preliminary gender-assessment tool, reserving more labor-intensive odontometric or osteometric analyses for ambiguous cases. The modest improvement observed when odontometric data are incorporated into a combined model indicates that odontometry retains ancillary value, particularly when the MF is partially obscured by artifacts or anatomical variants such as accessory foramina.

Limitations

The sample size (n=39) fulfills a prior power calculation but remains modest, restricting the robustness of subgroup analyses and limiting generalizability. The retrospective design introduced a selection bias toward individuals with high-quality CBCT scans and complete dentition, potentially limiting the generalizability to populations with higher prevalence of dental loss or prosthetic rehabilitation. Measurements were performed by a single calibrated examiner; although intra-examiner reliability was presumed high, formal intraclass correlation coefficients were not reported. The odontometric scope was confined to linear inter-tooth widths and three angular indices; additional parameters such as crown height, root length, or three-dimensional volumetric indices might capture further dimorphic signals.

Future Directions

Future research should focus on validating these findings in larger, multi-ethnic cohorts to develop population-specific reference values. Automated segmentation algorithms powered by deep-learning techniques could localize the MF and extract odontometric landmarks, minimizing observer bias and expediting data acquisition. Three-dimensional shape descriptors of the MF (e.g., elliptical fitting, surface area, volume) may reveal subtle dimorphic traits beyond linear distances. Additionally, integrating MF morphometry with established osteometric markers within a hierarchical forensic workflow could yield a comprehensive biological profile.

CONCLUSION

This retrospective CBCT analysis of 39 North-Indian adults confirms that mental foramen vertical measurements (SLM and ILM) demonstrate markedly higher sexual dimorphism and diagnostic reliability than conventional mandibular odontometric indices. The inter-molar width was the only odontometric variable to achieve statistical significance, yet its discriminative capacity remained limited. MF parameters alone yielded significant differences between males and females ($p \leq 0.009$ for all four measurements), with males showing consistently greater mean values.

These findings advocate for the routine inclusion of MF morphometry in forensic CBCT protocols and support its adoption as a first-line, non-invasive gender-estimation tool. The MF's anatomical stability, clear visibility on CBCT, and robust sexual dimorphism make it an ideal landmark for forensic identification. Future multicenter studies with larger, ethnically diverse samples and automated measurement pipelines are recommended to validate the present results and refine population-specific cut-off values.

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