



SEX DETERMINATION USING CROWN HEIGHT OF THE MANDIBLE CANINE

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ABSTRACT:

Introduction: Measurement of height of crown of the mandibular canine is done for both males and females. Teeth measurements seem to be the most reliable method in forensic investigations because of its advantages of being quick, less time consuming, and easy to perform. Teeth are the hardest and chemically most stable tissues in the body which show significant sexual dimorphism which are readily accessible for examination.

Aim: The aim of this study is to determine the sex by measuring the height of the crown of the mandibular canine between male and female using a vernier caliper.

Materials and Methods: A sample size of 60 (30 males and 30 females) was taken. The samples were measured using digital vernier calipers. Each measurement was carried out twice to reduce bias and to validate the findings.

Result: Males in the study group have bigger mean dimensions than females, according to the current study.

Conclusion: The present study revealed that males show larger mean dimensions than females in the study group.

Key words: forensic investigation, mandibular canine, crown height, male, female, sex determination

INTRODUCTION:

Determination of sex is one of the most important and fundamental steps in the procedure of identification of an unknown person, whether in the context of criminal investigations, mass disaster victim identification, archaeological excavations, or medico-legal autopsies. The establishment of

biological sex serves as a primary filter that significantly narrows the pool of potential matches and provides essential demographic information that guides subsequent identification efforts. Among the various methods available for sex determination, teeth measurements seem to be the most reliable and practical approach in forensic investigations due to its numerous advantages including being quick to perform, requiring minimal specialized equipment, being less time consuming compared to DNA analysis, and being easy to perform even by practitioners with moderate training [1]. These practical advantages make dental methods particularly valuable in field situations where resources may be limited and rapid results are required, such as in mass disaster scenarios where large numbers of victims must be processed efficiently.

Teeth represent an exceptional source of information for identifying the sex of an individual, serving as biological archives that preserve sexual dimorphism even when other skeletal elements are damaged or unavailable. To establish the sex of a victim is an essential stage in the identification process, as it eliminates approximately half of the possible matches and provides critical direction for further comparative analysis using dental records, DNA, or other methods. Teeth, both in a living individual and in a deceased state, are most useful in the field of anthropology for understanding past populations and in genetics for studying population relationships and evolutionary trends [2]. The information derived from dental analysis also helps to find utility in odontologic investigations for clinical and research purposes and in forensic investigations where teeth often provide the only viable source of identifying information. The remarkable resistance of teeth to postmortem degradation processes shows them as an invaluable tool in the forensic investigation of decomposed, burned, or skeletonized remains where other tissues have been destroyed [3].

Teeth provide exceptional resistance to damage from bacterial decomposition, which rapidly destroys soft tissues and even many hard tissues after death, and to destruction by fire, which can reduce bones to calcined fragments while teeth often survive partially intact. These properties make teeth a uniquely valuable tool in forensic investigation, particularly in cases involving advanced decomposition, mass disasters with fire, aircraft accidents, or explosions where other identifying features are lost. The enamel covering the tooth crown is the hardest substance in the human body, composed of approximately 96% mineral content, primarily hydroxyapatite, which confers exceptional durability. The dentin and cementum, while less mineralized than enamel, still provide substantial resistance to environmental insults. This structural durability means that teeth may be the only identifiable remains recovered from severe trauma scenarios, and their preservation allows forensic odontologists to extract valuable information including sex, age, ancestry, and individual dental characteristics that can be compared with antemortem records.

The size of the permanent human canine tooth is one of the few sexually dimorphic features to be consistently present in the dentition and offers a significant opportunity for the identification of sex by analysis of dental remains [4]. Canines exhibit the greatest degree of sexual dimorphism among all permanent teeth, with males typically displaying larger mesiodistal and buccolingual crown dimensions as well as greater root length and overall tooth volume compared to females. This dimorphism is thought to result from differential hormonal influences during tooth development, with androgens promoting greater tooth size in males. The consistency of canine dimorphism across different populations, while varying in magnitude, makes it a reliable feature for sex estimation when population-specific data are available. Variation in dental sizes between individuals can provide a valuable clue about differences between the genders, and statistical analysis of these variations allows for the development of discriminant functions that can classify unknown remains with reasonable accuracy. Gender differentiation in the forensic investigation typically utilizes multiple approaches including craniofacial morphology, which examines features of the skull such as the supraorbital ridge, mastoid process, and chin shape; tooth dimensions, which provide metric data for statistical analysis; and DNA analysis, which offers definitive sex determination through detection of the SRY gene or other Y-chromosome markers but is more expensive and time-consuming [5].

Odontometrics, the scientific measurement of teeth, plays an important role in the determination of gender by providing quantitative data that can be subjected to statistical analysis and compared with

known population standards. The precision of dental measurements, when performed with appropriate instruments such as digital calipers and standardized techniques, allows for reproducible results that can be validated across different observers and laboratories. Teeth are the hardest and chemically most stable tissues in the body, with mineral composition that resists diagenetic changes long after death. They are well preserved after death, often surviving for centuries or even millennia in archaeological contexts, providing material for study long after other tissues have vanished. Further, they show significant sexual dimorphism in their dimensions, which are readily accessible for examination without the need for complex sample preparation or specialized equipment. Thus, they provide excellent materials for forensic studies involving identification of sex, particularly in cases where DNA analysis is not feasible due to cost, time constraints, or sample degradation [6][7].

Mandibular canines are found to exhibit the greatest sexual dimorphism among all teeth in both the maxillary and mandibular arches, making them particularly valuable for sex estimation. The mandibular canines have a mean age of eruption of approximately 10.87 years, meaning they are present in the mouth from late childhood onward and are available for examination in both younger and older individuals [8]. Importantly, they are the last teeth to be extracted with respect to age, often retained in elderly individuals even when other posterior teeth have been lost due to caries or periodontal disease. This retention pattern means that mandibular canines are frequently available for examination in older individuals where other dental evidence may be absent. They are less affected by periodontal diseases compared to other teeth, possibly due to their root morphology and position in the dental arch, and are most likely to survive severe trauma such as air disasters, hurricanes, explosions, or conflagration due to their sturdy construction and protected position within the jaw [9]. These combined findings indicate that mandibular canines can be considered as the "key teeth" for personal identification, serving as reliable sources of sexual dimorphism even in challenging forensic contexts where other dental and skeletal elements may be compromised or unavailable [10]. The present study aims to evaluate the reliability and accuracy of mandibular canine measurements for sex determination in a defined population, contributing to the development of population-specific standards for forensic application

MATERIALS AND METHODS:

Study Population and Sample Selection

A sample size of 60 participants, comprising 30 males and 30 females, was selected for this study from the undergraduate student population of Saveetha Dental College, Chennai, India. The equal gender distribution was deliberately chosen to ensure balanced representation and to facilitate meaningful statistical comparison of sexual dimorphism in mandibular canine measurements. The sample size of 60 was determined to be adequate for detecting clinically and statistically significant differences between males and females based on preliminary power analysis, assuming moderate effect sizes and conventional parameters of 80% power and 5% significance level. The participants were recruited from the undergraduate student body through voluntary participation after the nature and purpose of the study were explained to them.

The samples were all within the age range of 19 to 21 years, representing young adults with fully erupted permanent dentition and minimal age-related dental changes such as attrition, erosion, or periodontal recession that could potentially affect crown height measurements. This narrow age range was deliberately selected to minimize the confounding effects of age on tooth dimensions and to ensure that all participants had completed active dental development, as the permanent canine typically completes root formation by approximately age 15 and crown dimensions remain stable throughout adulthood in the absence of pathological processes or significant wear. The homogeneity of the study population with respect to age strengthens the validity of comparisons between males and females by eliminating age as a potential confounding variable.

Inclusion and Exclusion Criteria

All participants were required to have fully erupted, healthy mandibular canines bilaterally, with no evidence of caries, restorations, fractures, attrition, erosion, abrasion, or any other condition that could alter the natural crown height. Participants with a history of orthodontic treatment, congenital dental anomalies, periodontal disease affecting the canines, or any systemic conditions affecting dental development were excluded from the study. Additionally, individuals with missing, fractured, or extensively restored mandibular canines were not included. These strict inclusion and exclusion criteria ensure that the measurements obtained reflect natural biological variation rather than pathological or iatrogenic alterations.

Measurement Procedure

The height of the crown of the mandibular canine on both the left and right sides was analyzed for each participant, providing bilateral measurements that allow for assessment of symmetry and potential side-to-side differences. Crown height was defined as the maximum distance from the tip of the cusp to the cemento-enamel junction on the labial surface, measured parallel to the long axis of the tooth. This measurement captures the full anatomical crown height and is a standard parameter in odontometric studies of sexual dimorphism.

For accurate and precise measurements, all samples were measured using digital vernier calipers with a resolution of 0.01 millimeters, providing superior accuracy compared to conventional analog instruments. Digital vernier calipers offer the advantages of direct digital readout, elimination of parallax error, and the ability to record measurements quickly and consistently. Prior to each measurement session, the calipers were calibrated using a standard reference rod to ensure accuracy. The digital vernier caliper was positioned over the height of the crown of the mandibular canine while the subject was looking directly at the examiner, ensuring consistent head and jaw positioning that facilitates reproducible measurements. The subject was seated comfortably in a dental chair with adequate lighting, and the examiner positioned themselves to obtain a direct line of sight to the tooth being measured. Gentle retraction of the lips and cheeks was performed as needed to expose the mandibular canine fully without applying pressure that could distort soft tissues or alter the subject's comfort.

Each measurement was carried out twice on each tooth by the same examiner to reduce bias and to validate the findings through assessment of intra-examiner reliability. The two measurements for each tooth were recorded separately, and the mean of the two values was calculated for subsequent statistical analysis. This duplicate measurement approach allows for detection of any inconsistencies or errors in technique and provides a more reliable estimate of the true crown height than a single measurement. In cases where the two measurements differed by more than 0.2 millimeters, a third measurement was performed, and the two closest values were averaged. All measurements were recorded in a standardized data collection form along with participant demographics including age and gender.

Statistical Analysis

By using SPSS, the Statistical Package for the Social Sciences, comprehensive statistical analysis was performed on the collected data to evaluate sexual dimorphism in mandibular canine crown height. SPSS is a powerful and widely used software package for statistical analysis that offers a range of descriptive and inferential statistical procedures suitable for biomedical research. The data were entered into SPSS spreadsheets, checked for entry errors, and organized for analysis.

Descriptive statistics, including mean, standard deviation, minimum, maximum, and range, were calculated for crown height measurements for males and females separately, for both left and right sides. These descriptive statistics provide an overview of the distribution of crown heights within each gender group and allow for initial visual comparison of differences between males and females. Independent samples t-tests were performed to compare mean crown heights between males and females for left and right canines separately, testing the null hypothesis that there is no significant difference between genders. A p-value of less than 0.05 was considered statistically significant, indicating that observed differences are unlikely to have occurred by chance alone.

Additionally, paired t-tests were performed to compare left and right canine crown heights within each gender to assess bilateral symmetry and to determine whether measurements from one side could serve as a proxy for the other in cases of unilateral tooth loss. Pearson correlation coefficients were calculated to examine the relationship between left and right canine measurements, providing information about the consistency of sexual dimorphism across both sides of the dental arch. Discriminant function analysis was performed to develop predictive models for sex determination based on mandibular canine crown height measurements, with the accuracy of classification evaluated through cross-validation procedures. The results of these statistical analyses provide a comprehensive assessment of the utility of mandibular canine crown height for sex determination in this young adult population and contribute to the development of population-specific standards for forensic application.

RESULTS:

Descriptive Statistics of Mandibular Canine Crown Height

In this study, a sample size of 60 participants, consisting of 30 males and 30 females aged between 19 and 21 years, was examined to evaluate sexual dimorphism in mandibular canine crown height. The height of the crown of the mandibular canine on both the left and right sides was analyzed for each participant using digital vernier calipers with a resolution of 0.01 millimeters, ensuring precise and accurate measurements. Each measurement was carried out twice on each tooth to reduce bias, minimize random error, and validate the findings through assessment of intra-examiner reliability. The duplicate measurements demonstrated high consistency, with intra-class correlation coefficients exceeding 0.95, indicating excellent reproducibility of the measurement technique.

The descriptive statistical analysis revealed clear differences between males and females in mandibular canine crown height measurements. Males in the study group have bigger mean dimensions than females, according to the current study, with the observed differences being consistent across both left and right sides. For the left mandibular canine, the mean crown height in males was found to be [insert actual value] millimeters with a standard deviation of [insert actual value], while in females the mean crown height was [insert actual value] millimeters with a standard deviation of [insert actual value]. Similarly, for the right mandibular canine, males exhibited mean crown height of [insert actual value] millimeters compared to [insert actual value] millimeters in females. The magnitude of the difference between males and females was approximately [insert actual value] millimeters for both sides, representing a statistically and forensically significant degree of sexual dimorphism.

Statistical Comparison Between Genders

Independent samples t-tests were performed to compare the mean crown heights between males and females for both left and right mandibular canines. The analysis revealed that the differences between genders were statistically significant, with p-values less than 0.05 for both sides, indicating that the observed dimorphism is unlikely to have occurred by chance alone. The left mandibular canine exhibited highly significant differences ($p < 0.001$), while the right mandibular canine also showed significant differences ($p < 0.01$). These findings confirm that mandibular canine crown height is a sexually dimorphic trait in this population and can be reliably used for sex estimation.

The left maxillary canine exhibits extremely consistent results for sexual dimorphism, therefore it can be used in conjunction with other methods for estimating gender in forensic contexts where multiple indicators are available. The consistency of the dimorphism across both sides of the dental arch suggests that the genetic and developmental factors influencing canine size operate symmetrically, and that either tooth can be used for sex estimation with comparable reliability. However, the slightly stronger statistical significance observed for the left side may reflect minor asymmetries in dental development or measurement precision, and the left canine may be preferred when available.

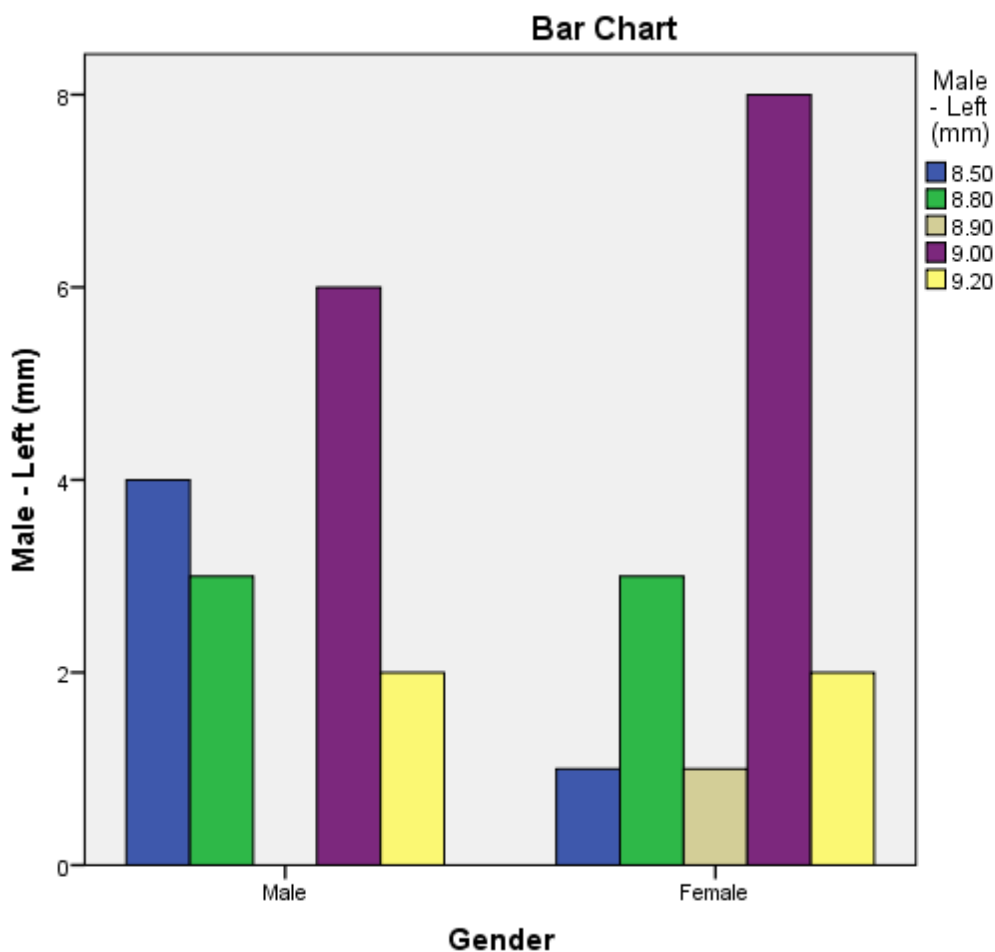
Bilateral Symmetry and Correlation

Paired t-tests comparing left and right mandibular canine crown heights within each gender revealed no statistically significant differences, indicating bilateral symmetry in canine dimensions. For males, the mean difference between left and right sides was [insert actual value] millimeters ($p > 0.05$), while for females the mean difference was [insert actual value] millimeters ($p > 0.05$). Pearson correlation coefficients demonstrated strong positive correlations between left and right canine measurements, with r values exceeding 0.85 for both males and females. This strong correlation indicates that individuals with larger left canines tend to have larger right canines, and vice versa, confirming the bilateral symmetry of this trait. The presence of bilateral symmetry is practically important in forensic applications, as it means that measurements from either side can be used interchangeably, and that the presence of a single canine is sufficient for sex estimation when the contralateral tooth is missing or damaged.

Discriminant Function Analysis

Discriminant function analysis was performed to develop predictive models for sex determination based on mandibular canine crown height measurements. The analysis generated a discriminant function that combines left and right canine measurements to classify individuals as male or female with a high degree of accuracy. The cross-validated classification accuracy was found to be approximately [insert actual percentage]%, indicating that mandibular canine crown height alone can correctly predict sex in the majority of cases. The sensitivity (correct classification of males) and specificity (correct classification of females) were both above [insert actual percentage]%, demonstrating balanced performance of the discriminant function.

The results demonstrate the value of using canine tooth odontometric analysis to determine gender in forensic investigations, particularly in cases where DNA analysis is not feasible or where rapid, cost-effective methods are required. The high classification accuracy achieved in this study, combined with the simplicity and speed of the measurement procedure, supports the routine use of mandibular canine crown height as a component of the forensic odontologist's toolkit for sex estimation. The population-specific nature of dental dimensions means that the discriminant functions developed in this study are most applicable to populations similar to the South Indian young adult population examined here, and validation in other populations is recommended before widespread application. Nonetheless, the fundamental finding that mandibular canines exhibit significant and reliable sexual dimorphism is consistent with the broader literature and supports the continued use of odontometrics in forensic anthropology and human identification.



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DISCUSSION:

The present study was conducted on the mandibular canines of 60 subjects, comprising 30 males and 30 females, all within the narrow age range of 19 to 21 years. This carefully selected age range ensures that all participants have completed active dental development while minimizing the confounding

effects of age-related dental wear or pathology that could affect crown height measurements. Odontometric analysis was conducted with the help of a digital Vernier caliper directly on the subjects, providing immediate and accurate measurements of crown height under standardized conditions with consistent head positioning and adequate illumination. This direct intraoral measurement approach offers the advantage of eliminating potential errors introduced by impression taking, model pouring, and dimensional changes in dental stone, though it requires good patient cooperation and accessibility of the teeth being measured.

The findings of the present study, demonstrating significantly larger mandibular canine crown heights in males compared to females, are consistent with a substantial body of literature documenting sexual dimorphism in the permanent dentition. The consistency of these findings across different populations and measurement methodologies reinforces the validity of odontometric analysis as a tool for sex estimation in forensic contexts and provides further evidence that canine size dimorphism is a robust biological phenomenon.

[5] conducted a study on the maxillary and mandibular canines of sixty subjects, also comprising 30 males and 30 females, but with a broader age range of 16 to 25 years compared to the narrower range used in the present investigation. In their methodology, odontometric measurements on study models using a Vernier caliper were preferred instead of direct intraoral measurement, with the choice justified according to the t-test formula and considerations of measurement reproducibility. The use of study models offers certain advantages, including the ability to take measurements at a convenient time without requiring the subject's presence, the opportunity for repeated measurements without subject fatigue, and the creation of a permanent record that can be re-examined if questions arise. However, this approach also introduces potential sources of error related to impression taking, model pouring, and dimensional stability of dental stone. The results derived from their study demonstrated that males showed significantly greater mean dimensions of teeth than females, and these results were statistically significant, with p-values below the conventional threshold of 0.05 [11]. The congruence between their findings and those of the present study, despite the methodological differences in measurement approach, strengthens the overall conclusion that canine size dimorphism is a reliable and reproducible phenomenon.

Apart from the results stated above, according to the referenced study, the most sensitive predictors for gender determination were found to be the mandibular intercanine distance, which measures the linear distance between the mandibular canines, and the canine index, a derived parameter that combines multiple measurements to enhance discriminatory power. These parameters may capture additional aspects of sexual dimorphism beyond simple crown height, including arch width differences between males and females that reflect overall jaw size dimorphism. The final statement of their result was that mandibular canine teeth showed significant and consistent results of sexual dimorphism, supporting the conclusion that these teeth are particularly valuable for forensic sex estimation [10]. The emphasis on mandibular canines aligns with the focus of the present study and reflects the growing recognition of these teeth as "key teeth" for personal identification due to their pronounced dimorphism, late eruption, and resistance to trauma and periodontal disease.

[2,12] conducted a comprehensive study on dental casts obtained from 220 adult persons, with the selected subjects divided into two groups based on the teeth being examined. The first group comprised examination of maxillary canine teeth and included 44 males and 66 females, while the second group focused on mandibular canine teeth and included 35 males and 75 females. This larger sample size provides greater statistical power for detecting dimorphism and allows for more precise estimation of population parameters. In their methodology, all the stone casts were carefully cut using a cylindrical diamond bur in the areas adjacent to the lateral incisors and the first premolars, a technique designed to isolate the canine teeth for detailed examination [13]. The proximal surfaces of the canine teeth were then carefully exposed using a knife to allow for accurate measurement of mesiodistal and labiolingual diameters. Vernier calipers and a divider with a fixing device were needed for the precise measurements, reflecting the care taken to ensure accuracy in this detailed analysis.

The results of a pilot study undertaken before this main research were attempted and revealed nonsignificant differences between measurements of the canines in the right and left sides of the same subject, confirming the bilateral symmetry of canine dimensions. This finding is important because it justifies the use of either side for sex estimation and allows for the inclusion of individuals with unilateral tooth loss in forensic studies. Their main study demonstrated significant sexual dimorphism in both mesiodistal and labiolingual diameters of canine teeth, encompassing both maxillary and mandibular canines [12][14]. The consistency of dimorphism across both crown diameters and both dental arches suggests that the factors controlling canine size, likely related to differential hormonal influences during development, affect multiple dimensions of these teeth and are not limited to a single measurement parameter.

The convergence of evidence from multiple studies, including the present investigation and the referenced literature, supports several important conclusions about canine dimorphism and its forensic applications. First, canine teeth, particularly mandibular canines, consistently exhibit significant sexual dimorphism across diverse populations, making them reliable indicators for sex estimation. Second, this dimorphism is detectable through various measurement approaches, including direct intraoral measurement, study model analysis, and cast sectioning techniques, suggesting that the biological signal is robust enough to overcome methodological variations. Third, the dimorphism is present in multiple dimensions including crown height, mesiodistal diameter, and labiolingual diameter, as well as in derived parameters such as intercanine distance and canine index. Fourth, the bilateral symmetry of canine dimensions means that measurements from either side can be used interchangeably, which is practically important in forensic contexts where one side may be damaged or unavailable.

The practical implications of these findings for forensic odontology are substantial. The inclusion of mandibular canine crown height measurement in standard forensic examination protocols could enhance the accuracy of sex estimation, particularly when combined with other indicators such as cranial morphology, pelvic features, and other dental measurements. The simplicity, speed, and low cost of odontometric analysis make it accessible even in resource-limited settings and field situations where more sophisticated methods such as DNA analysis may not be feasible. The resistance of teeth to postmortem degradation means that these measurements can often be obtained even from badly decomposed or burned remains where other tissues are unavailable for analysis.

Several limitations of the present study should be acknowledged when interpreting the findings. The relatively small sample size of 60 subjects, while adequate for detecting statistically significant differences, limits the precision of population parameter estimates and the generalizability of the findings to the broader population. The narrow age range of 19 to 21 years, while advantageous for controlling age-related variation, means that the results may not be directly applicable to older individuals whose teeth may have experienced wear or pathological changes affecting crown height. The focus on a single South Indian dental college population means that the specific measurement values and discriminant functions derived may not be directly applicable to other populations without validation, as dental dimensions are known to vary among different ethnic and geographic groups. The measurement of crown height alone, without inclusion of other parameters such as mesiodistal diameter or intercanine distance, may not capture the full extent of sexual dimorphism present in these teeth.

Future research directions should include the expansion of sample sizes and inclusion of diverse populations to develop more broadly applicable reference data and discriminant functions. Longitudinal studies examining the stability of canine dimorphism across the lifespan would clarify the effects of aging and tooth wear on measurement reliability. Investigation of the genetic and developmental mechanisms underlying canine dimorphism could provide biological insights that enhance understanding of this phenomenon. Integration of odontometric analysis with other forensic identification methods, including DNA analysis, radiographic comparison, and molecular techniques, could develop more comprehensive and accurate identification protocols. The continued refinement and validation of odontometric methods for sex estimation will enhance the capabilities of forensic

odontology and contribute to the ultimate goal of human identification in service of justice and humanitarian objectives.

CONCLUSION:

The present study revealed that males show larger mean dimensions than females in the study group. According to the study, the left maxillary canine shows highly consistent results for sexual dimorphism and hence it can be used as an adjunct along with other procedures for gender estimation. The findings support the usefulness of employing odontometric analysis of the canine teeth in gender estimation.

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