ORIGINAL ARTICLE

# Mandibular canine index: A study for gender determination in Gandhinagar population

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## Abstract

**Introduction:** One of the important pieces of information gathered from tooth analysis is the sex of an individual. In most human living populations, mandibular canines show the greatest dimorphism and greatest dimensional differences between males and females. In view of these facts, the aim of this study was to establish the standard mandibular canine index (MCI) and estimate the sexual dimorphism in the population of Gandhinagar district of Gujarat state. **Materials and Methods:** The study consisted of 400 subjects, 200 males and 200 females in the age group of 20–40 years. The mesiodistal (MD) width of the right and left canine and the intercanine distance were measured. These values were used to derive the MCI and establish the amount of sexual dimorphism exhibited by the mandibular canine. **Results:** The MD crown width of the permanent mandibular right and left canines as well as mandibular intercanine distance of the males was found to be larger in size than in the females. The right mandibular canine exhibited 8.42% of sexual dimorphism while the left mandibular canine exhibited 8.40% of sexual dimorphism. The intercanine distance showed 2.75% of sexual dimorphism. The value of standard MCI derived using the formula devised by Rao *et al.* was 0.254 mm for the population residing in the Gandhinagar district. **Conclusion:** The present study supports the usefulness of the MCI in gender determination. The method of using mandibular canine indices is advantageous as it is easy, rapid, and cost-effective, requires no elaborate apparatus, and is suited for situations where large a number of samples have to be analyzed.

**Key words:** Canine, mandibular canine index, sex determination, sexual dimorphism

## Introduction

The word forensic arrives from the Latin word "forensis," meaning "of or before the forum."[1] It derives paramount importance when the law enforcement community requires the identification of partial or complete remains of an individual.[2] A positive identification depends largely on an appropriate reconstruction of the biological profile, taking into account the ancestry, age, stature, and gender.[3] Determination of gender is one of the most essential aspects for establishing identity in cases involving any legal certification, cases related to heirship, disposal of property, marriage, education, impotence, rape, divorce, and other crime investigations.[4-6]

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The teeth are the hardest part of the skeleton and often are the sole remains of a fossil; and they also survive most postmortem events.[7] Hence, dentists are respected widely as a source of valuable data that can be used to answer questions that arise during a death investigation.[2] The widespread use of dental care by the population in the Developed countries of today provides the antemortem record bank for the procedure of dental comparison. The improved maintenance of dental records has served to amplify the specificity of the dental method as a scientific tool in identification.[8,9]

In fragmented cranial bones, jaws could be obtained, and measurements of the mesiodistal (MD) and buccolingual dimensions of the crown diameters of the permanent teeth along with their sexual differences might prove as one of the means of determining gender.[10] The mandibular canine shows the greatest dimorphism in most living human beings, being larger in males than in females.[11,12] The mandibular canines are least exposed to plaque, calculus, abrasion from brushing, heavy occlusal loading, periodontal disease and one of the last teeth to be extracted with respect to age.[13] Canines are also more likely to survive severe trauma such as air disasters, hurricanes, or conflagration. These findings indicated that the mandibular canines might be considered as a key tooth for the purpose of personal identifications.[14]

Since mandibular canines consistently exhibit sexual dimorphism, it was established that the Mandibular Canine Index (MCI) expressed as the ratio of the MD dimension of canines and the intercanine arch width.[11] Hence, the present study was conducted to compare the MD and intercanine widths as well as to derive and assess the mean MCI of the males and females residing in the Gandhinagar district.

## Materials and Methods

This study was conducted in the Oral Medicine and Radiology Department of the institute.

The subjects for this prospective study were selected based on simple random sampling technique within an 18-month period.

The study consisted of 400 subjects (200 males and 200 females). The subjects were divided into twenty age groups (with 1 year age range) ranging from 21 to 40 years. Each age group comprised 20 subjects (10 males and 10 females). The subjects were selected based on following selection criteria:

- Subjects must possess a complete set of fully erupted, morphologically well-formed teeth with a normal overjet and overbite, with the absence of interdental spacing and crowding and with normal molar and canine relationship
- Subjects must have periodontally healthy, noncarious, nonrestored, and nonattrited teeth
- Subjects with tumors or cysts in the anterior region, previous history of orthodontic treatment, systemic history of bone diseases, or any deleterious habit such as bruxism were excluded from the study.

All the randomly selected subjects were clinically examined, especially for the presence and status of the mandibular canines, with the use of diagnostic armamentarium.

The subjects, fulfilling the selection criteria, were explained the entire procedure with the aid of an information sheet. Informed consent was obtained, and they were asked to sign a consent form specially prepared for the study. The approval from the Ethical Committee of the institute was acquired before commencing the study.

A pro forma specially prepared for the study was filled for each of the subjects.

Then, the subjects were made to rinse with mouth rinse (diluted with water), and complete mandibular arch impressions were taken using alginate impression material.

The impression was poured immediately with dental stone, and the base for the study casts was made using the base former and dental plaster.

Each cast was coded corresponding to the subject ID for correct identification.

The greatest intraoral MD crown width of the mandibular right and left canines was measured between the contact points of the tooth, using the digital Vernier calipers [Figure 1] in 40 subjects (10% of the sample size).

The mandibular intercanine distance was also measured intraorally between the cusp tips of right and left canines, using the digital Vernier calipers [Figure 2] in 40 subjects (10% of the sample size).


**Figure 1:** Photograph showing intraoral mesiodistal width measurement for right mandibular canine

All measurements for the dental casts of the 200 male and 200 female subjects (as well as intraoral measurements) were made by two different observers X and Y while the observers being blinded regarding the age and sex of the respective subjects [Figures 3 and 4].

Each observer recorded three measurements for each observation, and the average of these three was considered as the final reading. In case of any discrepancy in the observations by the two observers, a third observer Z was employed. The data that were common in any two of the three observations were considered final. In case of discrepancy in the observations of all the observers, the particular subject was excluded from the study.

Three months later, the stone casts of 10% of the subjects were randomly selected and submitted to each observer to evaluate the reproducibility of findings of the observers and to check intraobserver variability.

Using the data recorded, the canine index of each individual for the right and left sides was derived as a ratio between the above two parameters, that is:

$$\text{Canine index} = \frac{\text{Mesiodistal crown width of mandibular canine}}{\text{Mandibular canine arch width}}$$

The data so obtained were computed, tabulated, and statistically analyzed with the purpose of establishing sexual dimorphism on the basis of MCI.

### Statistical analysis

All the collected data were statistically analyzed with SPSS (IBM Corp, Newyork Version 22.0) software using the Student's *t*-test (*P* value) and Spearman correlation (*r* value).

Sexual dimorphism in the right and left mandibular canines was calculated using the formula given by Garn *et al*. (1967) as follows: Sexual dimorphism = ($X$m ÷ $X$f − 1) × 100, where $X$m = Mean male canine width and $X$f = Mean female canine width.

The mean and standard deviation of MCI were derived separately for males and females, and a cutoff point to distinguish the sexes, termed as "Standard MCI," was calculated as follows: Standard MCI = ([Mean male MCI − SD] + [Mean female MCI + SD])/2.

If the MCI value of study cast was less than or equal to the standard MCI, the cast was considered to be of a female, and if MCI value more than the standard MCI, the cast was considered to be of a male subject.

Percentage accuracy of reporting gender identity by this method was then checked as the true sex of each subject was known.

**Figure 2:** Photograph showing intraoral intercanine measurement


**Figure 3:** Photograph showing mesiodistal width measurement for right mandibular canine on a cast

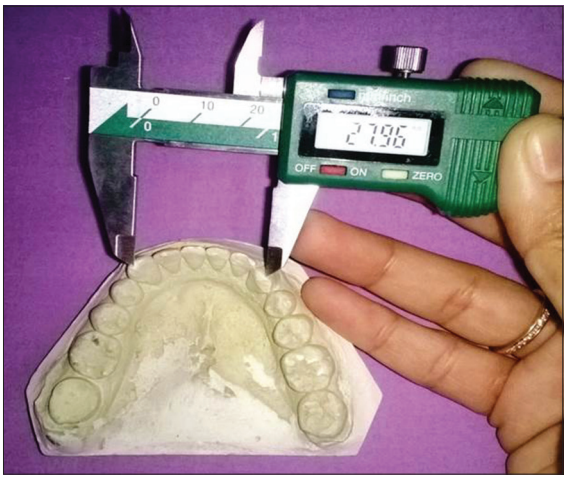



**Figure 4:** Photograph showing intercanine measurement on a cast

## Results

A total of 400 patients (200 males and 200 females) ranging in age from 21 to 40 years were selected for the study.

Table 1 shows comparison of MD width between right and left mandibular canines in males and females. Using the Student's *t*-test, the difference in mandibular right canine dimension between males and females was found to be highly significant ($P < 0.001$), and the degree of freedom was found to be 398 and confidence interval was 0.48–0.59. Using Student's *t*-test, the difference in the mandibular left canine dimension between males and females was found to be highly significant ($P < 0.001$), and the degree of freedom was found to be 398 and confidence interval was 0.48–0.59.

Graph 1a and b is the box plots showing comparison of mandibular intercanine distance between males and females in each age group. Among males, the mean and standard deviation of intercanine distance were calculated to be 26.361 (±2.09) mm, whereas among females, it was estimated to be 25.654 (±1.98) mm. Using Student's *t*-test, this difference in the intercanine distance was found to be highly significant ($P < 0.001$) in all except 38- and 39-year age groups. The degree of freedom was found to be 398 and confidence interval was 4.91–5.7.

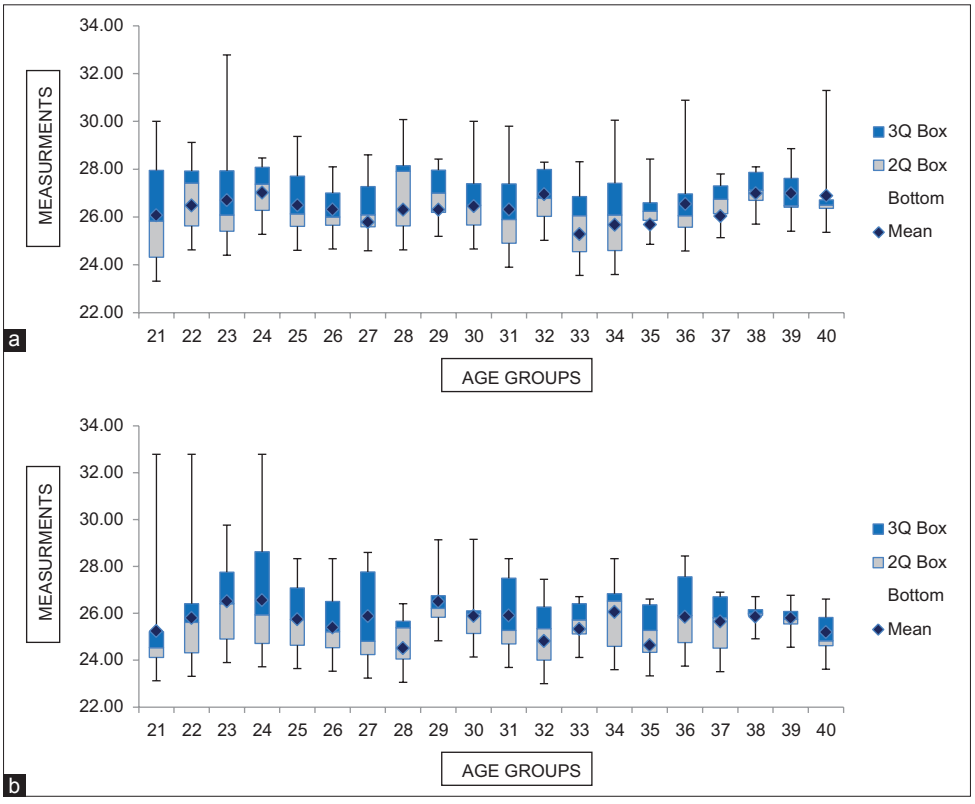
Graph 2a and b is the box plots showing comparison and calculation of the canine index of the right mandibular canine between males and females of each group. The mean and standard deviation of right canine index in males and females were 0.263 (±0.024) and 0.249 (±0.020), respectively. Using the Student's *t*-test, the difference between means was found to be highly significant ($P < 0.001$). These right canine indices of males and females were used in the equation for the standard MCI, given by Rao *et al*. The mean of the standard MCI was found to be 0.254. The degree of freedom was found to be 398 and confidence interval was −0.03 to −0.02.

Graph 3a and b is the box plots showing comparison and calculation of the canine index of the left mandibular canine between males and females of each age group. The mean and standard deviation of the left canine index in males and females were 0.263 (±0.024) and 0.249 (±0.020), respectively. Using the Student's *t*-test, the difference between means was found to be highly significant ($P < 0.001$). These left canine indices of males and females were used in the equation for the standard MCI, given by Rao *et al*. The mean of the standard MCI was found to be 0.254. The degree of freedom was found to be 398 and confidence interval was 0.48–0.59.

**Table 1: Comparison of mesiodistal width between right and left canines in males and females in each age group**

| Variables | Males | Females |
|---|---|---|
| *N* | 200 | 200 |
| Right canine (mm), mean±SD | 6.89±0.24 | 6.36±0.34 |
| Left canine (mm), mean±SD | 6.89±0.24 | 6.36±0.34 |
| *P* | 0.09 | 0.98 |
| Inference | Nonsignificant | Nonsignificant |

SD: Standard deviation



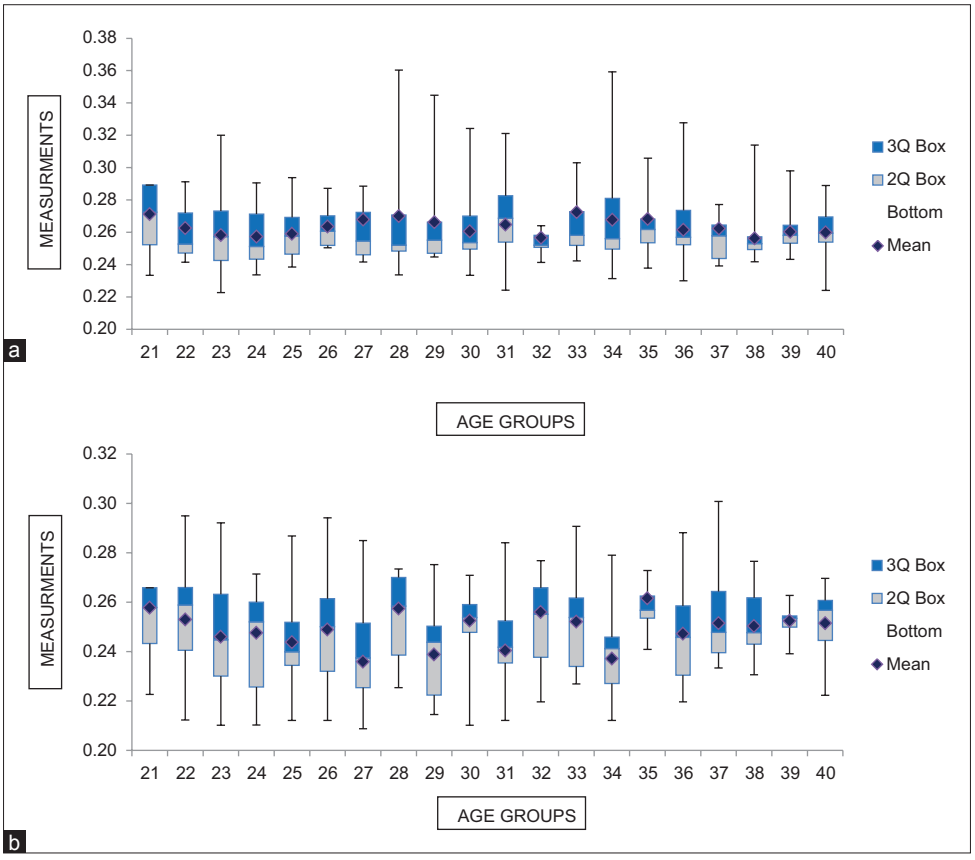

**Graph 1:** (a) Comparison of mean intercanine distance between males in each age group, (b) comparison of mean intercanine distance between females in each age group

Table 2 shows the comparison between *in vivo* and *in vitro* measurements of MD width of the right and left canines and the intercanine distance. Using the Student's *t*-test, the difference in the *in vivo* and *in vitro* measurements for the right and left canines and the intercanine distance was found to be nonsignificant ($P = 0.07048$, 0.09315, and 0.71664, respectively).

Table 3 shows the percentage of sex correctly predicted using this standard MCI value. All index values up to the limit of this Standard Maxillary Canine Index were reported as female while all those values above this limit were reported as male. It was observed that sex was correctly predicted in 160 out of 200 males (80%) and in 155 out of 200 females (77.5%). The accuracy of the method, when applied to combined data of the present study population, was 78.8%.

For the observations with the discrepancy between the two observers, the Spearman rank correlation coefficient was calculated for interobserver variability. The r value for X versus Y for the right permanent mandibular canine was 0.154, for the left permanent mandibular canine was 0.236, and for the mandibular intercanine distance was 0.823. This variability was very minute.

Ten percent of the stone casts were randomly selected and submitted to the observers again for taking measurements to check for intraobserver variability. The intraobserver variability was calculated for these measurements, and the values were 0.976 for the right canine, 0.946 for the left canine, and 0.997 for intercanine distance. In 10% of the subjects ($n = 40$), intraoral measurements of the MD width of right and left canines and intercanine distance were also recorded.

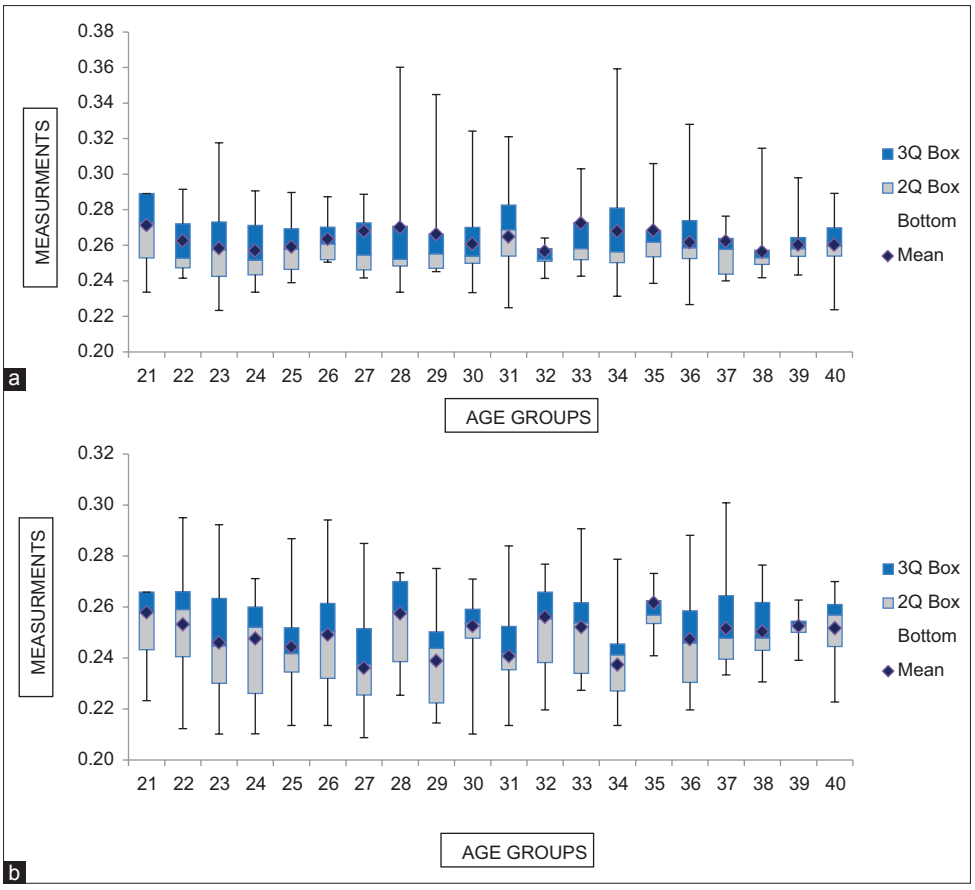



**Graph 2:** (a) Comparison of right mandibular canine index between males in each age group, (b) comparison of right mandibular canine index between females in each age group

**Table 2: Comparison between *in vivo* and *in vitro* measurements of mesiodistal width of the right and left canines and intercanine distance in 40 subjects (10% sample)**

| Variables | Right canine | | Left canine | | Intercanine distance | |
|---|---|---|---|---|---|---|
| Measurements | *In vivo* | *In vitro* | *In vivo* | *In vitro* | *In vivo* | *In vitro* |
| *N* | 40 | 40 | 40 | 40 | 40 | 40 |
| Mean±SD (mm) | 6.64±0.42 | 6.51±0.42 | 6.65±0.42 | 6.52±0.42 | 26.67±3.485 | 26.39±3.46 |
| *P* | 0.07 | | 0.09 | | 0.71 | |
| Inference | Nonsignificant | | Nonsignificant | | Nonsignificant | |

SD: Standard deviation




**Graph 3:** (a) Comparison of left mandibular canine index between males in each age group, (b) comparison of left mandibular canine index between females in each age group

**Table 3: Percentage of sex correctly predicted using standard mandibular canine index**

| Sex | *n* | Number of cases with correct gender | Percentage |
|---|---|---|---|
| Males | 200 | 160 | 80 |
| Females | 200 | 155 | 77.5 |
| Total | 400 | 315 | 78.75 |

## Discussion

Identification of sex from adult human skeletal remains is the most reliable, only if the complete skeleton is available.[15] The basic problem arises when sex determination is required for incomplete and fragmentary skeletal remains. In such cases, teeth can be used as an additional tool as they are very resilient to destruction,[16] readily accessible, and unique.[17]

There are two methods of gender identification that have been extensively described and used; metric and nonmetric. The metric approach offers advantages over the nonmetric approach which is inherently more objective. Furthermore, it has higher reliability, less dependence on the previous observer experience and is more readily amenable to statistical analysis and thus helps comparisons within the sample as well as with previous studies.[18,19]

Among the permanent teeth, canines are the most informative on the sexual dimorphism, not only through its crown dimensions (metric trait) but also by the presence of a minor distal groove (nonmetric trait) either on maxilla or on mandible.[20] The mandibular permanent canines have been considered key teeth for the purpose of personal identifications because they are least exposed to the periodontal disease, abrasion, or heavy occlusal loading; hence, one of the last teeth to be extracted with respect to age.[19] Furthermore, the mandible canines can be readily available as the mandible is the strongest bone in the human body and persists in a well-preserved state longer than any other bone.[17]

The present study was based on the metrical method, where the MD width of the mandibular canine and the intercanine distance were analyzed for gender differences. Furthermore, the study sought to derive the standard mandibular canine indices for the study population based on the method suggested in a previous study.[21] This was aimed considering the fact that there are differences in odontometric features in specific populations, even within the same population; hence, it is necessary to determine specific population values to make identification possible on the basis of dental measurements.[19] As India is a large

fraction of the world population, such studies would generate a raised area for making the dimensional data of Indian population as a standard that may be of beneficial in educational, research, and forensic fields in India.[22]

The study was performed on a sample size of 400 subjects (200 males and 200 females) to maintain an equal distribution of the subjects in the twenty age subgroups. The present study involved measurements of the MD width of the permanent mandibular canine in population sample comprising the ages from 21 to 40 for the sake of comparability with similar previous studies. However, the sample size and age range were considerably narrow in other studies; hence, a larger age range was considered to establish an accurate index. More importantly, the eruption of all permanent teeth is reported to be complete by 21 years. The wasting diseases of the teeth in the age group from 21 to 30 years are minimal. However, the mesiodistal diameter of canine teeth might be affected by several external factors such as proximal attrition, bruxism, or nail biting. Hence, individuals exhibiting such changes were excluded from the study.

When it comes to the developmental changes in the arch width, there is no consensus on the age at which the arch width attains stability. The arch width may change with age, but the magnitude of the change is smaller and variable among samples. Arch width has been reported to increase, with little change across the canines, but appreciably in the more distal regions of each arch.[23]

A review of literature found very few studies which were conducted on Indian subjects and to which the present study could be compared for values of the standard canine index.[10,18,19,21,24] The accuracy of measurements of tooth dimensions in the oral cavity and dental casts has been compared, and it was found that dental casts facilitate the analysis of tooth size with no statistically significant difference and with a high degree of accuracy [Table 2]. Moreover, measurements of the stone cast instead of direct intraoral measurement were preferred in the current study as this helped avoid transmission of infection between the included subjects. It is advantageous to measure the tooth dimensions on the casts as they may be examined at a later date to eliminate errors due to fatigue during measurements. Furthermore, it provides convenience for the second investigator to make measurements at a later date. Measurements with dental caliper showed high accuracy and reproducibility which favored the use of digital caliper as a suitable instrument for research work.[25]

According to the standard textbooks, the average MD diameter of the mandibular canines is 7.0 mm.[26] Under the present study, among males, the statistical mean of mandibular right canine was estimated to be 6.895 ± 0.24 mm, whereas among females, it was found to be 6.359 ± 0.34 mm. This difference is statistically highly significant although the difference in the mean values was only marginal [Table 1]. As reported in the previous studies, male mandibular right canine dimension was greater than that of female.[11,21,25] The values were lower than those found in the previous studies on North Indian and South Indian males and Nigerian males[22,24,27] although they fall in the near range. However, the female values coincided with those found in the South Indian population.[22] A statistically highly significant dimorphism was detected in the dimensions of mandibular left canine which was calculated to be 6.897 ± 0.24 mm for males and 6.362 ± 0.34 mm for females [Table 1]. Male mandibular left canines were once again found to be larger than the female ones. This sexual dimorphism is reflected in earlier reports.[19,24,27] The values were lower than those found in the previous studies on North Indian and South Indian males and Nigerian males[22,24,27] although they fall in the near range. However, the female values coincided with those found in the south Indian population.[25] A study on Chinese population, Egypt population, Caucasians, Negroids, Uruguayans, South and North Indians revealed statistically significant difference between male and female in MD diameter of canine.[11,22,24,27,28] This is confirmed by the present study. This is a known fact and is attributed to differences in enamel thickness due to a longer period of amelogenesis in the male.[27]

Among males, the statistical mean of mandibular intercanine arch width was found to be 26.361 ± 2.09 mm, whereas among females, it was estimated to be 25.654 ± 1.98 mm [Graph 1a and b]. It is evident that the dimensions in male subjects were more than those for the female subjects. These dimensions were slightly larger for males compared to that of the North Indian population but almost same for the females.[24] The dimensions were considerably smaller than that found in the Nigerian population.[27] This study showed statistically significant differences between males and females for the mandibular intercanine distance. The differences between both sexes are explained by the fact that the bony ridges, crests, and alveolar processes are larger in males than in females. Furthermore, the average strength in the musculature in males may affect both maxillary and mandibular arch dimensions.[28] These findings are in accordance with the studies on Egyptian sample[28] as well as Negroid and Indian population.[21,24,27] However, contrary results were found by Kaddah[29] in adult Egyptians and Vishwakarma and Guha[30] in the Indian population. These differences are a clear proof of the fact that magnitude of canine tooth sexual dimorphism varied among different ethnic groups.[11]

For bilateral symmetry of mandibular canines, no significant difference was found in the dimensions of the mandibular right and left canines indicating almost symmetric dimensions [Table 1]. A nonsignificant difference of the measurements of permanent teeth between right and left sides was reported in

a study of samples of three populations from Egypt, Mexico, and the United States. Furthermore, it could be concluded that measurement of one side could be representative when measurement of the other side was unobtainable.[28]

Although studies reveal variable sexual dimorphism in linear measurements, these are not consistent enough to be used as the sole indicator of sex. Efforts to improve on this led to the calculation of dental indices where, in addition to tooth size, tooth proportions have been used to differentiate the sexes.[18] It has been shown that the mandibular canine width has a direct relationship with the canine arch width, enabling the MCI to be derived.[21] Among the males, the statistical mean of MCI for the right and left sides was calculated to be 0.263 ± 0.024 while it was 0.249 ± 0.20 for the females [Graphs 2 and 3]. It has been shown that the Y chromosome appeared to have a direct effect on the tooth size, which may be due to a specific gene or may be related to a more nonspecific effect of heterochromatism on cellular activity.[31] This may be the reason for the observed greater variations among the males as compared to the female subjects. There exist very few studies which assessed the MCI in gender estimation.[18,19,21,24,30] These were conducted by Rao *et al*. (male MCI 0.296 ± 0.016 and female MCI 0.254 ± 0.014),[21] Yadav *et al*. (male MCI 0.310 ± 0.016 and female MCI 0.288 ± 0.014),[10] and Kaushal and Patnaik (male MCI 0.28 ± 0.01 and female MCI 0.26 ± 0.01).[24]

In the present study, the accuracy of gender determination identity was found to be 80% in the male and 77.5% in the female while it was 78.8% for combined sample [Table 3]. The method is simple and inexpensive to conduct and therefore can be applied in forensic odontology as a method for establishing sex identity. Kaushal and Patnaik reported that the sex determination in North Indian was as high as 75%.[21] The standard MCI for the population residing in the Gandhinagar population was found to be 0.254 mm. Rao *et al*. reported the value as 0.274 mm in a south Indian population, and Kaushal and Patnaik reported the same as 0.273 mm in a North Indian population.[21,24]

Garn *et al*., in their study in Caucasians in 1967, had found that the mandibular canine showed the maximum sexual dimorphism at 6.4%.[11] Hence, Using the formula given by Garn and Lewis (1967), sexual dimorphism was calculated from the mean of the right and left mandibular canines and intercanine distance. The formula was = ($X$m/$X$f − 1) × 100, where $X$m = Mean value of male canine width and $X$f = Mean value of female canine width. The present study showed that the right mandibular canine exhibited 8.42% of sexual dimorphism while the left canine exhibited 8.40% of sexual dimorphism. The intercanine distance showed 2.75% of sexual dimorphism. These values are consistent with the study by Kaushal and Patnaik (2004) who reported 9.058 and 8.891%, on the right and left sides, respectively.[24] However, the values were less when compared to other population studies. The percentage sexual dimorphism in a Nigerian population showed that the left mandibular canine exhibited a greater percentage of sexual dimorphism of 16.74% while the right mandibular canine was 15.23%.[27]

## Conclusion

The MD crown width and intercanine arch width of the permanent mandibular canines showed no statistical difference between the *in vivo* and *in vitro* measurements. The MD crown width of the permanent mandibular right and left canines as well as mandibular intercanine distance of the males was found to be larger in size than in the females residing in the Gandhinagar district of Gujarat state.

The right mandibular canine exhibited 8.42% of sexual dimorphism while the left canine exhibited 8.4% of sexual dimorphism. The intercanine distance showed 2.75% of sexual dimorphism. The right and left mandibular canine indices derived using the MD width of the right and left canines, respectively, were also of a greater value in males than in females.

The value of standard MCI derived using the formula devised by Rao *et al*. was 0.254 mm, for the population residing in the Gandhinagar district of Gujarat.

Using the derived standard MCI for the present study population, sex of 160 out of 200 males and 155 out of 200 females was correctly predicted. In the overall sample, sex of 315 out of 400 subjects was correctly predicted. In other words, the percentage accuracy of sex determination of standard MCI was 80% among males, 77.5% among females. The accuracy of the method, when applied to combined data of the present study population, was 78.8%. Hence, the present study supports the usefulness of the MCI in gender determination.

The method of using mandibular canine indices is advantageous as it is easy, rapid, and cost-effective, requires no elaborate apparatus, and is suited for situations where large a number of samples have to be analyzed for gender estimation. This method is of particular significance when more advanced methods for sex determination are not readily available. However, it is of not absolute certainty.

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### Conflicts of interest
There are no conflicts of interest.

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