Original Article

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Sex Determination from Mandibular Canine Index for the Age Group of 17-40 Years in North Indian Population

Mehreen Latif[1], Wasim Rashid[2], Balbir Kaur[3], Amit Aggarwal[4], Aamir Rashid[5]

[1]Senior Resident, Department of Forensic Medicine, SKIMS Medical College, Srinagar, Jammu and Kashmir, India, [2]Medical Officer, Department of Health and Medical Education, Sub District Hospital, Pampore, Jammu and Kashmir, India, [3]Professor, Department of Forensic Medicine, Maharishi Markandeshwar Institute of Medical Sciences and Research, Ambala, Harayana, India, [4]Reader, Department of Oral Medicine and Radiology, MM College of Dental Science and Research, Mullana, Haryana, India, [5]Postdoctoral Fellow, Department of Paediatric Cardiology, SCTIMST, Thiruvananthapuram, Kerala, India

Abstract

Introduction: Gender determination of skeletal remains is a part of archaeological and medicolegal examinations. Teeth are readily accessible for examination and since no two teeth have similar morphology, they form an excellent forensic tool for sex determination. Sexual dimorphism refers to those differences in size, stature, and appearances between males and females that can be applied to dental identification.

Purpose: The purpose of this study was to establish mandibular canine index (MCI) for sex determination in North Indian population for the age group of 17-40 years, to compare the established MCI value among North Indian population, and to find how efficient is MCI in establishing sex identity of an individual.

Materials and Methods: The study was conducted on 150 subjects, out of which 75 were males and 75 were females. The following parameters were determined in this study: Mesiodistal width of the right and left mandibular canine, intercanine distance, and the right and left MCI. All the measurements were taken intraorally in a clean and well-illuminated room, keeping all the aseptic precautions. MCI was calculated by dividing the mesiodistal width of the canine by the intercanine distance.

Results: The standard MCI value for North Indian population is 0.257. Using the MCI value, sex can be correctly predicted up to 80% in males and 76% in females. The total percentage accuracy of sex determination (male and female) was found to be 78%. The MCI values among North Indian population are comparable among themselves although they have a difference with each other.

Conclusion: MCI method is a simple, quick, inexpensive, and reliable method for sex determination when a standard for population is available. As the accuracy of MCI in the identification of sex has never exceeded 87.5%, it can only be used as a supplemental tool for sex identification.

Key words: Intercanine distance, Mandibular canine index, Mesiodistal width

INTRODUCTION

Forensic odontology is the forensic science that is concerned with dental evidence. The use of teeth as evidence is not recent. There are historical reports of identification by recognizing specific dental features as early as AD 49. However, forensic odontology as a science did not appear before 1897 when Dr. Oscar Amoedo wrote his doctoral thesis entitled, "L'Art Dentaire en Medecine Legale" describing the utility of dentistry in forensic medicine with particular emphasis on identification.[1]

Gender determination of skeletal remains is a part of archaeological and medicolegal examinations. The methods vary and depend on the available bones and their condition. The only method that can give a totally accurate result is

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Corresponding Author: Dr. Wasim Rashid, House No. 8, LD Colony Goripora Rawalpora, Srinagar, Jammu and Kashmir, India. Phone: +91-9622229898. E-mail: dr.wasim.rashid@gmail.com

the DNA technique, but in many cases, for several reasons, it cannot be used. Then, anthropological measurements of the skeleton and the comparison with existing standard data must be applied and they may help to differentiate between male and female remains. On an individual basis, however, gender differences are not always distinctive, but taken collectively, they can give a good indication in the majority of cases.[2] Identification of living or dead human beings can be established by examining the external or internal sexual characters when whole of the body of unidentified person is available. Sometimes, it is possible to identify the sex of the body where only fragments of the body are available (as in air crashes, railway accidents, etc.). In the cases of highly decomposed bodies, the prostate or non-gravid uterus can be used for sex determination as they are the last organs to get putrefied. Determination of sex using skeletal remains presents a challenge for forensic experts, especially when only the skeletal remains are recovered. In skeletonized bodies, bones help to establish the sex of the person - skull and pelvis being the most important.

When only or part of the mandible or only teeth are available, the mandibular canines are the best teeth to exhibit the greatest sexual dimorphism.[3] Human teeth are the hardest and chemically the most stable tissues in the body and are extremely durable even at high temperatures.[4] Teeth can be identified even when the rest of the body has undergone decomposition.[5,6]

Teeth are readily accessible for examination and since no two teeth have similar morphology, they form an excellent forensic tool for sex determination. The identification of sex is of significance in the case of major disasters where bodies are often damaged beyond recognition. Of all the teeth in the human dentition, canines are not only exposed to less plaque, calculus, abrasion from brushing, or heavy occlusal loading, than other teeth, but also less severely affected by periodontal diseases. Canines are favored as ideal teeth to study in view of their durability in the oral cavity.[4]

Mandibular canines are considered as the "key teeth" for personal identification and have the mean age of eruption of 10.87 years.[3,7]

Studies performed on the lower canines using the ratio between the maximum crown width and inter canine width, resulting in mandibular canine index (MCI), have shown an ability to determine gender with an accuracy of 84.3% in males and 87.5% in females and 83.3% in males and 81% in females by comparing the observed MCI with a standard MCI value, respectively.[8,9] MCI was employed in numerous studies in large populations as it is simple, reliable, inexpensive, and easy to perform.

The present study establishes the impact of sex factors on the morphometry of the mandibular canines and can be of immense medicolegal use in forensic practice in living, dead, decomposed, and unidentified bodies. The aim of the study was:

1. To establish MCI for sex determination in North Indian population for the age group of 17-40 years.
2. To compare the established MCI value among North Indian population.
3. To find how efficient is MCI in establishing the sex identity of an individual.

MATERIALS AND METHODS

This study was carried out in the Department of Forensic Medicine, Maharishi Markandeshwar Institute of Medical Sciences and Research, Mullana, Ambala, in collaboration with the Department of Oral Medicine and Radiology, MM College of Dental Sciences and Research, Mullana, Ambala. The study was conducted on 150 subjects, out of which, 75 were males and 75 were females. The procedure was explained to the subjects, their written consent was taken on consent forms, and approval from Ethics Committee was obtained. Date of birth proof was taken for the authenticity of age. The clinical findings were recorded in the pro forma and analyzed statistically.

The subjects were selected for their suitability on the basis of the following inclusion and exclusion criteria.

Inclusion Criteria

1. Subjects in the age group of 17-40 years
2. Fully erupted, healthy, and non-worn out mandibular canine
3. Well-aligned lower dental arches
4. Healthy state of gingiva and periodontium
5. Normal overjet and overbite (2-3 mm)
6. Normal molar and canine relationship.

Exclusion Criteria

1. Signs of wasting diseases, i.e., attrition, abrasion, and erosion on mandibular canines
2. Lower anterior canines affected by caries or fractures on their mesial and distal surfaces
3. Crowding or spacing in the lower anterior arch segment
4. Developmental anomalies in relation to number, size, and structure of teeth
5. Partially erupted and ectopically erupted teeth
6. Patients with deleterious oral habits (such as bruxism).

Method

The subjects were comfortably seated on a chair and the examination was carried out under good artificial

illumination. The subjects were told to rinse their mouth with 0.2% chlorhexidine mouth wash for a minute. Mandibular canine impressions of all the samples were made with alginate. The study models were then prepared in dental stone (Figure 1).

The alginate impressions were poured immediately to avoid any dimensional changes and distortion. Dental stone was mixed according to the quantities recommended by the manufacturer for about 30 s and the casts were poured after manual tapping to avoid air bubbles.

The impression was separated from the casts after 30 min as it was the sufficient time for initial setting. Any stone that interfered with separation from the tray was trimmed away with Bard Parker (BP) knife. The casts were dipped in 2% glutaraldehyde for 2 h for disinfection.

The impressions were trimmed if required and bases were poured with dental plaster using orthodontic base formers.

The measurements were done on the study models placed on a stable base and in a well-illuminated room using a digital Vernier Calliper at a least count of 0.001 mm.

The following measurements were taken in all the casts:

1. The greatest mesiodistal width of the mandibular canine (both on the right and left sides). The mean mandibular canine width was recorded for each subject (Figure 2).
2. The intercanine distance was measured as the linear distance between the cusp tips of the right and left mandibular canines. All the measurements were repeated three times and the mean was recorded (Figure 3).

The MCI was then calculated for each subject using the formula given by Rao *et al.*[8] as follows:

$$\text{MCI} = \frac{\text{Mean mesiodistal width of mandibular caninine}}{\text{Intercanine mandibular arch width}}$$

The mean values for male MCI and female MCI were calculated. After this, the standard MCI value was obtained by applying the following formula:

$$\text{Standard MCI} = \frac{(\text{Mean male MCI} - \text{SD}) + (\text{Mean female MCI} + \text{SD})}{2}$$

The standard MCI value was used as a cutoff point to differentiate males from females. All MCI values up to the limit of the standard MCI values were reported as females. Those values above the limit were reported as males. Percentage accuracy of reporting sex identity by this method was then checked as the true sex of each participant was known.[8]

Figure 1: Study cast

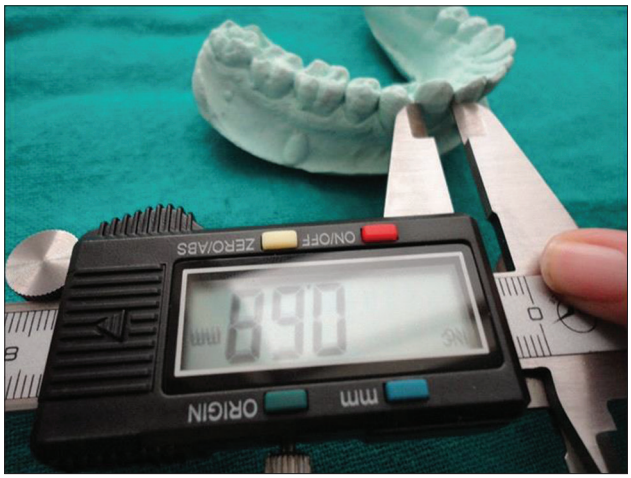

Figure 2: Measurement of mesiodistal width

Figure 3: Measurement of interarch canine width

Observations

The mean age of our study group was 24.77 ± 4.626 years (Table 1). The subjects were taken randomly from different states of North India. Majority of the subjects were from the state of Haryana (49.3%) and Punjab (31.3%) followed by Jammu and Kashmir at 11.3% (Figure 4).

Table 2 depicts the difference in the mesiodistal width between male and female canines. It was found that the mean mesiodistal width of the male canines was 7.062 ± 0.426 mm and that of female canines was 6.473 ± 0.445 mm. This was then statistically analyzed and the $P < 0.001$, which was highly significant. Table 3 shows male interarch canine width to be 26.290 ± 1.794 mm whereas in females, the interarch canine width was 25.611 ± 1.550 mm. The male inter-arch canine width was more than the female inter-arch canine width and the difference was statistically significant. The mean MCI value for males was found to be 0.269 ± 0.019 and for female it was found to be 0.253 ± 0.011 as depicted in Table 4. This was then statistically analyzed and the $P < 0.001$ which was highly significant (Table 4).

After this, the standard value of MCI was calculated and found to be 0.257 for North Indian population.

Utilizing this standard value, reporting of sex was done with each of the MCI values already calculated for each participant. All MCI values up to the limit of standard MCI value of 0.257 were reported as female. Those above this limit were reported as male. Percentage accuracy of reporting sex identity by this method was then checked against the true sex of each participant which was known as shown in Table 5. The percentage accuracy was found to be 80% in males and 76% in females as shown in Table 5.

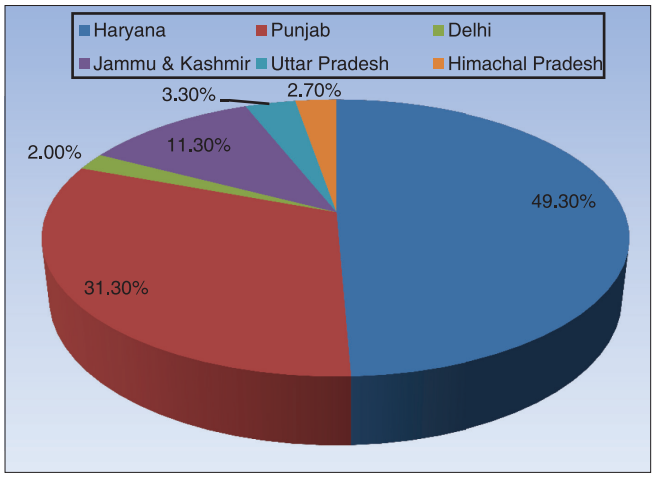

Figure 4: Geographical distribution of subjects

Table 1: Age distribution of subjects

Subjects	Mean±SD (years)	Range
Male	25.37±4.724	(18, 38)
Female	24.17±4.476	(18, 37)
Total	24.77±4.626	(18, 38)

SD: Standard deviation

Table 2: Mesiodistal diameter of male and female subjects

Parameter	Sex	Mean	SD	*P* value	Significance
Mesiodistal width of right mandibular canine	Male	7.059	0.428	<0.001	Highly significant
	Female	6.470	0.444		
Mesiodistal width of left mandibular canine	Male	7.064	0.424	<0.001	Highly significant
	Female	6.476	0.446		
Mean mesiodistal width of mandibular canine	Male	7.062	0.426	<0.001	Highly significant
	Female	6.473	0.445		

SD: Standard deviation

DISCUSSION

The words intriguing, mysterious, and fascinating describe the study of ancient remains. Museums abound with archaeologic and anthropologic exhibit that include teeth and jaws.

Dental artifacts can shed a wealth of information pertaining to our long dead ancestors and vanished civilizations.

Table 3: Inter-arch canine width of male and female subjects

Parameter	Sex	Mean	SD	*P* value	Significance
Inter-arch canine width	Male	26.290	1.794	0.014	Significant
	Female	25.611	1.550		

SD: Standard deviation

Table 4: Statistical significance of mandibular canine index between male and female subjects

Parameter	Sex	Mean	SD	*P* value	Significance
MCI	Male	0.269	0.019	<0.001	Highly significant
	Female	0.253	0.011		

SD: Standard deviation, MCI: Mandibular canine index

Table 5: Percentage accuracy of sex establishment by mandibular canine index method

Sex	Number of cases studied	Number of cases predicted sex correctly by MCI study method	Percentage accuracy
Male	75	60	80
Female	75	57	76
Total	150	117	78

MCI: Mandibular canine index

Researchers have examined the remains of homo erectus from Kenya, where growth rates of dentition were almost twice than those of modern man.[10]

The determination of sex makes identification easier and it is of immense forensic importance. In fact, it has been suggested that the first reported crime in the history of humankind was solved when bite marks were discovered in the remains of forbidden fruits in the Garden of Eden and identified as those of Adam and Eve.[11]

In the present study, there exists a statistically significant sexual dimorphism in the morphometry of mandibular canines as far as mandibular canine widths are concerned. We observed the mean value of the right canine width in males and females to be 7.059 ± 0.428 mm and 6.470 ± 0.444 mm, respectively, and that of the left canine width in males and females to be 7.064 ± 0.424 mm and 6.476 ± 0.446 mm, respectively. These values are found to be highly significant ($P < 0.001$). It is also observed that mean values of canine width are higher in males compared to females, and the difference was statistically highly significant ($P < 0.001$). Our findings in males and females are supported by Kaushal *et al.*[3] who have reported mean right canine width in males to be 7.229 ± 0.280 mm and in females to be 6.690 ± 0.256 mm and the left canine width in males to be 7.299 ± 0.292 mm and in females, it has been reported to be 6.693 ± 0.323 mm in their study on sixty subjects (males 30 and females 30). Agarwal *et al.*[12] found that males exhibit larger mesiodistal width than females. It is consistent with Nair *et al.*[13] who conducted a study on South Indian males and females in the age group of 16-28 years and found that canines in both jaws exhibited a significant sexual difference. Lew and Keng[14] gave similar findings in their study on ethnic Chinese population with normal occlusions.

In spite of tooth size variability factors, the studies conducted by Sherfudhin *et al.*[15] on Saudi Arabian population and by Bishara *et al.*[16] on the population of Egypt, Mexico, and the United States showed the consistent finding that the mesiodistal width of the mandibular canines is more in males than females, and the difference is statistically significant.

In the present study, it was observed that the mean intercanine difference in males is 26.290 ± 1.794 mm and the value in females is 25.611 ± 1.550 mm, thus values in males being higher than those of females and the difference is statistically significant. Similar observation in males and females has been observed by Kaushal *et al.*[3] (males: 25.873 ± 1.293 mm; females: 25.070 ± 1.197 mm), Reddy *et al.*,[2] (males: 26.860 ± 1.48 mm, females: 26.287 ± 1.45 mm), and Al-Rifaiy *et al.*[17] (males: 27.0171 ± 2.3168 mm and females: 26.4615 ± 2.7761 mm). These values are comparable to each other; however, the slight differences could be accounted for the racial variations in tooth size.

In our present study, MCI in males was found to be 0.269 and for females, MCI value was 0.253. The difference in the MCI values of males and females was highly significant ($P < 0.001$). This is in agreement with other studies done in different parts of the country by Rao *et al.*[8] in 1989, Yadav *et al.*[9] in 2002, Kaushal *et al.*[3] in 2004, and Reddy *et al.*[2] in 2008. In all those studies, MCI values of males were greater than that of females and the difference was statistically significant.

Human sexual dimorphism is said to be an outcome of a survival strategy, a balancing of the need for high degree of biological variation within the species with the need for a narrow range of variation in the female, who is physically structured for the support of an infant prenatally and postnatally.[18] Thus, the differences are a reflection of the ongoing process of evolution. The genetic basis for variation has been explained by a polygenic model of inheritance. This is the basis of sexual dimorphism in the morphological and metric attributes of males and females.[19]

Canines vary from other teeth with respect to survival and sex dichotomy. The differences in all probability are correlated to their function, which is different on an evolutionary basis from other teeth. In many animals, large canines are considered to be the visual sexual signs of dominance and rank. In carnivores and in most primates, their chief function is related to threat of aggression and actual aggression.[20] A transfer of this aggressive function occurred from the teeth to the fingers in man and until this transfer was completed, survival was dependent on canines, especially in males. Thus, in present day humans, sexual dimorphism in mandibular canines is not merely a coincidence but can be expected to be based on the functional activity.[21]

The notable difference between canines in determining sex was noted to be due to the influence of Y-chromosome which was not uniform in all teeth. On the other hand, the X-linked genetic influence on tooth width was rather uniform for all teeth. It is the Y-chromosome which intervenes most in the size of the teeth by controlling the thickness of dentine, whereas the X-chromosome only comes into play concerning the thickness of the enamel.[22]

Males also possess larger tooth crowns than females in contemporary human populations. This may be due to a longer period of amelogenesis for both deciduous and permanent dentitions in males.[23]

There are many studies done using permanent mandibular canine in estimating the sexual dimorphism and have obtained reliable accuracy. Among all these studies, the study carried out by Rao *et al.*[8] on a diverse sample that originated from the state of Karnataka in Southern Indian stands out because they proposed the MCI. They concluded that 84.3% of the males and 85.7% of the females could be discriminated correctly with respect to sex. The method has been tested on other Indian samples in Southern India and they achieved 72% accuracy in sex estimation. Similar study was conducted by Reddy *et al.*[2] from the state of Uttar Pradesh in Northern India and they have achieved 72% accuracy in sex estimation.

In the present study, the standard MCI value among North Indian population is established to be 0.257. This is comparable to the MCI values established for different North Indian populations in previous studies (Table 6).

The value is comparable to standard MCI value of 0.256 established for North Indian population in western Uttar Pradesh, India, by Reddy *et al.*[2] in 2008.

Our standard MCI value of 0.257 is similar to the value obtained by Srivastava *et al.*[24] in Uttar Pradesh (North India) in which standard MCI value was found to be 0.257.

However, our standard MCI value is slightly less than the standard MCI value established by Kaushal *et al.*[6] in 2004 for a North Indian population in Punjab, India. The established value of MCI in this case was 0.274.

Agarwal *et al.*[12] in 2010 conducted a study on a North Indian population and established standard MCI value of 0.274, which is slightly more than that of established by our study.

Thus, it can be concluded that the standard MCI values among North Indian populations are comparable among themselves, although they have a difference with each other.

The differences could be attributed to sample size, wider geographical distribution, wider age group, and better usage of armamentarium in this study. Here, digital vernier caliper of resolution 0.001 mm was used whereas manual caliper of resolution 0.02 mm was used in most of the above-mentioned studies.

The percentage accuracy of sex determination in our study is 80% in males and 76% in females. Total number of cases correctly predicted (males and females) is 78%. These values are comparable to other studies using MCI for sex prediction (Table 6).

This is slightly <84.3% in males and 87.5% in females accuracy in the study conducted by Rao *et al.*[8] in 1989 among South Indian population.

Table 6: Comparison of MCI values and % accuracy with other studies

Study	MCI value	% Accuracy of sex determination		
		Male	Female	Average
Rao *et al.*[8]	0.274	84.3	87.5	85.9
Yadav *et al.*[9]	0.298	83.3	81	82.15
Kaushal *et al.*[3]	0.274	68.35	81.6	75
Reddy *et al.*[2]	0.256	78	66	72
Present study	0.257	80	76	78

MCI: Mandibular canine index

The percentage accuracy of the present study is comparable with the result of 83.3% in males and 81% in females in a study conducted by Yadav *et al.*[9] in 2002.

Kaushal *et al.*[3] in 2004 conducted a study to establish the effectiveness of MCI in predicting sex in a North Indian population. It was seen that with standard MCI, it was possible to detect sex in a North Indian population to as high as 75%. In our present study, we could detect sex to as high as 78% in the total population (male and female) which compares favorably with the value in the above-mentioned study.

Reddy *et al.*[2] in 2008 studied the percentage accuracy of sex determination in western Uttar Pradesh and found that males could be predicted correctly in 78% of cases and in females, the accuracy was 66%, so total percentage accuracy was 72%. This is comparable to our study in which total number of cases predicted correctly was 78%.

The percentage accuracy of the present study is comparable with the result of 75.97% (male 71.67% and female 78.72%), which was based on calculated MCI of 0.2504 for both males and females by Mughal *et al.*[5] in 2010 in the Punjab province of Pakistan.

Padmavati *et al.*[7] in 2011 conducted a study in Andhra Pradesh to study the effectiveness of the MCI in determining sex and found that they could correctly predict sex to an accuracy of 76.66% (males 73.33%, females 80%) using MCI. These values compare favorably with the values obtained in the present study.

In this study, it was also found that 89.3% of the females had mesiodistal width of mandibular canine ≤7 mm whereas only 52% males had mesiodistal width more than 7 mm.

However, according to a study by Kaushal *et al.*[25] in 2003, whenever the width of either canine was more than 7 mm, the probability of sex being male was 100%.

This difference in finding could again be attributed to larger sample size, wider geographical distribution, and wider

age group in our study. Moreover, digital vernier caliper of resolution 0.001 mm was used in our study whereas manual vernier caliper of resolution of 0.02 mm was used in the above-mentioned study.

This study which has established MCI value to be 0.257 for a North Indian population may prove to be beneficial in sex identification from mutilated dental remains and can be helpful in medicolegal matters.

CONCLUSION

Any measurement of teeth unaccompanied by information about age, race, and sex must be treated with great caution. In the present study, sex could be predicted to an extent of about 78%. However, such a method of sex determination has its limitations due to variation of this parameter with geographical distribution. This implies that it is necessary to make up a random sample of the population from this geographical area to calculate the corresponding standard MCI.

The emerging field of forensic odontology in India depends a lot on inexpensive and easy means of identification of sex. MCI is a simple, quick, and reliable method for establishing sexual identification when a standard for the population is available.

The present study establishes the impact of sex factors on the morphometry of the mandibular canines and can be of immense medicolegal use in forensic practice in living, dead, decomposed, and unidentified bodies.

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