Sex Prediction Assessment via Mandibular Canine Index and Logistic Regression in Pakistani Population: A Digital Model Study

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Abstract

The prime aim of the study was to establish sex prediction assessment via mandibular canine index (MCI) and logistic regression in Pakistani population thorough a digital model study. The selected sample consisted of 128 subjects with the ages ranged from 18 to 24 years. The mesiodistal and buccolingual tooth size were measured via scanned digital dental models. Male's measured canine width and MCI is larger than female. SMCI anticipated erroneously 48% male and 51% female. Sex assessment via binary logistic regression (BLR) for inclusion of two (MD 43 and LICW) variables showed the overall percentage of prediction were 66.4%, and 64.1% and 68.8% for male and female respectively. BLR for inclusion of more tooth size (MD and BL widths of maxillary and mandibular right side) variables. The overall percentages of prediction were 75.4%, with 80% and 71% for male and female respectively. The Rao index is not a reliable way for the sex identification in Pakistani population. BLR sex prediction models is applicable for Pakistani population.

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Introduction

Sex predictions are of considerable importance to anthropologist and forensic odontologist.[1,2] Several methods have been used for sex determination from human skeletal remains where body physiques are impaired far afield from recognition.[3,4]

Teeth have important role in sex determination due to its robustness from decomposition process and incineration.[2,5-13] There is obvious population variation in the pattern and magnitude of tooth sexual dimorphism.[14-17] Among the human teeth, canine dimension have regularly shown the highest sexual dimorphism[1,18,19] and is part of mandibular canine index (MCI) that show a very good sex prediction in Indian population.[20]

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Rao (1989) proposed the MCI (Mandibular Canine Index). MCI shows a very good sex prediction based only on the mesiodistal canine and intercanine width of the mandibular arch.[20] However, when MCI was applied to other human populations the outcome varies.[21-23] Previous tooth size dimensions i.e. mesiodistal (MD) and buccolingual (BL) variables produced an acceptable accuracy of sex prediction derived from discriminant function analysis (DFA).[6]

Considering some limitations in handling DFA[22,23] and the inconsistent prediction performance of MCI thus we aimed to-

- compare the methods of sex prediction between Rao MCI and logistic regression
- investigate whether the inclusion of two predictor variable will improve the sex prediction
- investigate whether the inclusion of more predictor variable will improve the sex prediction
- establish the data base for sex prediction in Pakistani population

Materials and methods

Ethical approval was granted by the Ethics Committee of the Universiti Sains Malaysia (USM/JEPeM/140376) and informed consent was obtained from subjects. This investigation was designed and conducted according to the guidelines of Strengthening the Reporting of Observational studies in Epidemiology (STROBE), and we applied the STROBE specification in this manuscript.[24]

Sample size calculation

All patients were of Pakistani origin determined via interviews, with mutual paternities and ancestors without any multi-ethnic nuptials. Their ages were between 18 to 24 years old. The sample size was calculated at a power of 80%, utilizing estimated standard deviations of 0.60mm, a biologically meaningful mean difference of 0.3mm, and equal sample sizes [25].

The calculated sample size was 128 subjects (64 males and 64 females). The following inclusion and exclusion criteria were used.

Inclusion criteria

- Well-aligned mandibular arches, with normal patterns of growth and development.
- None of the participants had undergone orthodontic treatment, with all sound erupted permanent teeth (except third molars).
- Ideal occlusion with Class I molar and canine relationship with incisors according to the British Standards Institute[26]
- No crowding, cross bite and spacing.
- Straight profile (identify by examining the profile view).
- No craniofacial anomalies.

Exclusion criteria

- Interproximal caries or restorations.
- Missing or supernumerary teeth.
- Abnormal size or morphology of teeth.
- Tooth wear that affected the tooth size measurements.
- Damage to dental casts.

Oral and dental investigations were carried out with careful selection of subjects. Cross-examination of subjects was done to diminish sample bias and error; with an experienced orthodontist and dentists contributing throughout the screening sittings. Dental impressions of each subject were obtained with alginate impression material **(**Zhermack Orthoprint alginate ISO 1563 –ADA 18 Italy) and poured with dental stone (Type III hard plaster quick stone China) according to the manufacturer's instructions.

Measurement of canine and intercanine width

Figure 1. Fabrication of the digital models via Hirox digital stereomicroscope

Dental models of each subject were scanned using a Hirox digital stereomicroscope (SM) (HIROX KH7700 Japan) for the fabrication of the digital models (Figure 1).

The models were placed so that the occlusal plane was parallel with the table surface. Low magnification lens was used to scan the occlusal images of dental casts. The analysis software was equipped with auto calibrated system that ensure life size image regardless of the lens-object distance. SM is a reputable, valid[27] and reliable tool for such measurements with the accuracy of 0.1×10^{-6} mm. The acquisition of measurements was as follows-

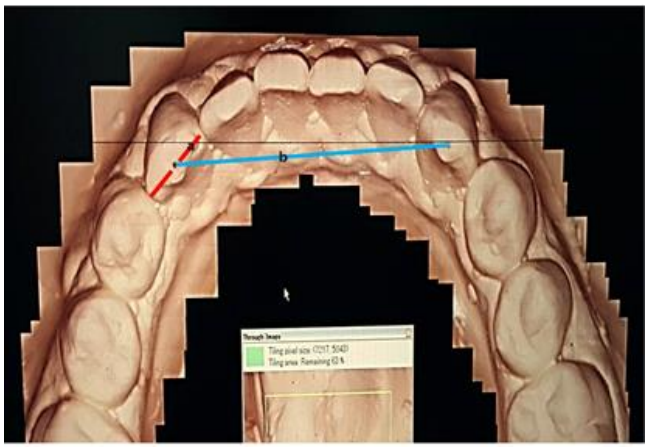

Figure 2. Measurement of (a) canine mesiodistal width (b) inter canine arch width

Variables Measurement

Mesiodistal crown diameters were measured from the anatomical contact of one tooth to another perpendicular to the long axis of the teeth (Figure2a).[28,29] Buccolingual crown diameters were measured from the maximum distance buccolingually perpendicular to the mesiodistal land mark. The mandibular inter-canine widths were obtained between the cusp tips **(Figure 2b)**.

SMCI calculation for current study

SMCI = ((Mean male MCI-Standard deviation) + (Mean female MCI + Standard deviation))/2
SMCI = ((0.2617-0.02486) + (0.2588+0.01991))/2
SMCI = 0.25775 (Values larger than SMCI were assigned as male)

Error study

20% of dental casts were randomly selected for intra-observer errors. The time interval between the first and second readings was approximately 2 weeks. The method error (ME) was analyzed by the Dalhberg's formula: $ME = (\Sigma (x_1-x_2)^2 / 2(28))^{1/2}$. Where x_1 is the first measurement, x2 the second measurement and n the number of repeated measurements.[30]

Statistical analyses

The data were verified and analyzed statistically using IBM SPSS Statistics Version 22.0 (Armonk, NY: IBM Corp.) with the significance level set at 5% ($P < 0.05$). Independent t tests were applied to compare mean values between males and females for lower left canine tooth size and inter-canine width. Logistic regression was used for the determination of sex prediction in which the outcome was in a binary form.[31]

Results

Univariate sex differences

Table 1 shows the measured canine and intercanine width are larger statistically in males than in females ($p<0.05$).

variables	Sex	N	Mean	SD	95% CI		p value
					Lower	Upper	
MCI	M	64	.26	.02	.00	.01	.468
	F	64	.26	.02	.00	.01	
SMCI	M	64	.26	.00	.00	.00	1.000
	F	64	.26	.00	.00	.00	
MD 43	M	64	7.03	.43	.11	.41	.001
	F	64	6.77	.43	.11	.41	
LICW	M	64	26.98	1.92	.09	1.40	.026
	F	64	26.24	1.82	.09	1.40	

Table 1. Univariate sex differences.
MCI, mandibular canine index; SMCI, Standard mandibular canine index, MD, Mesiodisatal width; LICW, Lower arch inter canine width; N, number of subject; CI, confidence interval; SD, standard deviation

Prediction via SMCI

Table 2 shows the percentage of accurate prediction of 51.30% and 43.70% for male and female respectively in the study subjects. While 48.70% male and 56.30% female were anticipated erroneously.

Sex	Accurate Prediction	False prediction
Male	51.30%	48.70%
Female	43.70%	56.30%

Table 2. SMCI percentage of predictability.

The model summary showed, the -2 log like hood value is 164.39. While the Hosmer–Lemeshow test did not show any significant difference between the measured and the predicted sex (x= 6.236; df =8; p= 0.621). **Figure 3** shows the classification plot for accuracy of prediction model.

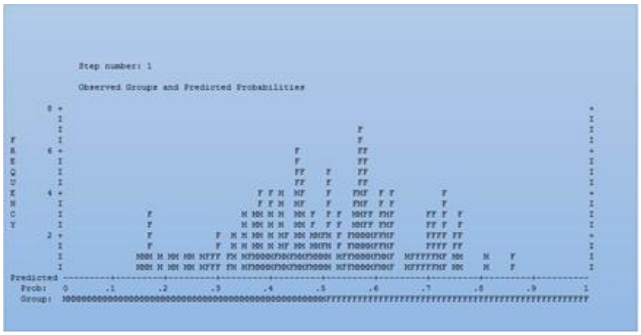

Figure 3. Classification plot for accuracy of prediction model Predicted for MD 43 and LICW with Cut Value is .50. Symbols: M – Male F – Female, Each Symbol Represents 5 Cases.

Sex assessment via logistic regression (BLR) for inclusion of MCI variables.

Variables	B	Exp(B)	Wald	S.E.	95% C.I. EXP(B)		Sig.
					Lower	Upper	
MD 43	-1.274	.280	7.192	.475	.110	.710	.007
LICW	-0.136	.873	1.578	.108	.706	1.079	.209

Table 3. Summary of Logistic Regression Analysis for variables predicting.

Table 3 shows the BLR for the MD 43 and lower intercanine width variables. The overall percentage of prediction was 66.4%, (64.1% and 68.8% for male and female respectively).

Sex assessment via logistic regression for inclusion of more variables.

Variables	B	Exp(B)	Wald	S.E.	95% C.I.for EXP(B)		Sig.
					Lower	Upper	
Mx11	-1.03	0.36	1.87	0.75	0.08	1.57	0.172
Mx12	0.46	1.59	0.42	0.72	0.39	6.47	0.517
Mx13	-0.20	0.82	0.08	0.72	0.20	3.38	0.781
Mx14	-0.11	0.90	0.02	0.89	0.16	5.17	0.902
Mx15	0.87	2.38	1.07	0.84	0.46	12.32	0.3
Mx16	0.14	1.14	0.06	0.55	0.39	3.36	0.806
Mx17	-1.49	0.23	7.25	0.55	0.08	0.67	0.007
Mn41	0.31	1.36	0.11	0.92	0.22	8.32	0.739
Mn42	-1.47	0.23	1.49	1.20	0.02	2.43	0.222
Mn43	-0.76	0.47	0.89	0.81	0.10	2.26	0.345
Mn44	1.92	6.85	4.27	0.93	1.10	42.47	0.039
Mn45	0.19	1.20	0.05	0.80	0.25	5.82	0.817
Mn46	-1.08	0.34	4.15	0.53	0.12	0.96	0.042
Mn47	-0.52	0.59	1.23	0.47	0.24	1.49	0.268
MxB11	-0.26	0.77	0.15	0.66	0.21	2.82	0.695
MxB12	-0.16	0.85	0.06	0.65	0.24	3.05	0.807
MxB13	-0.63	0.53	0.74	0.73	0.13	2.23	0.389
MxB14	-0.90	0.41	1.32	0.78	0.09	1.89	0.251
MxB15	0.34	1.40	0.15	0.88	0.25	7.91	0.701
MxB16	0.33	1.40	0.26	0.65	0.39	5.01	0.61
MxB17	0.05	1.05	0.02	0.43	0.45	2.45	0.902
MnB41	-2.09	0.12	2.49	1.33	0.01	1.66	0.115
MnB42	1.64	5.14	1.96	1.17	0.52	50.83	0.162
MnB43	-0.46	0.64	0.48	0.66	0.17	2.31	0.491
MnB44	-0.72	0.49	0.67	0.88	0.09	2.73	0.413
MnB45	0.04	1.04	0.00	0.74	0.24	4.46	0.961
MnB46	0.16	1.17	0.06	0.64	0.33	4.12	0.807
MnB47	0.68	1.97	1.13	0.64	0.56	6.88	0.288

Table 4. Summary of Logistic Regression Analysis for variables predicting sex via adding more variables.

Table 4 shows the BLR for inclusion of more tooth size (via MD and BL widths of maxillary and mandibular right side) variables. The overall percentages of prediction were 75.4%, (80% and 71% for male and female respectively). The model summary showed, the -2 log like hood value is 119.18. While the Hosmer–Lemeshow test did not show any significant difference between the measured and the predicted sex (x= 11.75; df =8; p= 0.621). Figure 4 shows the classification plot for accuracy of prediction model.

Figure 4. Classification plot for accuracy of prediction model Predicted via tooth size (via MD and BL widths of maxillary and mandibular right side) variables, with Cut Value is .50. Symbols: M – Male F – Female, Each Symbol Represents .5 Cases.

Discussion

Tooth size and arch dimension has sexual disparities, along with the population and racial dimorphism around the globe.[2,3,14,16] However, the canine teeth have shown the greatest variation and the sturdiest teeth in the oral cavity used for forensic investigation. Researchers selected the canine tooth and other variables as a gender predictor.[3,20] Current study found that single canine variable is not an accurate predictor for Pakistani population.

The sexual dimorphism via tooth dimensions is established by various researchers.[2,5-13] Current study evaluates the gender prediction via SMCI as a cut-off point. The percentage of accurate prediction of 56.3% and 43.8 % for male and female were obtained respectively from the study subjects. However, due to the considerable overlapping of male and female values, it is unwise to rely on the SMCI measurements singularly. Our study evaluated the gender prediction for the Pakistani population via adding two variables (the MD 43 and LICW variables) into a logistic regression. The overall percentage of prediction was 66.4%, which is slightly better than MCI Rao's prediction. A MD43 variable contributed significantly to the regression. The prediction result 66.4% is only slightly better than chance, thus rose the question whether by inclusion of more crown dimension variables would improve the sex prediction. Twenty-eight variables were tested that three variables were selected contributing significantly to the regression analysis. The overall percentage of prediction was 75.4%. The results indicated that adding more variables improved the prediction rate. Figure 5 shows the ROC plot for accuracy of prediction model. Therefore, the MCI use is inadequate for forensic odonatological and anthropological investigation. Various researchers[22,29,32-36] in Table 5 shows the agreement and disagreements with canine index gender assessment.

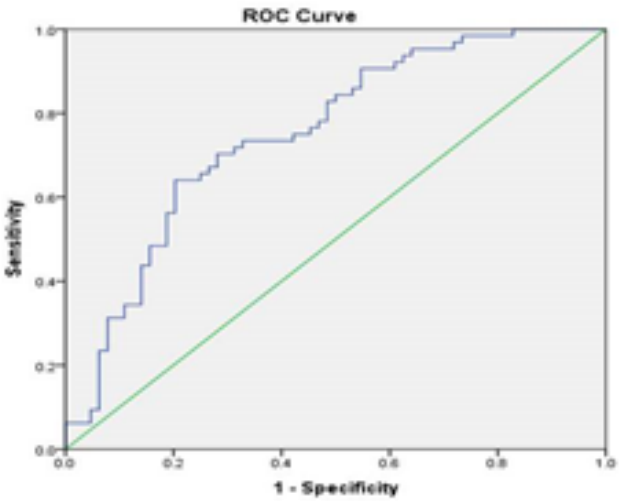

Figure 5. ROC curve for the predicted probabilities of adding (via MD and BL widths of maxillary and mandibular right side) more tooth size variables.

Author Name/year	Valuable tool for gender determination	Study Population
Current study (2017)	Disagree	Pakistani
Acharya and Mainali (2009)	Disagree	Nepalese
Acharya, Angadi et al. (2011)	Disagree	Indian
Bakkannavar, Manjunath et al. (2015)	Agree	South India
Gupta and Daniel (2016)	Agree	India
Hussain M Siddiqui et al. (2012)	Agree	Pakistani
Khaitan, Ramaswamy et al. (2014)	Agree	Indian
Latif, Rashid et al. (2016)	Agree	North India

Table 5. Agreement and disagreement with canine index gender assessment.

Conclusion

- The Rao index is not a reliable way for the sex identification in Pakistani population.
- Inclusion of two predictor variable improved the sex prediction.
- Inclusion of more predictor variable improved the sex prediction.
- our study establish the gender prediction model data base via BLR for sex prediction in Pakistani population.

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