Gender determination analysis using anthropometrical dimensions of 2D:4D, foot index and mandibular canine index

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Abstract

Introduction: Sex determination is a challenge for forensic experts during mass disasters. Teeth are an excellent source in both living and nonliving population, where bodies are mutilated beyond recognition. Mandibular canines can be employed for gender determination in such situations. Similarly, second-to-fourth digit ratio (2D:4D) and foot index (FI) are sexually dimorphic and differ in males and females. Mandibular canine index (MCI), 2D:4D and FI are considered quick, easy and reproducible methods for determining the sex of an individual.

Aim: This study aimed to determine the combined role of MCI, 2D:4D and FI in denoting gender identity and establish their correlation.

Materials and Methods: The present study comprised of 100 dental students (50 males and 50 females) of our institution, aged 19–25 years, with specific inclusion and exclusion criteria. The measurements were done using a Vernier caliper, a divider and a ruler, and MCI, 2D:4D and FI were calculated using their specific formulae. The calculated values of FI, MCI and 2D:4D were subjected to statistical analysis.

Results: There was a statistically significant difference observed between left MCI ($P < 0.05$), right and left 2D:4D and FI ($P < 0.05$). The results revealed that 2D:4D was less, whereas MCI and FI were higher in males than in females. The observed MCI was compared with standard MCI, and left MCI revealed higher sexual dimorphic characteristics (15.2%). Although the overall correlation between 2D:4D, FI and MCI was insignificant, the measurements were comparable.

Conclusion: This study indicated that the anthropometric dimensions of 2D:4D, FI and MCI can be used for sex determination independently with accurate results.

Keywords: 2D:4D, foot index, forensic anthropometry, gender determination, mandibular canine index

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INTRODUCTION

Anthropometry is described as a technique of expressing the form of human body quantitatively as it is the systematic collection and correlation of measurement of the human body. Forensic anthropometry which includes somatometry, cephalometry, craniometry, odontometry and

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osteometry deals with the study of dimensions of human body parts for recognition of an individual.[1] Individual identification is determination of personality of a living or dead person in certain circumstances such as mass disasters, blast and assault cases. Establishing the identity of an injured individual is a huge challenge for forensic experts especially where the body is dismembered and mutilated. Among the different parameters, sex identification is considered the chief criterion in establishing the uniqueness of an individual. Accurate sex identification of the human remains has the potential to primarily narrow down the search to a particular sex, thereby giving a sense of direction to the ongoing forensic investigation. Identification of sex is the least complex criterion in forensic analysis, as the external and internal genitalia can straightforwardly propose the sex of an individual, but the trouble arises when there are cases of intersex and bodies in highly degenerated, mutilated, fragmented and skeletonized state.[2]

Application of DNA technique is the exceptionally accurate method for conclusive results, however due to several reasons, it cannot be employed in all the cases. To overwhelm this drawback nowadays, the individual recognition by measuring anthropometrical dimensions of human remains has become progressively significant in certain cases of mass disasters, where feet and hands are found separated from the body.[3] Dismembered remains including the terminal parts of the human body such as hands and feet are customarily found in cases of mass calamities and homicides. Excluding the finger length, for example, index finger length (IFL) and Ring finger length (RFL), finger proportions have additionally been utilized for anticipating the sex of a person. The finger proportion is an explicitly dimorphic and a biometric populace marker. This proportion is identified with prebirth estrogen and testosterone levels and hereditarily constrained by the HOX genes.[4]

No two individuals are alike in their characteristics, and the morphological difference in the form, either in shape or size between individuals of different sexes, can be termed as sexual dimorphism. The forensic odontometry deals with the prediction of sexual dimorphism by measuring the dimensions of the teeth.[5] Gender assessment using them is specifically based on the comparison of tooth dimensions in males and females. Albeit, disparity in tooth size, diversity in root length and crown diameter, dental index, odontometric differences, Barr bodies and enamel protein have additionally been used for sex determination.[6] Among all the teeth, canines are perhaps the most stable teeth in the oral cavity because of bulkiness of the crown and the root anchorage in the alveolar process of the jaws. The morphological characteristics of canines allow the self-cleansing quality. Mandibular canines are preserved by a thick, compact mandibular bone which makes them very stable even at extreme conditions such as earthquakes, tsunami, floods and avalanches. It has also been stated that left mandibular canines explicitly tend to show best sexual dimorphism and they could be possibly be considered the "key teeth" for personal identification.[7]

Forensic podiatry deals with the study of foot dimensions for human identification. Genetics and environmental factors greatly influence the morphology of human feet in a combined effect. These determine the size and shape of the feet, thereby making it an important data to establish the human identity.[8] Although several researchers have attempted in estimating sex from foot bones and foot shape, studies on sex determination from foot dimensions among various populations are limited in number, but sill they can be considered unique features in sex identifications.[9] Mandibular canine index (MCI) has already been established as a better technique for gender determination and most of the studies have used MCI, 2D:4D and foot index (FI) separately to find a sexual distinction, thus the present study was an attempt to correlate MCI with 2D:4D and FI to increase the sensitivity and specificity in gender determination.

MATERIALS AND METHODS

The present study comprised 100 dental students (Haryanvi Jat – 50 males and 50 females) of our institution (PGIDS, Rohtak, Haryana), aged between 19 and 25 years. Students with healthy periodontium, caries-free canine and teeth having Class I canine relationship without any congenital deformities of teeth, hand and foot were included in the study. Students with carious or missing mandibular anterior teeth and presence of spacing, crowding, abrasion and attrition affecting the mandibular anterior teeth and students undergoing orthodontic treatment and having congenital or acquired deformities were excluded from the study. The odontometric, hand and foot measurements of all the students were noted, and the respective indices were calculated. The mean values were calculated for each index for both males and females. The obtained results were compared with the standard values using statistical tests.

Calculation of mandibular canine index, second-to-fourth digit ratio and foot index

The MCI was calculated as follows: MCI = mesiodistal crown width of mandibular canine/intercanine distance (ICD)[6] where the mesiodistal crown width of the mandibular canine was measured using the divider intraorally by placing them over the tooth and was measured between the contact points of the tooth on either side of the jaw [Figure 1]. The ICD was measured as the linear distance between the cuspal tips of the right and left mandibular canine using the divider [Figure 2].

The standard MCI was measured using the following formula: Standard MCI = ([(mean male MCI − standard deviation [SD]) + mean female MCI + SD]/2).[10]

Sexual dimorphism = ($[X_m/X_f] - 1 \times 100$) where X_m is the mean value of male canine width and X_f is the mean value of female canine width.[6]

2D:4D ratio: The IFL and the ring finger length (RFL) were measured in each hand with the help of a Vernier caliper as explained by Singh and Bhasin [Figure 3].[11] The IFL and RFL were measured as the linear distance between the mid-point of the proximal-most flexion crease at the base and the tip of the index and the ring fingers along the midline on the palmer surface, respectively. Abduction or adduction of the wrist joint should be avoided during measurement as it may lead to error in the results. The index and ring finger ratio was computed by dividing the IFL with the ring finger length. 2D:4D = IFL/length of the ring finger.[12]

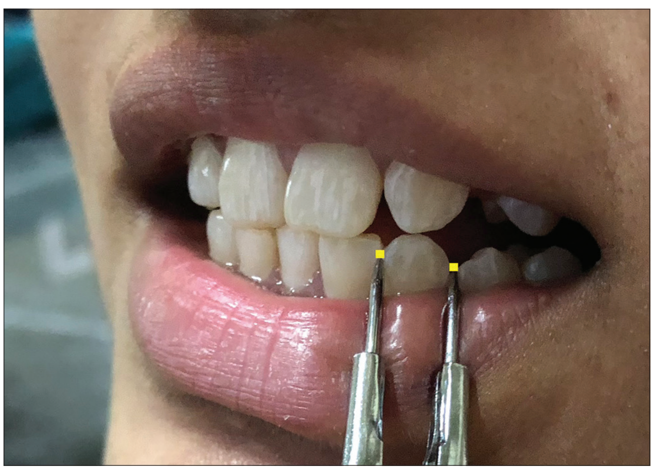

Figure 1: Measurement of canine width (intraorally)

Figure 3: Landmarks of anthropometric measurements of fingers

The FI was calculated by using the following formula: FI = FB/FL × 100[1] where FB is the foot breadth which was measured between the heads of the metatarsal bones, such as metatarsal fibulare laterally and metatarsale tibiale medially on the outline of the foot drawn by making the individual to keep his/her foot stretched over a white paper and FL is the foot length which was measured from the acropodian (anterior-most point on the bigger toe) and the pternion (posterior-most point on the heel foot) using a metal scale[13] [Figure 4].

Statistical analysis

The data obtained were analyzed statistically using IBM SPSS Statistics for Windows, Version 25.0. IBM Corp., Armonk, NY, USA. computer software. Student's *t*-test was performed to compare the IFL and ring finger lengths and their ratio in the two hands, FL, FB and FI on both the feet; mesiodistal width of the mandibular canine on either side of the jaw and ICD and MCI in both the sexes. Statistical significance was defined at the standard 0.05

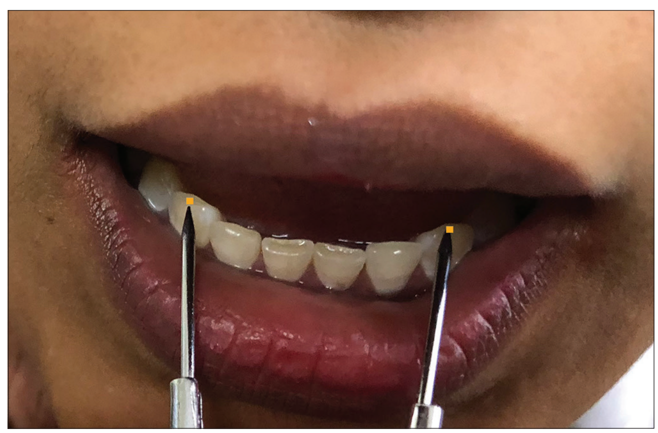

Figure 2: Measurement of intercanine distance (intraorally)

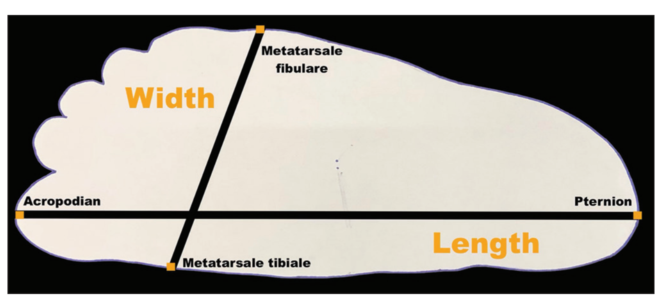

Figure 4: Landmarks of anthropometric measurements of foot

level ($P < 0.05$), and Pearson's correlation test was used to find the correlation between MCI, 2D:4D and FI.

RESULTS

In the present study, the anthropometry of feet, hand and teeth was studied in 100 students. The average mesiodistal crown width of the mandibular canine for males and females on the right side was 7.4 and 6.4, respectively, and on the left side, it was 7.3 and 6.7, respectively [Table 1]. The MCI was calculated by using a standardized formula given by Rao *et al*.[14] The results of both right and left MCI were found to be higher in males than in females, but the results were significant only for left MCI and not for the right MCI. Upon intragroup comparison, no significant difference was found between right and left MCI among males or females. The overall average left MCI (0.28) was higher than the overall right MCI (0.27) among both males and females. The standard MCI calculated using Rao's formula was 0.28, and it was used as the deviation point. The students who had MCI >0.28 were considered as males and less as females, and the sexual dimorphism using Garn's formula was found to be 15.6% for the left and 10.44% for the right side. All the values of right and left MCI for both males and females are tabulated in Table 2.

The average mesiodistal crown width of the mandibular canine on the right side was greater than that of the left side, and males possessed higher average width than females with significant P values. Similar to crown width, ICD was another parameter higher in males than females. The minimum and maximum values of mesiodistal crown width of mandibular canine and ICD are depicted in Table 1.

Table 1: Comparison of right and left mandibular canine dimensions of the study participants

Parameters	Sex	*n*	Mean±SD (cm)	*P**
Right canine width	Male	50	7.4±0.6	0.00
	Female	50	6.4±0.4	
Left canine width	Male	50	7.3±0.6	0.01
	Female	50	6.7±0.6	
Intercanine distance	Male	50	27.20±2.1	0.02
	Female	50	27.02±2.2	

*$P<0.05$ have been considered to be statistically highly significant. SD: Standard deviation

Table 2: Comparison of right and left mandibular canine index of the study participants

Parameters	Sex	*n*	Mean±SD	*P**
Right MCI	Male	50	0.27	0.07
	Female	50	0.26	
Left MCI	Male	50	0.28	0.03
	Female	50	0.27	

*$P<0.05$ have been considered to be statistically highly significant. SD: Standard deviation, MCI: Mandibular canine index

The length of ring fingers in both the hands was found to be significantly longer in males than females. The IFL does not have any significant difference between males and females [Table 3]. The difference between the mean of RFL and the IFL was 3.4 mm in the right hand and 3.3 mm in the left hand of males, and 0.8 mm in the right and 1.18 mm in the left hand of females. The difference between the mean RFL and IFL between males and females was statistically significant ($P < 0.05$) in both the hands. Right-hand digit ratio was found to be significant than that of the left hand.

The average 2D:4D calculated was higher in females than in males, and the results were found significant on both the hands. Among all the parameters included in this study, only the values of 2D:4D were significantly higher in males than in females, and rest of all the other parameters were significantly higher in males than in females. The index and ring finger ratio derived from the finger lengths ranged from 0.88 to 1.00 in males, with a mean of 0.96, and from 0.92 to 1.00, with a mean of 0.98, in females for both hands. For the left hand, the index and ring finger ratio ranged 0.97 in males. The derived ratio showed a statistically significant difference between males and females ($P < 0.05$) [Table 4].

The mean values of FL, FB and FI were significantly higher in males than females. These sex differences were statistically significant as indicated by the Student's *t*-test ($P < 0.05$). The minimum, maximum and average FL in both the feet were significantly higher in males than in females [Table 5]. In males, the right FL (Right FL) varied from 24.90 to 29.00 cm (mean 26.63 and SD 1.26) and left FL (Left FL) varied from 25.0 to 28.90 cm (mean 26.69

Table 3: Comparison of right and left digit dimensions of the study participants

Parameters	Sex	*n*	Mean±SD (mm)	*P**
Right index finger (R2D)	Male	50	74.16±3.43	0.02
	Female	50	72.18±4.23	
Right ring finger (R4D)	Male	50	77.16±4.15	0.02
	Female	50	73.36±4.5	
Left index finger (L2D)	Male	50	75.45±3.7	0.03
	Female	50	71.88±4.27	
Left ring finger (L4D)	Male	50	78.57±4.22	0.03
	Female	50	72.05±4.22	

*$P<0.05$ have been considered to be statistically highly significant. SD: Standard deviation

Table 4: Comparison of right and left digit ratio of the study participants

Parameters	Sex	*n*	Mean±SD	*P**
R2D:4D (right index finger: ring finger)	Male	50	0.96±0.02	0.02
	Female	50	0.98±0.08	
L2D:4D (left index finger: ring finger)	Male	50	0.97±0.03	0.03
	Female	50	0.98±0.02	

*$P<0.05$ have been considered to be statistically highly significant. SD: Standard deviation

and SD 1.22). In females, the Right FL varied from 21 to 26.4 cm (mean 23.18 and SD 1.18) and Left FL varied from 21.30 to 25.90 cm (mean 23.30 and SD 1.13).

The average FB measured in males was found significantly higher than the FB of females [Table 6]. As in males, the right FB (RFB) varied from 8.20 to 11.50 cm (mean 10.03 and SD 0.73) and left FB (LFB) varied from 7.90 to 11.40 cm (mean 9.94 and SD 0.70). In females, the RFB varied from 8.00 to 9.70 cm (mean 8.54 and SD 0.52) and LFB varied from 7.00 to 9.70 cm (mean 8.49 and SD 0.53). The average FB in both the feet was higher in males than females.

The mean FI in males was significantly higher than that in females in both right and left feet ($P < 0.001$). The average FI in males and females was 37.66 and 37.26, respectively. In males, the right FI (RFI) varied from 31.53 to 41.82 cm (mean 37.67 and SD 2.12) and left FI (LFI) varied from 30.50 to 40.37 cm (mean 37.25 and SD 2.09). In females, the RFI varied from 33.48 to 40.45 cm (mean 36.88 and SD 1.59) and LFI varied from 31.67 to 40.00 cm (mean 36.43 and SD 1.74) [Table 7].

Table 5: Comparisons between right and left foot length of the total participants

Parameters	Sex	*n*	Mean±SD (cm)	*P**
Right FL	Male	50	26.63±1.26	0.00
	Female	50	23.18±1.19	
Left FL	Male	50	26.69±1.22	0.00
	Female	50	23.30±1.13	

*$P<0.05$ have been considered to be statistically highly significant.
SD: Standard deviation, FL: Foot length

Table 6: Comparisons between right and left foot breadth of the study participants

Parameters	Sex	*n*	Mean±SD (cm)	*P**
Right FB	Male	50	10.03±0.74	0.00
	Female	50	8.54±0.53	
Left FB	Male		9.94±0.71	0.00
	Female		8.48±0.53	

*$P<0.05$ have been considered to be statistically highly significant.
SD: Standard deviation, FB: Foot breadth

Table 7: Comparison between right and left foot index of the study participants

Parameters	Sex	*n*	Mean±SD	*P**
Right FI	Male	50	37.67±2.14	0.044
	Female	50	36.88±1.67	
Left FI	Male	50	37.26±2.11	0.03
	Female	50	36.44±1.74	

*$P<0.05$ have been considered to be statistically highly significant.
SD: Standard deviation, FI: Foot index

DISCUSSION

"Sexual dimorphism" is variation that occurs at the morphologic level between males and females. It is found because of the differential development of internal and external genitalia along with other features such as body size, appendages and specific cellular components.[2]

The present study included extragenital features such as MCI, 2D:4D and FI. The contribution of various tissues in sexual dimorphism of tooth size was reported by Harris *et al*.[15] They found that males typically have significantly larger dentine and pulp dimensions than females, while marginal enamel thickness is similar in both sexes, as chromosome Y intervenes in the size of teeth by controlling the thickness of dentin and chromosome X controls the thickness of enamel. It is of definite significance, as tooth morphology can also be influenced by cultural, environmental and racial factors. This difference in the size of canine makes it a perfect tool for sexual differentiation. Considerable difference was seen in between right and left canine widths of males and females, and comparable outcomes were found in the past investigations done by Kaushal *et al*.[16] and Reddy *et al*.[3] The existence of a statistically significant sexual dimorphism in mandibular canines was established by Sharma *et al*.[17] It is consistent with the findings of Hashim and Murshid, who conducted a study on Saudi males and females in the age group of 13–20 years and found that only the canines in both jaws exhibited a significant sexual difference, whereas the other teeth did not. It has been concluded separately on different ethnical group that mandibular canines exhibit greatest sexual dimorphism.[18,19] We also found similar findings, however the findings were comparatively higher than that of previously reported. The left mandibular canine showed a significant difference in the mean mesiodistal width of males and females than the right mandibular canine, so the left MCI was higher as compared to RCI.[7] Thus, usage of left MCI to estimate the gender of the individual will give more precise results than that of the right canine.

We found a significant difference between the right and left MCI among males and females along with a significant difference between the ICD of males and females. Similar findings were also reported in the study done by Kaushal *et al*.[16]

The 2D:4D has been used for the correlation of IQ, gender determination and detection of different types of cancer in literature, as the digit ratios could be influenced by the action of HOX gene and 2D:4D was used as a putative marker for susceptibility to diseases influenced by such genes.[20,21] Sexual dimorphism in the extent and length of the fingers has been documented from interdigital ratios by Lippa,[22] i.e., the various possible ratios for different finger lengths. The sex difference obtained from the finger ratios was independent of the body size, as the ratios were not significantly related to the height and age in either sex. Manning *et al*.[23] suggested that index-to-ring finger ratio does not change with age and growth in a population group. Voracek[24] inferred that the IFL and ring finger length proportion was sexually distinguishable, and therefore the proportions of index and ring finger were a proper characteristic for gender determination.

In the present study, the IFL and ring finger length in both the hands of males were higher than those of female hands, and the results are similar to those of previously concluded studies.[22,23]

A normal human foot shows great variation in its dimensions such as length and breadth. Such variation exists in every individual, which helps in the determination of sex from foot dimensions, thereby playing an important role in personal identification.[1] The mean values of FL, FB and FI on both right and left feet in our study population were significantly larger in males than that in females. Males had an average FL about 3 cm greater than the FL of females. The FB was about 1 cm greater in males as compared to females. The FI in males was found to be >37, and in females, it was < 37. Therefore, the value of 37 can be used as the standard value for the determination of sex. Thus, the present study indicates a positive correlation between an individual's foot measurements and gender, which is consistent with the study conducted by Tyagi *et al*.[25]

FL and FB in males as well as females were found to be higher on right-sided foot than left-sided foot in the present study. Similar data were found in studies done on the population of North India, Mauritius and Nigeria, whereas other studies done on Slovakia and Turkish population found higher foot dimensions on the left side, which is not similar to the present study.[26]

We found that the FI was higher in males than in females, with values of 37.67 and 36.88, respectively. This goes in hand with the earlier study done by Bob and Didia.[27] among Nigerian population. The foot dimension in males and females in their study was comparatively larger than that of Caucasian values. This finding is in accordance with the theoretical expectation that the FI will not be same for all the populations living in the world.

Our study findings are comparable to the study conducted by Sen *et al*.[4] in a Bengali Rajbanshi population comprised of 175 males and an equal number of females, who reported an FI of 41.3 in males and 40.5 in females on both right and left sides.

A higher mean value of FI among men than women has also been reported in a recent study among the Gujjar population of North India by Moudgil *et al*.[28] However, the results were not statistically significant. However, in their study, they have reported that there was a statistically significant bilateral difference in FI. The FI in the present study has been observed to be marginally higher for the right side among men and women, but the differences between right and left sides within sexes were not statistically significant.

The FI values found in the study by Singla *et al*.[9] on North Indian population reported lower FI than our study, and few studies reported higher FI in females than in males.[29,30] These variations could be due to fact that anatomic structures of foot show ethnical and regional variations owing to genetic background, climatic factors, physical activities, socioeconomic status, nutritional conditions and practice of using different footwear.

CONCLUSION

The present study has focused on the assessment of sex from canine, hand and foot dimensions. It provides the imperative methodology for the sex identification, chiefly in cases of mass disasters and criminal mutilation. It can be concluded that 2D:4D, MCI and FI were higher in males than females with significant sex differences and that sex can be estimated with rational accuracy, when used independently. They can be employed when only reduced facilities are available for examination as it is cost-effective, is easy to carry out, is relatively less time-consuming and is a reasonably reliable alternative to determine the sex of an individual. As it is not a confirmatory test, it could instead be used as an adjunct with other tests for gender identification. However, the results from the present study were statistically significant, thus similar studies are proposed to confirm the findings of our study with larger sample size in different population group and to find the degree of sexual dimorphism disclosed by 2D:4D, MCI and FI.

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Conflicts of interest

There are no conflicts of interest.

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